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Plastics piping systems — Multilayer pipes and their joints, based on thermoplastics, for water supply

Systèmes de canalisations en plastique — Tubes multicouches et leurs assemblages, à base de thermoplastiques, pour l'alimentation en eau

Reference number
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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 21004 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

An overview of standards to be applied for multilayer pipes and their joints, based on thermoplastics, for water supply, is given hereafter.

Parts	Applicable standards
Materials	Relevant reference product standards (see 4.2 and Clause 5 of this International Standard)
Pipes	This International Standard
Fittings	Relevant reference product standards (see Clause 9 of this International Standard)
Valves	Relevant reference product standards (see Clause 9 of this International Standard)
Fitness for purpose	This International Standard (see Clause 10)

Plastics piping systems — Multilayer pipes and their joints, based on thermoplastics, for water supply

1 Scope

This International Standard specifies the general requirements and the performance requirements for multilayer pipes based on thermoplastics intended to be used for water supply outside buildings, for buried water mains and services and for water supplies above ground.

It gives guidance for the design of piping systems consisting of multilayer pipes based on thermoplastics or, for which at least 60 % of the wall thickness is polymeric material, and the inner layer in contact with water is made of polymeric material.

The polymeric layers used for the stress-bearing layers are selected from polybutylene (PB), polyethylene (PE), crosslinked polyethylene (PE-X), polypropylene (PP), chlorinated poly(vinyl chloride) (PVC-C) and unplasticized poly(vinyl chloride) (PVC-U).

NOTE 1 For the purpose of this document, crosslinked polyethylene (PE-X) as well as adhesives are to be considered as thermoplastic materials, and polyethylene of raised temperature resistance (PE-RT) is to be considered as polyethylene (PE).

This document is applicable to piping systems used for the conveyance under pressure of cold water (up to approximately 20 °C) for drinking. It is also applicable to piping systems for the conveyance of water (up to and including 40 °C) for general purposes.

It applies where special functional requirements are needed.

NOTE 2 As an example, the different pipe layers can provide information on colour, barrier and mechanical properties, according to the intended application.

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

ISO 161-2, *Thermoplastics pipes for the conveyance of fluids — Nominal outside diameters and nominal pressures — Part 2: Inch-based series*

ISO 472, *Plastics — Vocabulary*

ISO 527-1, *Plastics — Determination of tensile properties — Part 1: General principles*

ISO 527-1:1993/Cor.1:1994, *Plastics — Determination of tensile properties — Part 1: General principles*

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

ISO 1043-1, *Plastics — Symbols and abbreviated terms — Part 1: Basic polymers and their special characteristics*

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

ISO 1167-2, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 2: Preparation of pipe test pieces*

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

ISO 3213, *Polypropylene (PP) pipes — Effect of time and temperature on expected strength*

ISO 3459, *Polyethylene (PE) pressure pipes — Joints assembled with mechanical fittings — Internal under-pressure test method and requirement*

ISO 3501, *Assembled joints between fittings and polyethylene (PE) pressure pipes — Test of resistance to pull out*

ISO 3503, *Assembled joints between fittings and polyethylene (PE) pressure pipes — Test of leakproofness under internal pressure when subjected to bending*

ISO 4422-1, *Pipes and fittings made of unplasticized poly(vinyl chloride) (PVC-U) for water supply — Specifications — Part 1: General*

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

ISO 4422-3, *Pipes and fittings made of unplasticized poly(vinyl chloride) (PVC-U) for water supply — Specifications — Part 3: Fittings and joints*

ISO 4422-4, *Pipes and fittings made of unplasticized poly(vinyl chloride) (PVC-U) for water supply — Specifications — Part 4: Valves and ancillary equipment*

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

ISO 4427-1 [1)], *Plastics piping systems — Polyethylene (PE) pipes and fittings for water supply — Part 1: General*

ISO 4427-2 [1)], *Plastics piping systems — Polyethylene (PE) pipes and fittings for water supply — Part 2: Pipes*

ISO 4427-3 [1)], *Plastics piping systems — Polyethylene (PE) pipes and fittings for water supply — Part 3: Fittings*

ISO 4427-5 [1)], *Plastics piping systems — Polyethylene (PE) pipes and fittings for water supply — Part 5: Fitness for purpose of the system*

ISO 6259-1, *Thermoplastics pipes — Determination of tensile properties — Part 1: General test method*

ISO 6259-2, *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)*

1) To be published.

ISO 6259-3, *Thermoplastics pipes — Determination of tensile properties — Part 3: Polyolefin pipes*

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

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

ISO 10146, *Crosslinked polyethylene (PE-X) pipes — Effect of time and temperature on the expected strength*

ISO 11413:1996, *Plastics pipes and fittings — Preparation of test piece assemblies between a polyethylene (PE) pipe and an electrofusion fitting*

ISO 11414:1996, *Plastics pipes and fittings — Preparation of polyethylene (PE) pipe/pipe or pipe/fitting test piece assemblies by butt fusion*

ISO 12230, *Polybutene (PB) pipes — Effect of time and temperature on the expected strength*

ISO 13761, *Plastics pipes and fittings — Pressure reduction factors for polyethylene pipeline systems for use at temperatures above 20 degrees C*

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*

ISO 13953, *Polyethylene (PE) pipes and fittings — Determination of the tensile strength and failure mode of test pieces from a butt-fused joint*

ISO 13954, *Plastics pipes and fittings — Peel decohesion test for polyethylene (PE) electrofusion assemblies of nominal outside diameter greater than or equal to 90 mm*

ISO 13955, *Plastics pipes and fittings — Crushing decohesion test for polyethylene (PE) electrofusion assemblies*

ISO 13968, *Plastics piping and ducting systems — Thermoplastics pipes — Determination of ring flexibility*

ISO 15874-1, *Plastics piping systems for hot and cold water installations — Polypropylene (PP) — Part 1: General*

ISO 15874-2, *Plastics piping systems for hot and cold water installations — Polypropylene (PP) — Part 2: Pipes*

ISO 15874-3, *Plastics piping systems for hot and cold water installations — Polypropylene (PP) — Part 3: Fittings*

ISO 15874-5, *Plastics piping systems for hot and cold water installations — Polypropylene (PP) — Part 5: Fitness for purpose of the system*

ISO 15875-1, *Plastics piping systems for hot and cold water installations — Crosslinked polyethylene (PE-X) — Part 1: General*

ISO 15875-2, *Plastics piping systems for hot and cold water installations — Crosslinked polyethylene (PE-X) — Part 2: Pipes*

ISO 15875-3, *Plastics piping systems for hot and cold water installations — Crosslinked polyethylene (PE-X) — Part 3: Fittings*

ISO 15875-5, *Plastics piping systems for hot and cold water installations — Crosslinked polyethylene (PE-X) — Part 5: Fitness for purpose of the system*

ISO 15876-1, *Plastics piping systems for hot and cold water installations — Polybutylene (PB) — Part 1: General*

ISO 15876-2, *Plastics piping systems for hot and cold water installations — Polybutylene (PB) — Part 2: Pipes*

ISO 15876-3, *Plastics piping systems for hot and cold water installations — Polybutylene (PB) — Part 3: Fittings*

ISO 15876-5, *Plastics piping systems for hot and cold water installations — Polybutylene (PB) — Part 5: Fitness for purpose of the system*

ISO 15877-1, *Plastics piping systems for hot and cold water installations — Chlorinated poly(vinyl chloride) (PVC-C) — Part 1: General*

ISO 15877-2, *Plastics piping systems for hot and cold water installations — Chlorinated poly(vinyl chloride) (PVC-C) — Part 2: Pipes*

ISO 15877-3, *Plastics piping systems for hot and cold water installations — Chlorinated poly(vinyl chloride) (PVC-C) — Part 3: Fittings*

ISO 15877-5, *Plastics piping systems for hot and cold water installations — Chlorinated poly(vinyl chloride) (PVC-C) — Part 5: Fitness for purpose of the system*

ISO 16871, *Plastics piping and ducting systems — Plastics pipes and fittings — Method for exposure to direct (natural) weathering*

ISO 17454, *Plastics piping systems — Multilayer pipes — Test method for the adhesion of the different layers using a pulling rig*

ISO 17456:—[1)], *Plastics piping systems — Multilayer pipes — Determination of long-term strength*

ISO 22391-1 [1)], *Plastics piping systems for hot and cold water installations — Polyethylene of raised temperature resistance (PE-RT) — Part 1: General*

ISO 22391-2 [1)], *Plastics piping systems for hot and cold water installations — Polyethylene of raised temperature resistance (PE-RT) — Part 2: Pipes*

ISO 22391-3 [1)], *Plastics piping systems for hot and cold water installations — Polyethylene of raised temperature resistance (PE-RT) — Part 3: Fittings*

ISO 22391-5 [1)], *Plastics piping systems for hot and cold water installations — Polyethylene of raised temperature resistance (PE-RT) — Part 5: Fitness for purpose of the system*

ISO 24033 [1)], *Pipes made of raised-temperature-resistance polyethylene (PE-RT) — Effect of time and temperature on the expected strength*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472 and ISO 1043-1 and the following apply.

3.1 Terms and definitions related to construction

3.1.1
multilayer pipe
pipe comprising more than one layer in which at least 60 % of the wall thickness is a polymeric material

3.1.2
multilayer M pipe
multilayer pipe comprising layers of polymers and one or more metallic layers

NOTE The wall thickness of the pipe consists of at least 60 % of polymer layers.

3.1.3
multilayer P pipe
multilayer pipe comprising two or more polymeric layers

3.1.4
inner layer
layer in contact with the conveyed fluid

3.1.5
outer layer
layer exposed to the outer environment

3.1.6
embedded layer
layer between the outer and inner layer

3.1.7
application layer
layer which provides a specific property linked to the conditions of use of the pipe

3.2 Terms and definitions related to construction groups

3.2.1
reference product standard
International Standard or Draft International Standard prepared by Technical Committee ISO/TC 138, Subcommittee SC 2, applicable for non-multilayer pipes, to which this document can refer for clauses related to the materials, components (e.g. fittings), and fitness for purpose of the system

3.2.2
construction group A
group comprising multilayer pipes in which all the layers considered to be stress-bearing are made of polymeric materials selected from the list of reference product standards

3.2.3
construction group B
group comprising multilayer pipes in which all the layers considered to be stress-bearing are made of polymeric materials selected from the list of reference product standards and including a stress-bearing metallic layer

3.2.4
similar construction type
〈multilayer M pipes〉 construction type which is the same for more than one pipe diameter under the following conditions:

— the same process technology is used (e.g. welding process for the aluminium layers, type of welding, etc.);

— materials having the same characteristics are used for each stress-bearing layer; i.e. material type and specifications;

— the layers are assembled in the same sequence for different diameters;

— for all diameters, the SDR_m of the metal layer is the same ± 10 %.

NOTE If for a certain diameter range, the same metal layer thickness is used, the SDR_m value of the metal layer of all smaller diameters of this diameter range can be adapted up to the SDR_m of the metal layer for the biggest diameter of the diameter range (e.g. a diameter range from 12 mm up to 20 mm with a 0,2 mm metal layer).

3.3 Terms and definitions related to geometry

3.3.1
nominal size
DN
numerical designation of the size of a component, other than a component designated by a thread size, which is a convenient round number, approximately equal to the manufacturing dimension

NOTE The nominal size is expressed in millimetres.

3.3.2
nominal size
DN/OD
nominal size, related to the outside diameter

3.3.3
nominal outside diameter
d_n
specified outside diameter assigned to a nominal size DN/OD

NOTE The nominal outside diameter is expressed in millimetres.

3.3.4
outside diameter at any point
d_e
outside diameter measured through the cross-section at any point on a pipe, or the spigot end of a fitting

NOTE The outside diameter at any point is rounded up to the nearest 0,1 mm.

3.3.5
mean outside diameter
d_{em}
measured length of the outer circumference of a pipe, or the spigot end of a fitting, divided by π (≈ 3,142)

NOTE The mean outside diameter is rounded up to the nearest 0,1 mm.

3.3.6
out-of-roundness
difference between the measured maximum outside diameter and the measured minimum outside diameter in the same cross-sectional plane of a pipe, or the spigot end of a fitting

3.3.7
metal layer standard dimension ratio
SDR_m
nominal outside diameter (DN/OD) divided by the nominal wall thickness of the metal layer $e_{n,m}$

3.4 Terms and definitions related to service conditions

3.4.1
nominal pressure
PN
numerical designation used for reference purposes and related to the mechanical characteristics of the components of a piping system

NOTE For plastics piping systems conveying water, nominal pressure corresponds to the maximum continuous operating pressure in bars [2)] which can be sustained with water at 20 °C for 50 years, based on the minimum overall service (design) coefficient.

3.5 Terms and definitions related to materials

3.5.1
virgin material
material in a form such as granules or powder that has not been subjected to use or processing other than that required for its manufacture and to which no reprocessable or recyclable material has been added

3.5.2
own reprocessable material
material prepared from clean unused rejected pipes or fittings, produced in a manufacturer's plant by a process such as moulding or extrusion, which will be reprocessed in the same plant and for which the complete formulation or material specification is known

3.5.3
external reprocessable material
material from unused rejected pipes or trimmings therefrom, that will be reprocessed and that were originally processed by another manufacturer, or material from the production of unused products other than pipes and fittings, regardless of where they are manufactured

3.6 Terms and definitions related to material characteristics

3.6.1
long-term hydrostatic strength
σ_{LTHS}
quantity with the dimensions of stress, which represents the predicted mean strength at a temperature T and time t

NOTE The long-term hydrostatic strength is expressed in megapascals.

3.6.2
lower confidence limit of the predicted hydrostatic strength
σ_{LPL}
quantity with the dimensions of stress, which represents the 97,5 % lower confidence limit of the predicted hydrostatic strength at a temperature T and time t

NOTE 1 It is given by

$$\sigma_{LPL} = \sigma_{(T,\, t,\, 0{,}975)}$$

NOTE 2 The lower confidence limit of the predicted hydrostatic strength is expressed in megapascals.

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

3.6.3
minimum required strength
MRS
value of σ_{LPL} at 20 °C and 50 years

NOTE 1 The value is rounded down to the next lower value in the R 10 series when σ_{LPL} is less than 10 MPa, or to the next lower value in the R 20 series when σ_{LPL} is greater than or equal to 10 MPa.

NOTE 2 R10 and R20 series are the Renard number series according to ISO 3:1973 [1] and ISO 497:1973 [2].

3.6.4
minimum required pressure
MRP
value of the estimated long-term hydrostatic pressure strength of a pipe at a temperature of 20 °C and a time 50 years

NOTE The value is rounded down to the next lower value of the R10 series.

4 Products classification

4.1 Construction group

The multilayer pipes can include polymeric or metallic layers which may have several purposes including the ability to withstand the pressure.

For the purpose of this document, multilayer pipes are classified in two construction groups as defined in 3.2. For these definitions, adhesives are not considered as stress-bearing layers.

The pipe manufacturer shall declare the construction group of the multilayer pipe.

4.2 Reference product standard

The pipe manufacturer shall declare the reference product standard applicable to his product, as listed in Annex A.

4.3 PN Range

PN values shall be selected from the following PN range: PN 6; PN 6,3; PN 8; PN 10; PN 12,5; PN 16; PN 20; PN 25.

Above PN 25, other PN values may be used following the Renard R 10 series.

National regulations should be taken into account in the selection of the PN value.

4.4 Design coefficient

A minimum design coefficient of 1,25 is applicable. Annex B gives rules for the selection of actual values.

4.5 Stiffness range

If a stiffness classification is required, it shall be rounded down to the next smaller units in the range 4, 8, 16 and 32 when tested according to ISO 9969.

4.6 Specific properties

Any specific property (e.g. barrier, peeling, abrasion properties) shall be described by the pipe manufacturer in a technical file.

NOTE It is foreseen that standards will be developed in the future to enable determination of specific properties.

5 Materials

5.1 General characteristics

The pipe manufacturer shall declare the materials used for each layer of the multilayer pipe and the function of each layer.

The material characteristics of the stress-bearing layers shall comply with the requirements of the relevant reference product standards (see Annex A).

Clean own reprocessable material may be added to the virgin material of the same polymer type provided that it is prepared from products manufactured according to the relevant reference product standard.

External reprocessable material shall not be used.

The choice of colour should follow local specifications/national identification requirements.

5.2 Effect on water quality

Pipes intended for conveyance of drinking water shall conform to existing national regulations applicable to materials in contact with water intended for human consumption.

5.3 Resistance to weathering

For storage, the materials used for the outer layer of the multilayer pipe shall withstand a minimum total radiant exposure of 3,5 GJ/m^2 when tested in according to ISO 16871. If applicable, guidance is given by the relevant reference product standards. Otherwise, the material of the non-stress-bearing outer layer, in pipe form, shall be exposed according to ISO 16871 and tested for tensile elongation according to ISO 6259, or, if not applicable, according to ISO 527-1 and ISO 527-2. The elongation at break of the material of the outer layer shall be above 50 % of the value before exposure.

For above-ground use, the resistance to weathering of the materials used for manufacturing the multilayer pipes shall be considered. Otherwise, protective measures shall be taken.

6 Long-term hydrostatic strength

6.1 General

The long-term hydrostatic strength of the multilayer pipes shall be calculated or measured as defined in 6.2 or 6.3, as applicable.

Two procedures for determination of long-term hydrostatic strength of multilayer pipes are defined in this document:

— procedure I (calculation method);

— procedure II (testing of pipe construction method).

For design purposes, the value of the long-term hydrostatic strength of the multilayer pipes at a time of 50 years and at a temperature of 20 °C shall be determined to obtain MRS or MRP.

PN is determined by dividing MRS or MRP by the design coefficient. More details are given in Annex B.

6.2 Procedure I (calculation method)

Procedure I can only be used for multilayer P pipes.

The long-term hydrostatic strength, σ_{LTHS}, shall be calculated using the reference lines or from data determined according to ISO 9080 for each individual pressure-bearing polymer layer according to Annex A of ISO 17456:—. The addition rule related to each pressure-bearing layer assumes complete interlayer adhesion.

Extrapolation lines shall include a control point at 20 °C and, taking into account the different polymers used, a control point at another temperature permitting the calculation of the lifetime of 50 years at 40 °C in accordance with the scope of this document, taking into account 8.1 and the relevant extrapolation time factors of ISO 9080.

For validation of this calculation, tests shall be carried out at an elevated temperature for 3 000 h on a pipe of each diameter group. This test shall be carried out at 95 % of the calculated LPL[3)].

6.3 Procedure II (testing of pipe construction method)

6.3.1 General

Evaluate at least one diameter (the pipe with the lowest strength) of every similar construction type in accordance with ISO 9080 for each group of dimensions as defined in Table 1.

Table 1 — Groups of dimensions

	Dimension group		
	1	**2**	**3**
Nominal outside diameter, d_n, in mm	$\leqslant$ 63	$>$ 63 and $\leqslant$ 250	$>$ 250

The test temperature shall be chosen from the reference material standards.

To determine the diameter of the pipe with the lowest strength within a construction group, a burst test on each diameter shall be performed.

To calculate PN, the design coefficient of the inner layer shall be used for multilayer M pipes and the design coefficient of each layer shall be taken into account for multilayer P pipes (see Annex B).

6.3.2 Pressure strength of all diameters

All diameters of a similar construction type, excluding the diameter tested in accordance with 6.3.1, shall undergo a confirmation testing of 3 000 h at a temperature of at least 60 °C or in accordance with the reference material standard and at a stress or pressure level of 95 % of LPL.

3) The lower prediction limit, LPL, is the lower confidence limit of the prediction of the value of the stress that can cause failure in the stated time at a stated temperature (the ultimate stress).

7 Geometrical characteristics

7.1 General

The pipe manufacturer shall give detailed information in a technical file related to the geometrical characteristics of the component, including the wall thickness of each layer.

The pipes are characterised by the nominal size, DN, related to the outside diameter, DN/OD.

The pipe shall be manufactured such that d_e or DN/OD, as applicable, prior to jointing, conforms to the values given by ISO 161-1 or ISO 161-2, as applicable.

7.2 Dimensions

7.2.1 Measurements of dimensions

Dimensions of the pipes shall be measured in accordance with ISO 3126.

7.2.2 Mean outside diameters and out-of-roundness

The mean outside diameter, d_{em}, of the jointing zone of the pipes shall be in accordance with the relevant clause of the reference product standard. Jointing systems shall depend on the basis of the pipe construction.

If applicable, the maximum out-of-roundness of the pipes shall conform to the geometrical characteristics of the reference product standard.

7.2.3 Wall thicknesses and their tolerances

The values of the wall thickness and tolerances shall be specified by the pipe manufacturer.

8 Mechanical characteristics

8.1 Control points for pressure characteristics

Control points at the required time and temperature shall be calculated using the 95 % value of LPL obtained from 6.2 or 6.3 as applicable for a duration of 22 h, 165 h or 1 000 h (or other required testing time according to the reference material standard).

When a multilayer pipe comprises more than one polymer for the stress-bearing layers, testing shall be carried out at the elevated temperature above 20 °C normally used for the determination of the hydrostatic strength in the reference product standards related to these materials (e.g. 60 °C for PVC-U, 80 °C for PE, etc.).

8.2 Structural performance

8.2.1 Multilayer M pipes

When tested in accordance with the test methods as specified in Table 2, using the indicated parameters, the pipe shall have the structural performance conforming to the requirements given in Table 2.

Table 2 — Structural performance of M pipes

Characteristic	Requirement	Test parameters	Test method
Delamination	Adhesion force $\geqslant$ 1,5 N/mm	Shall conform to ISO 17454	ISO 17454

8.2.2 Multilayer P pipes

When tested in accordance with the test methods as specified in Table 3, using the indicated parameters, the pipe shall have the structural performance conforming to the requirements given in Table 3.

Table 3 — Structural performance of P pipes

Characteristic	Requirement	Test parameters		Test method
Integrity of the structure after deflection	$\geqslant$ 80 % of the initial stiffness value	Deflection Position of test piece	30 % of d_{em} when applicable, at 0°, 45° and 90° from the upper plate	ISO 13968

For the determination of the integrity of the structure after deflection of multilayer P pipes, the following procedure shall be applied:

a) determine the initial ring stiffness of the pipe according to ISO 9969;

b) carry out the ring flexibility test according to ISO 13968;

c) after a 1 h period for recovery, determine again the ring stiffness of the pipe according to ISO 9969.

The ring stiffness of the multilayer P pipes shall be at least 80 % of the initial ring stiffness.

9 Fittings and valves

Fittings and valves to be used are given in the reference product standards (see Annex A) and no specific requirements are given in this document.

Attention is drawn to the importance of the geometrical characteristics of the connecting zone.

10 Fitness for purpose of the system

10.1 Specific properties

The application layer may provide a specific property. This specific property shall be proved by testing the multilayer pipes.

The addition of a layer should not compromise the performance of the pipe.

EXAMPLE Examples of application layers are the following:

— improvement of barrier properties (e.g. to oxygen permeability, permeation of contaminants);

— improvement of embedding properties by increasing abrasion or craze propagation resistance through the use of a specific material for the outer layer.

NOTE If required, specific test methods may be developed by SC 5, *General properties of pipes, fittings and valves of plastic materials and their accessories — Test methods and basic specifications*, of ISO/TC 138.

10.2 Jointing techniques

10.2.1 General

The jointing techniques to be used are based on those described in the reference product standards, e.g.

— butt fusion jointing,

— electrofusion jointing,

— elastomeric ring seal jointing and solvent cement jointing,

— mechanical jointing.

In any jointing system, contact with water should be avoided in the cross section of the multilayer M pipes.

10.2.2 Butt fusion jointing (for polyolefin primarily)

The manufacturer shall demonstrate that each compound intended to be used for a stress-bearing layer of a multilayer pipe is fusible by the appropriate tests given in Table 4.

Butt fusion jointing is applicable for products manufactured from polyolefin materials primarily.

If the metallic layer cannot be removed in the welding zone before fusion, then butt fusion should be avoided. When the metallic layer has been removed, additional longer term tests should be carried out to confirm long-term strength in agreement with the purchaser or end user.

In order to demonstrate that no degradation has occurred and no notches or notch sensitivity have been created, the following tests shall be performed as listed in Table 4:

a) the hydrostatic strength test on the butt-fused pipe to pipe assemblies at the appropriate high temperature (80 °C or 95 °C) 165 h and 1 000 h control points according to the reference materials used (see 8.1);

b) the tensile strength tests for butt-fused joints.

The butt fusion joint shall be prepared under normal conditions in accordance with ISO 11414 or under extreme conditions if requested by the purchaser or end user. The selected butt fusion conditions shall be appropriate for the materials used in the pipe construction.

The butt fusion assemblies shall be prepared using pipe and or fittings with spigot ends having the same SDR in accordance with ISO 11414 under normal conditions (ambient temperature 23 °C), or if required under minimum and maximum conditions as specified in Annex B of ISO 11414:1996 and including misalignment requirements given in Clause 6 a) of ISO 11414:1996.

Butt fusion assemblies shall conform to the requirements specified in Table 4 for the characteristics of hydrostatic strength and tensile strength.

Table 4 — Characteristics for fitness for purpose of butt fusion joints

Characteristic	Requirements	Test parameters		Test method
Hydrostatic strength at 80 °C or 95 °C	No failure during test period	End caps	Type A [a]	ISO 1167-1
		Type of test	Water-in-water	ISO 1167-2
		Test temperature	80 °C or 95 °C [c]	
		Test period	165 h and 1 000 h	
		Circumferential (hoop) stress [b]	in accordance with control points (see 8.1)	
Tensile strength	Test to failure ductile: pass brittle: fail	Test temperature	23 °C	ISO 13953

[a] Type B end caps may be used for tests for diameters $\geqslant$ 315 mm.

[b] Stress shall be calculated for the multilayer pipes used in the test.

[c] According to control points for the reference materials used.

10.2.3 Electrofusion jointing (for polyolefin primarily)

The manufacturer shall demonstrate that the combination of the material of the fitting and the pipe layer intended to be used for the electrofusion jointing are fusible by the appropriate tests given in Table 5.

Electrofusion jointing is applicable for construction groups A and B products manufactured from polyolefin materials primarily.

In order to demonstrate that no degradation has occurred, the following tests shall be performed as listed in Table 5:

a) the leaktightness under long-term internal pressure;

b) the decohesive resistance for electrofusion socket fittings or cohesive strength for electrofusion saddle fittings.

The electrofusion joint shall be prepared under normal conditions in accordance with ISO 11413 or under extreme conditions if requested by the purchaser or end user. The electrofusion conditions selected shall be appropriate for the materials used in the pipe construction.

The assemblies shall be prepared in accordance with ISO 11413 under normal conditions (ambient temperature 23 °C), or if required under minimum and maximum conditions as specified in Table C.1 of ISO 11413:1996.

Electrofusion assemblies shall conform to the requirements specified in Table 5 for the characteristics of leaktightness under long-term internal pressure and decohesive resistance or cohesive resistance, as applicable.

Table 5 — Characteristics for fitness for purpose of electrofusion joints

Characteristic	Requirements	Test parameters		Test method
Leaktightness under long-term hydrostatic internal pressure	No failure during test period	End caps	Type A	ISO 1167
		Type of test	Water-in-water	
		Test period	1 000 h	
		Test temperature	20 °C	
		Test pressure	1,5 PN [a]	
		followed by		
		Test period	1 000 h	
		Test temperature	40 °C	
		Test pressure	1,1 PN [a]	
Cohesive resistance for electrofusion socket fittings	Length of initiation rupture $\leqslant L_2/3$ in brittle failure	Test temperature	23 °C	ISO 13954 or ISO 13955
Cohesive resistance for electrofusion saddle fittings	Surface rupture: $\leqslant$ 25 %, brittle failure	Test temperature	23 °C	Annex C
Resistance to pull out under constant longitudinal force	No pull-out or separation of the pipe from the fitting	Test temperature	23 °C	ISO 3501
		Test period	1 h	
		Force	1,5 π PN $(d_e/2)^2$ [a]	

[a] The PN value is the lowest PN value of the components in the test assembly (either pipe or fitting).

10.2.4 Elastomeric ring seal, solvent cement and mechanical jointing (for PVC-U and PVC-C primarily)

10.2.4.1 General

Elastomeric ring seal, solvent cement and mechanical jointing are applicable for construction groups A and B products manufactured from PVC-U/PVC-C primarily.

10.2.4.2 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 Table 6.

a) PVC-U/PVC-C multilayer pipe assemblies with elastomeric ring seal joints, when the fitting is applied to the PVC-U/PVC-C layer of the pipe;

b) metal fitting and PVC-U/PVC-C multilayer pipe assemblies with elastomeric ring seal joints when the fitting is applied to the PVC-U/PVC-C layer of the pipe.

Table 6 — Characteristics for fitness for purpose of non-end-load-bearing joints

Characteristic	Requirements	Test parameters			Test method
Leaktightness at short-term hydrostatic internal pressure	No leakage at any point of the jointing areas during the test period	Test pressure	1,7 PN [a]		ISO 13845
		Ambient temperature	15 °C to 25 °C		
		Variation in temperature	± 5 K		
		Deflection	2°		
		Test period	60 min		
Leaktightness at short-term negative air pressure	Negative pressure change shall be ⩽ 0,005 MPa (⩽ 0,05 bar) for the first and for the second 15 min	Test pressure	$^{-0,01}_{-0,08}$ MPa		ISO 13844
		Ambient temperature	15 °C to 25 °C		
		Variation in temperature	± 2 K		
		Deflection	2°		
		Deformation	5 %		
		Test period	15 min/15 min		
Leaktightness at long-term under internal water pressure	No leakage at any point of the jointing areas during the test period	Water temperature [b]	20 °C	40 °C	ISO 13846
		Test pressure	1,7 PN [a]	1,3 PN [a]	
		Test period	1 000 h	1 000 h	

[a] The PN value is the lowest PN value of the components in the test assembly (either pipe or fitting).

[b] To be chosen alternatively.

10.2.4.3 Assemblies with end-load-bearing joints

The following types of assemblies with end-load-bearing joints shall fulfil the fitness for purpose requirements given in Table 7:

a) PVC-U/PVC-C multilayer pipe assemblies with solvent cement joints, when the fitting is applied to the PVC-U/PVC-C layer of the pipe;

b) flange assemblies with PVC-U/PVC-C multilayer pipes;

c) mechanical fitting assemblies with PVC-U/PVC-C multilayer pipes, when the fitting is applied to the PVC-U/PVC-C layer of the pipe.

Table 7 — Characteristics for fitness for purpose of end-load-bearing joints

Characteristic	Requirements	Test parameters			Test method
Leaktightness at short-term hydrostatic pressure under bending and at negative air pressure	No leakage at any point of the jointing areas and negative pressure change shall be ⩽ 0,005 MPa (⩽ 0,05 bar)	Hydrostatic pressure cycles with bending and negative air pressure period	Shall conform to ISO 13783		ISO 13783
Leaktightness at long-term under internal water pressure	No leakage at any point of the jointing areas during the test period	Water temperature [a]	20 °C	40 °C	ISO 13846
		Test pressure	1,7 PN [b]	1,3 PN [b]	
		Test period	1 000 h	1 000 h	

[a] To be chosen alternatively.

[b] The PN value is the lowest PN value of the components in the test assembly (either pipe or fitting).

10.2.5 Mechanical jointing (for polyolefin primarily)

Mechanical jointing is applicable for construction groups A and B products manufactured from polyolefin materials, (PE, PE-X, PP and PB) primarily.

Mechanical assemblies shall conform to the requirements specified in Table 8.

Table 8 — Characteristics for fitness for purpose of mechanical jointing

Characteristic	Requirements	Test parameters		Test method
Leaktightness under long-term hydrostatic internal pressure	No failure during test period	End caps	Type A	ISO 1167
		Type of test	Water-in-water	
		Test period	1 000 h	
		Test temperature	20 °C	
		Test pressure	1,5 PN [a]	
		followed by		
		Test period	1 000 h	
		Test temperature	40 °C	
		Test pressure	1,1 PN [a]	
Leaktightness under internal pressure when subjected to bending	No leaks	Test temperature	23 °C	ISO 3503
		Test period	1 h	
		Test pressure	1,5 × PN [a]	
External pressure	No leaks	Test temperature	23 °C	ISO 3459
		Test pressure	Δp_1 = 0,01 MPa	
		Test period	1 h	
		Test pressure	Δp_2 = 0,08 MPa	
		Test period	1 h	
Resistance to pull out under constant longitudinal force	No pull-out or separation of the pipe from the fitting	Test temperature	23 °C	ISO 3501
		Test period	1 h	
		Force	1,5 π PN $(d_e/2)^2$ [a]	

[a] The PN value is the lowest PN value of the components in the test assembly (either pipe or fitting).

10.3 Pressure reduction coefficients for operating temperatures

For applications operating at constant temperatures greater than 20 °C up to and including 40 °C, the pressure reduction coefficients given in Annex D shall be used.

11 Marking

When applicable, the marking shall include all the product classification items of Clause 4.

Multilayer pipes shall be permanently and legibly marked at intervals not greater than 1 m, in such a way that the marking does not initiate cracks or other types of failure and that normal storage, weathering, handling, installation and use shall not affect the legibility of the marking.

If printing is used, the colour of the printed information shall differ from the basic colour of the product.

The marking shall be such that it is legible without magnification.

The marking shall include at least the following information:

a) manufacturer's name or trade mark;

b) reference to this document (ISO 21004);

c) nominal pressure, PN;

d) nominal outside diameter, d_n (applicable for jointing);

e) pipe composition starting from the inside layer of the pipe, e.g. PE/Al/PE-X, PE/PE-X;

f) production period (year and month) in figures or in code form.

Annex A
(normative)

List of the reference product standards

The reference product standards published or under preparation are listed in Table A.1.

Table A.1 — List of reference product standards

Material	Reference product standard
PE	ISO 4427-1, ISO 4427-2, ISO 4427-3, ISO 4427-5
PVC-U	ISO 4422-1, ISO 4422-2, ISO 4422-3, ISO 4422-4, ISO 4422-5
PB [a]	ISO 15876-1, ISO 15876-2, ISO 15876-3, ISO 15876-5
PE-X [a]	ISO 15875-1, ISO 15875-2, ISO 15875-3, ISO 15875-5
PP [a]	ISO 15874-1, ISO 15874-2, ISO 15874-3, ISO 15874-5
PVC-C [a]	ISO 15877-1, ISO 15877-2, ISO 15877-3, ISO 15877-5
PE-RT [b]	ISO 22391-1, ISO 22391-2, ISO 22391-3, ISO 22391-5
[a] For the purpose of this International Standard, the hot and cold water product standards are applicable.	
[b] For the purpose of this International Standard, PE-RT is considered as PE conforming with ISO 4427.	

Annex B
(normative)

Application of design coefficient for multilayer pipes

B.1 Multilayer polymer pipes (only polymer layers) with an evaluated long-term hydrostatic strength of each material and given design coefficients

The long-term hydrostatic strength is calculated using the additive rule, adding the pressure strength of each layer intended for stress-bearing.

The pressure strength (resistance) takes into account the individual categorized lower confidence limit of the predicted hydrostatic strength, σ_{LPL}, the design coefficient and the dimension of each layer.

B.2 Multilayer polymer pipes (only polymer layers), σ_{LPL} not given, design coefficients for each material given

The long-term pressure strength of each individual construction is measured by using ISO 9080. The pressure strength takes into account the categorized lower confidence limit of the predicted hydrostatic pressure, P_{LPL}, and a global design coefficient calculated from the individual design coefficients and their fraction (percentage) of the wall thickness.

B.3 Multilayer metal pipes (polymer and metal layers)

The long-term pressure strength of each individual construction is measured by using ISO 9080. The pressure strength takes into account the lower confidence limit of the predicted hydrostatic pressure, P_{LPL}, and the design coefficient of the inner layer.

Annex C
(normative)

Tear test for polyethylene (PE) saddle assemblies

C.1 Principle

The method given in this annex tests the cohesive resistance of an electrofusion or heated tool saddle fused onto a pipe by applying a load along the centreline of the saddle. The test is conducted at an ambient temperature of (23 ± 2) °C.

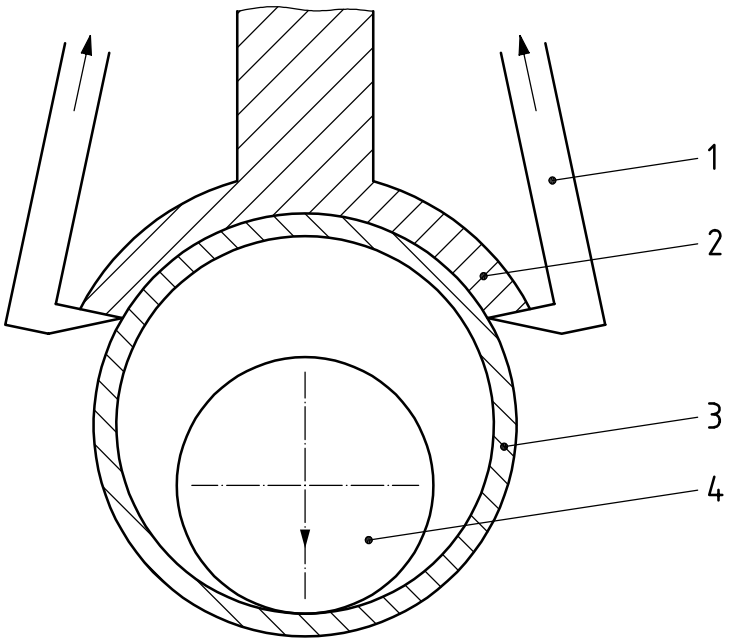
The cohesive resistance of the assembly is characterized by the nature of the failure in the fusion plane and by a percentage of decohesion, where the appearance and location of the failure is taken into account in interpreting the quality of the assembly.

C.2 Apparatus

C.2.1 Tensile testing machine, capable of maintaining a speed of (100 ± 10) mm/min and having sufficient force to separate the saddle from the pipe.

C.2.2 Loading pin (see Figure C.1), with an outside diameter equal to (66,6 ± 2) % the nominal outside diameter of the pipe.

C.2.3 Clamping device, of an appropriate form to allow the saddle to be gripped and separated from the pipe (see Figure C.1).



Key
1 clamping device
2 PE saddle
3 PE pipe
4 loading pin

Figure C.1 — Example of tear test assembly

C.3 Test piece

C.3.1 Preparation of test pieces

Test pieces shall be assembled in accordance with the manufacturer's instructions.

Unless otherwise specified, the main pipe shall not be perforated.

The free length on both sides of the saddle shall be minimum $0{,}1\,d_n$ (nominal outside pipe diameter).

Any attached under-clamp shall be removed.

For practical reasons, the branch outlet of the saddle may be removed.

NOTE The pipe wall thickness could influence the magnitude of applied peel stress.

C.3.2 Number of test pieces

The number of test pieces shall be as specified in the product standard.

Testing of at least three test pieces is recommended.

C.4 Conditioning

The testing shall not be carried out within a period of time of 24 h after completion of jointing.

Condition the test piece at an ambient temperature of (23 ± 2) °C for at least 6 h before carrying out the procedure given in C.5.

C.5 Test procedure

Carry out the following procedure at an ambient test temperature of (23 ± 2) °C.

a) Insert the loading pin inside the pipe.

b) Position the test piece and the clamping device such that the saddle is separated from the pipe at a speed of (100 ± 10) mm/min. An example of the tear test assembly, using a tensile test, is given in Figure C.1. Alternatively, the saddle may be separated from the pipe by a compression test assembly.

c) Continue the loading until complete separation or rupture of one of the parts of the test piece occurs, and record the maximum applied force.

d) Inspect the test piece for, and record the location of, any rupture (in the pipe or the saddle, between the wires or the fusion interface, etc.), also recording the type of rupture, and whether or not a brittle fracture surface is observed.

e) Measure and record the maximum brittle fracture length in radial direction of the fusion zone (d_2) and the overall length between the first and last wire in the fusion zone at the same location (y).

f) Calculate the percentage decohesion, C_c, using the following equation:

$$C_c = \frac{d_2}{y} \times 100$$

C.6 Test report

The test report shall include the following information:

a) a reference to this document (ISO 21004);

b) full identification of the components tested;

c) nature of the material for each of the assembly components tested;

d) nominal size of the saddle;

e) dimensions of the pipes, including nominal diameter, thickness or SDR;

f) fusion conditions of the test pieces;

g) test temperature;

h) number of test pieces subjected to testing;

i) time between fusion of test piece and test, conditioning period;

j) maximum separation force;

k) in case of failure — type of failure, i.e. brittle or ductile, and details of its appearance including, as applicable, decohesion at interface, tearing between wires, yielding of the pipe or saddle;

l) the percentage decohesion, C_c;

m) observations made during and after the test;

n) any factors which could have affected the results, such as any incidents noted or any operational details not specified in this document;

o) identification of test laboratory;

p) date of test.

Annex D
(normative)

Pressure reduction coefficients

D.1 Procedure I

The pressure reduction coefficients between 20 °C and 40 °C applicable to a 50-year lifetime are given by Table D.1 derived from the corresponding standard.

If more precise data are needed, calculation at 40 °C from the ISO 9080 evaluation can be carried out.

Table D.1 — Pressure reduction coefficients

Material	International Standard	Pressure reduction coefficients at		
		20 °C	30 °C	40 °C
PB	ISO 12230	1	0,92	0,84
PE	ISO 13761	1	0,87	0,74
PE-X	ISO 10146	1	0,88	0,79
PP-R	ISO 3213	1	0,84	0,71
PVC-C	ISO 15877-2	1	0,90	0,75
PVC-U	ISO 4422-2	1	0,85	0,71
PE-RT	ISO 24033	1	0,91	0,83

D.2 Procedure II

The pressure reduction coefficients are derived directly from the MRP evaluation according to ISO 9080.

Bibliography

[1] ISO 3, *Preferred numbers — Series of preferred numbers*

[2] ISO 497:1973, *Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers*

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