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Plastics piping systems for industrial applications — Unplasticized polyamide (PA-U) — Metric series for specifications for components and system

Systèmes de canalisations en matières plastiques pour les applications industrielles — Polyamide non plastifié (PA-U) — Séries métriques pour les spécifications pour les composants et le système

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Contents

Page

Foreword ... v

Introduction ... vi

1 Scope ... 1

2 Normative references ... 1

3 Terms and definitions ... 3
- 3.1 Geometrical definitions ... 3
- 3.2 Material definitions ... 4
- 3.3 Definitions related to material characteristics ... 4
- 3.4 Definitions related to service conditions ... 5

4 Symbols and abbreviated terms ... 6
- 4.1 Symbols ... 6
- 4.2 Abbreviated terms ... 7

5 Material ... 7
- 5.1 General ... 7
- 5.2 Long-term hydrostatic strength properties ... 7
- 5.3 Material characteristics ... 7
- 5.4 Virgin, reworkable and recyclable material ... 8
- 5.5 Materials for components not made from PA-U ... 8
  - 5.5.1 General ... 8
  - 5.5.2 Metallic materials ... 8
  - 5.5.3 Sealing materials ... 8
  - 5.5.4 Other materials ... 8

6 General characteristics ... 8
- 6.1 Appearance ... 8
- 6.2 Colour ... 8
- 6.3 Influence of UV radiation ... 9
- 6.4 Conditioning or saturation of pipe-based test specimens ... 9

7 Geometrical characteristics ... 9
- 7.1 General ... 9
- 7.2 Mean outside diameters, out-of-roundness (ovality), and tolerances ... 9
- 7.3 Wall thicknesses and related tolerances ... 9
- 7.4 Angles ... 9
- 7.5 Laying lengths ... 10
- 7.6 Threads ... 10
- 7.7 Mechanical fittings ... 10
- 7.8 Joint dimensions of valves ... 10

8 Mechanical characteristics ... 10
- 8.1 Resistance to internal pressure of components ... 10
- 8.2 Calculation of the test pressure for components ... 10
  - 8.2.1 Pipes ... 10
  - 8.2.2 Fittings ... 10
  - 8.2.3 Valves ... 11
  - 8.2.4 Resistance to rapid crack propagation (RCP) ... 11

9 Physical characteristics ... 11

10 Chemical characteristics ... 11
- 10.1 Effects on the component material(s) ... 11
- 10.2 Effects on the fluids ... 11

11 Electrical characteristics ... 11

12 Performance requirements ... 12
- 12.1 General ... 12

12.2 Fusion compatibility 12
13 Components performance 12
14 Classification of components 12
15 Design and installation 12
16 Declaration of conformity 12
17 Marking 13
17.1 General 13
17.2 Minimum required marking of pipes 13
17.3 Minimum required marking of fittings 13
17.4 Minimum required marking of valves 14
Annex A (normative) **Industrial piping systems made from unplasticized polyamide (PA-U) 15**
Annex B (informative) **Design and installation 32**
Bibliography 33

Foreword

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

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This document was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 3, *Plastics pipes and fittings for industrial applications*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document specifies the characteristics and requirements for a piping system and its components made from unplasticized polyamide (PA-U), as applicable, intended to be used for industrial applications above ground or below ground by authorities, design engineers, certification bodies, inspection bodies, testing laboratories, manufacturers, and users.

At the date of publication of this document, standards for piping systems of other plastics used for industrial applications include the following:

ISO 10931, *Plastics piping systems for industrial applications — Poly(vinylidene fluoride) (PVDF) — Specifications for components and the system*

ISO 15493, *Plastics piping systems for industrial applications — Acrylonitrile-butadiene-styrene (ABS), unplasticized poly(vinyl chloride) (PVC-U) and chlorinated poly(vinyl chloride) (PVC-C) — Specifications for components and the system — Metric series*

ISO 15494, *Plastics piping systems for industrial applications — Polybutene (PB), polyethylene (PE), polyethylene of raised temperature resistance (PE-RT), crosslinked polyethylene (PE-X), polypropylene (PP) — Metric series for specifications for components and the system*

Plastics piping systems for industrial applications — Unplasticized polyamide (PA-U) — Metric series for specifications for components and system

1 Scope

This document specifies the characteristics and requirements for a piping system and its components, made from unplasticized polyamide (PA-U) intended to be used for thermoplastics piping systems in industrial applications above and below ground.

NOTE 1 Requirements applying to industrial valves are given in this document and in other standards.

This document is applicable to PA-U pipes, fittings, valves and their joints, and to joints with components of other plastics and non-plastic materials, depending on their suitability, intended to be used for the conveyance of liquid and gaseous fluids as well as solid matter in fluids for industrial applications such as the following:

— transport of oil, gaseous fuels and multiphase mixtures (exploration and production; general purpose hydrocarbon-based fluids);

— transport of renewable gases (hydrogen, biomethane);

— transport of contaminated sewer (e.g. contaminated with hydrocarbons);

— transport of CO_2 [carbon capture and utilisation or storage (CCUS)].

NOTE 2 National regulations can apply.

NOTE 3 Other application areas are possible if the requirements of this document and/or applicable national requirements are fulfilled.

Characteristics and requirements which are applicable for PA-U are covered by the relevant clauses of this document. Those characteristics and requirements which are dependent on the material are given in the relevant normative Annex A.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 7-1, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation*

ISO 228-1, *Pipe threads where pressure-tight joints are not made on the threads — Part 1: Dimensions, tolerances and designation*

ISO 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 307, *Plastics — Polyamides — Determination of viscosity number*

ISO 472, *Plastics — Vocabulary*

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

ISO 1110, *Plastics — Polyamides — Accelerated conditioning of test specimens*

ISO 1133-2, *Plastics — Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics — Part 2: Method for materials sensitive to time-temperature history and/or moisture*

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 1167-3, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 3: Preparation of components*

ISO 1167-4, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids — Determination of the resistance to internal pressure — Part 4: Preparation of assemblies*

ISO 1183-1, *Plastics — Methods for determining the density of non-cellular plastics — Part 1: Immersion method, liquid pyknometer method and titration method*

ISO 1183-2, *Plastics — Methods for determining the density of non-cellular plastics — Part 2: Density gradient column method*

ISO 2505, *Thermoplastics pipes — Longitudinal reversion — Test method and parameters*

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

ISO 6964, *Polyolefin pipes and fittings — Determination of carbon black content by calcination and pyrolysis — Test method*

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

ISO 11922-1, *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, designation and design coefficient*

ISO 13478, *Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Full-scale test (FST)*

ISO 13479, *Polyolefin pipes for the conveyance of fluids — Determination of resistance to crack propagation — Test method for slow crack growth on notched pipes*

ISO 15512:2019, *Plastics — Determination of water content*

ISO 15853, *Thermoplastics materials — Preparation of tubular test pieces for the determination of the hydrostatic strength of materials used for injection moulding*

ISO 16135, *Industrial valves — Ball valves of thermoplastics materials*

ISO 16486-4, *Plastics piping systems for the supply of gaseous fuels — Unplasticized polyamide (PA-U) piping systems with fusion jointing and mechanical jointing — Part 4: Valves*

ISO 18553, *Method for the assessment of the degree of pigment or carbon black dispersion in polyolefin pipes, fittings and compounds*

IEC 60529, *Degrees of protection provided by enclosures (IP-code)*

EN 12099, *Plastics piping systems — Polyethylene piping materials and components — Determination of volatile content*

3 Terms and definitions

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

3.1 Geometrical definitions

3.1.1
nominal outside diameter
d_n
specified outside diameter assigned to a nominal size, DN/OD

Note 1 to entry: The nominal inside diameter of a socket is equal to the nominal outside diameter of the corresponding pipe.

Note 2 to entry: It is expressed in millimetres.

3.1.2
outside diameter
d_e
value of the measurement of the outside diameter through its cross-section at any point of the pipe, rounded to the next greater 0,1 mm

Note 1 to entry: The symbol d_e corresponds to d_{ey} given in other International Standards such as ISO 11922-1.

3.1.3
mean outside diameter
d_{em}
value of the measurement of the outer circumference of the pipe or spigot end of a fitting in any cross-section divided by π (= 3,142), rounded to the next greater 0,1 mm

3.1.4
nominal size
DN/OD
numerical designation of the size of a component, other than a component designated by thread size, which is a convenient round number, approximately equal to the manufacturing dimension in millimetres (mm) and related to the outside diameter

3.1.5
nominal size of flange
DN
numerical designation of the size of a flange for reference purposes and related to the manufacturing dimension in millimetres

3.1.6
out-of-roundness
ovality
difference between the maximum and the minimum outside diameter in the same cross-section of a pipe or spigot

3.1.7
nominal wall thickness
e_n
numerical designation of the wall thickness of a component, which is a convenient round number, approximately equal to the manufacturing dimension in millimetres (mm)

Note 1 to entry: For thermoplastics components conforming to Annexes A and B, the value of the nominal wall thickness, e_n, is identical to the specified minimum wall thickness at any point, e_{min}.

Note 2 to entry: The symbol e_n corresponds to e_{ey} given in other International Standards, such as ISO 11922-1.

3.1.8
wall thickness at any point
e
wall thickness at any point around the circumference of a component, rounded to the next greater 0,1 mm

3.1.9
minimum wall thickness at any point
$e_{\mathbf{min}}$
minimum value for the wall thickness at any point around the circumference of a component, as specified

3.1.10
pipe series
S
dimensionless number for pipe designation

Note 1 to entry: The pipe series, S, conforms to ISO 4065.

Note 2 to entry: The relationship between the pipe series, S, and the standard dimension ratio, SDR, is given by the following formula as specified in ISO 4065:

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

Note 3 to entry: Flanges are designated on the basis of nominal pressure, PN.

3.1.11
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

3.2 Material definitions

3.2.1
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 materials have been added

3.2.2
reworked material
plastics material from rejected unused products or trimmings capable of being reclaimed within the same process that generated it

Note 1 to entry: Previously referred to as “own reprocessed material”.

3.3 Definitions related to material characteristics

3.3.1
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 to entry: It is expressed in megapascals.

3.3.2
minimum required strength
MRS
value of σ_{LPL} (lower confidence limit of the predicted hydrostatic strength) at 20 °C and 50 years, rounded down to the next smaller value of the R10 series or the R20 series

Note 1 to entry: The R10 series conforms to ISO 3 and the R20 series conforms to ISO 497.

3.3.3
design stress
σ_s
allowable stress for a given application at 20 °C that is derived from the minimum required strength (MRS) by dividing it by the coefficient *C*

Note 1 to entry: Design stress can be calculated using the following formula:

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

Note 2 to entry: It is expressed in megapascals.

3.3.4
design coefficient
C
coefficient with a value greater than one which takes into consideration service conditions as well as the properties of the components of a piping system other than those represented in the lower confidence limit

3.4 Definitions related to service conditions

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

Note 1 to entry: A pressure, in bar, with the numerical value of PN is identical with the pressure, PS, as defined by Reference [19] if both pressures are taken at 20 °C.

Note 2 to entry: For plastics piping systems conveying water, PN corresponds to the maximum continuous operating pressure in bar, which can be sustained for water at 20 °C for 50 years, based on the following minimum design coefficient:

$$\text{PN} = \frac{10\sigma_s}{[S]} = \frac{20\sigma_s}{\text{SDR}-1}$$

where

σ_s is expressed in MPa;

PN is expressed in bar.

Note 3 to entry: 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa= 1 N/mm^2.

3.4.2
hydrostatic stress
σ
stress induced in the wall of a pipe when an internal hydrostatic pressure is applied

Note 1 to entry: The hydrostatic stress is related to the applied internal hydrostatic pressure (in bar), *p*, the wall thickness at any point, *e*, and the mean outside diameter, d_{em}, of a pipe. It is calculated using the following formula:

$$\sigma = p\frac{d_{em} - e_{min}}{20e_{min}}$$

Note 2 to entry: This formula is applicable for pipes only.

Note 3 to entry: The value is expressed in megapascals.

4 Symbols and abbreviated terms

4.1 Symbols

C design coefficient (design factor)

D_1 mean inside diameter in the fusion zone

D_2 minimum diameter of the flow channel through the body of the fitting

d_e outside diameter (at any point)

d_{em} mean outside diameter

d_n nominal outside diameter

D_{f1} outside diameter of chamfer on shoulder

D_{f2} outside diameter of flange adaptor

DN nominal size of flange

e wall thickness (at any point)

e_n nominal wall thickness

h height of the service pipe

H height of the saddle

L width of the tapping tee

L_1 depth of penetration of the pipe or male end of a spigot end fitting

L_2 nominal length of the fusion zone

L_3 nominal unheated entrance length of the fitting

L_{b2} outside tubular length

p internal hydrostatic pressure

p_c critical pressure

$p_{c,REF}$ critical reference pressure

p_s maximum allowable pressure

r_f radius of chamfer on shoulder

T temperature

t time

σ hydrostatic stress

4.2 Abbreviated terms

MOP maximum operating pressure

MRS minimum required strength

PA-U unplasticized polyamide (PA-U11 or PA-U12)

PN nominal pressure

RCP rapid crack propagation

S pipe series S

SDR standard dimension ratio

5 Material

5.1 General

The PA-U material from which the components are made shall either be PA-U 11 or PA-U 12, to which are added those additives that are needed to facilitate the manufacture of pipes, fittings, and valves conforming to this document.

If additives are used, they shall be uniformly dispersed.

The additives shall not be used separately or together in quantities sufficient to impair the fabrication or fusion characteristics of the component or to impair the chemical, physical, or mechanical characteristics as specified in this document.

5.2 Long-term hydrostatic strength properties

The material shall be evaluated in accordance with ISO 9080 by analysis of pressure tests carried out in accordance with ISO 1167-1 and ISO 1167-2 to classify the material in accordance with ISO 12162.

EXAMPLE PA-U12 180 or PA-U11 180 compounds are classified for MRS 18 MPa.

Conformity of the relevant material to the reference curves given for PA-U 180 shall be proven according to Annex A, Formula (A.1) and Formula (A.2) or corresponding Figure A.1. At least 97,5 % of the data points shall be on or above the reference curves. For design, these reference curves shall be used as a basis.

The material shall be classified by the raw material producer.

NOTE In some cases, the component manufacturer can be regarded as the raw material producer.

Where fittings and valves are manufactured from the same material as pipes, the material classification shall be the same as for pipes.

For the classification of a material intended only for the manufacture of fittings and valves, the test piece shall be an injection-moulded or extruded test piece in the form of a pipe where a test pressure is applied according to ISO 1167-1. The free length shall be $3d_n$, as defined in ISO 1167-2 or ISO 15853.

5.3 Material characteristics

The details of the material characteristics of PA-U mechanical and physical properties with requirements are given in Annex A.

5.4 Virgin, reworkable and recyclable material

Stress-bearing parts shall only be made from virgin material in accordance with Annex A. Non-stress-bearing parts shall be made from virgin material or reworked material from a compound with the same MRS or a mixture of both, virgin and reworked material.

The use of reworkable material obtained during the production and testing of components according to this document is not permitted.

Reprocessable material obtained from external sources and recyclable material shall not be used.

5.5 Materials for components not made from PA-U

5.5.1 General

All components shall conform to the relevant International Standard(s). Alternative standards may be applied in cases where suitable International Standard(s) do not exist. In all cases, fitness for purpose of the components shall be demonstrated.

Materials and constituent elements used in making the relevant component (including rubber, greases, and any metal parts used) shall have comparable resistance to the external and internal environments as all other elements of the piping system according to this document.

Materials other than PA-U in contact with components conforming to this document shall not adversely affect the performance of the components or initiate stress cracking.

5.5.2 Metallic materials

All metal parts susceptible to corrosion shall be adequately protected.

When dissimilar metallic materials are used which can be in contact with moisture, steps shall be taken to avoid the possibility of galvanic corrosion.

5.5.3 Sealing materials

Sealing materials shall have no detrimental effects on the properties of the components, joints, and assemblies.

5.5.4 Other materials

Greases or lubricants shall not exude onto fusion areas and shall not affect the long-term performance of materials conforming to this document.

6 General characteristics

6.1 Appearance

When viewed without magnification, the internal and external surfaces of the components shall be smooth, clean, and free from scoring, cavities, and other surface defects to an extent that would prevent conformity to this document. The components shall not contain visible impurities.

Each end of a component shall be square to its axis and shall be deburred.

6.2 Colour

The colour of the components shall be as given in Clause A.2 of this document.

NOTE National or regional legislation relating to the colour coding of piping in respect of its purpose or contents for the location in which the components are intended to be used can apply.

6.3 Influence of UV radiation

Components for external above ground installations shall be adequately protected against UV radiation or the material shall be resistant to UV radiation for the intended application. For products which are usually stored outside in direct sunlight prior to installation, the effect of UV radiation shall be taken into account. To assess materials for resistance to UV radiation for storage purposes, pipe shall subject to a cumulative radiant exposure of ≥7,0 GJ/m^2 in accordance with ISO 16871. Following this exposure, the pipe is assessed for any significant change in mechanical properties.

6.4 Conditioning or saturation of pipe-based test specimens

Unless otherwise specified in the applicable test method, test pieces shall be conditioned for at least 16 h at 23 °C and 50 % relative humidity in accordance with ISO 291 before testing.

The test pieces shall not be tested within the period of 48 h after their manufacture.

Long-term hydrostatic strength data shall be generated on saturated polyamide pipe specimens representing the most severe case to prevent rising humidity content of the pipe over test duration and resulting effects on the analysis of time to failure test results. The saturation process in water shall be accelerated according to ISO 1110. Data shall show the uptake of water until saturation over time according to ISO 15512.

NOTE In ISO 16486-2:2024 Annex B, information is given about the saturation performance of pipes in water.

7 Geometrical characteristics

7.1 General

The measurement shall not be made less than 24 h after manufacture.

Dimensions shall be measured in accordance with ISO 3126 at (23 ± 2) °C after being conditioned for at least 4 h unless specified otherwise in Annex A.

Indirect measurement during the stage of production is allowed at shorter time periods providing that evidence is shown of correlation.

The figures provided in Annex A are schematic sketches only, to indicate the relevant dimensions. They do not necessarily represent the manufactured component(s). The given dimensions shall be followed.

Dimensions not given shall be specified by the manufacturer.

7.2 Mean outside diameters, out-of-roundness (ovality), and tolerances

For components made from PA-U the diameters, out-of-roundness (ovality) and related tolerances shall conform to Clause A.3.

The out-of-roundness (ovality) shall be measured at the point of manufacture.

7.3 Wall thicknesses and related tolerances

For components made from PA-U, the wall thicknesses and related tolerances shall conform to Clause A.3.

7.4 Angles

The permitted deviations from the nominal or declared angle for a nonlinear fitting shall be ±2° where the angle comprises the relevant change of axis of the flow through the fitting.

The recommended nominal angles for a nonlinear fitting are 45° or 90°.

7.5 Laying lengths

The laying lengths for fittings and valves shall be declared by the manufacturer.

The laying lengths are intended to assist in the design of moulds and are not intended to be used for quality control purposes. ISO 265-1 may be used as a guideline.

7.6 Threads

Joints made pressure-tight by the mating of the threads shall conform to ISO 7-1 and fastening pipe threads to ISO 228-1

International Standard with the same content as ISO 7-1 exist, e.g. EN 10226-1 and EN 10226-2.

7.7 Mechanical fittings

Mechanical fittings such as adaptors, unions, compression fittings, and reducing bushes may be used, provided that their joint dimensions are in accordance with the applicable dimensions of components conforming to this document.

7.8 Joint dimensions of valves

The joint dimensions of valves shall conform to the relevant dimensions of pipes and fittings conforming to this document.

8 Mechanical characteristics

8.1 Resistance to internal pressure of components

Components shall withstand the hydrostatic stress induced by internal hydrostatic pressure without bursting or leaking when tested in accordance with ISO 1167-1, ISO 1167-2, and ISO 1167-3 and the test conditions specified for PA-U in Annex A.

8.2 Calculation of the test pressure for components

8.2.1 Pipes

For pipes, the relation between hoop stress, σ, expressed in MPa, and internal hydrostatic pressure, p, expressed in bar, is given by Formula (1):

$$\sigma = p\frac{d_{em} - e_{min}}{20e_{min}} \quad (1)$$

For tests the internal hydrostatic pressure, p, expressed in bar, shall be determined for pipes using Formula (2):

$$p = \frac{10\sigma}{[S]} = \frac{20\sigma}{SDR - 1} \quad (2)$$

where σ is the hoop stress for PA-U conforming to the A.1.2.

8.2.2 Fittings

For tests the internal hydrostatic pressure, p, expressed in bar, shall be determined for fittings using Formula (2). For S and SDR respectively, the value of the corresponding pipe shall be taken.

8.2.3 Valves

For tests the hydrostatic pressure, p, expressed in bar, is defined for valves in ISO 16486-4.

8.2.4 Resistance to rapid crack propagation (RCP)

For a pipeline system carrying air or a compressible gas, for design purposes, the resistance of the material to the phenomenon known as rapid crack propagation shall be taken into account (see ISO 16486-1, ISO 16486-2 and ISO 16486-5). The critical pressure p_c is dependent on the material, pipe diameter, and operating temperature.

The critical reference pressure $p_{c,REF}$ measured in accordance with ISO 13478 shall be greater than 1,5 times the maximum operating pressure of the pipeline system.

Information provided by the pipe or material supplier should be taken into account when designing an industrial pipeline system for the transport of air or a compressible gas. The maximal wall thickness for RCP resistance shall be provided by the compound manufacturer.

NOTE For unplasticized polyamide (PA-U) SDR 11 pipe produced in accordance with ISO 16486-2 for natural gas applications, the KRV listing[9] show an RCP resistance for a wall thickness up to including 14,6 mm that allows an operation at 18 bar (for CEN limited to 16 bar) for temperatures above 0 °C with diameters up to including 160 mm.

9 Physical characteristics

The physical characteristics of components made from PA-U shall conform to Annex A.

10 Chemical characteristics

10.1 Effects on the component material(s)

Where fluids other than water are to be conveyed, the effect of the fluid on the component material should be considered.

NOTE Guidance is available in ISO/TR 10358 or from the component manufacturer.

The chemical resistance of the pipe shall be evaluated for a particular application. Then the pipe can be classified in accordance with ISO 4433-1.

The influence of chemical fluids on the long-term hydrostatic strength of PA-U pressure pipes may be determined by DIN 16463 or, if applicable, by long-term, in situ creep rupture tests as described in Reference [13], where the results are used for ASTM F 3524.

10.2 Effects on the fluids

Where fluids other than water are to be conveyed, the effect of the component material on the fluid should be considered.

11 Electrical characteristics

The electrical protection that shall be provided by the fusion process depends on the characteristics of the electricity power source.

NOTE The relevant component during the fusion process is part of an electrical system, see Reference [21] or Reference [15].

Protection against direct contacts with active parts (live conductors) shall be in accordance with IEC 60529. This protection is a function of the work site conditions.

The surface finish of the terminal pins shall allow a minimum contact resistance.

12 Performance requirements

12.1 General

When components made from the same material conforming to this document are jointed to each other, the pipes, fittings, valves, and the joints shall conform to the requirements of Clause A.6.

NOTE If test pressures defined for pipes are used for assemblies made from components of dissimilar materials (e.g. screwed joints, flanged joints), the resulting strain exceeds the strain occurring under service conditions. These strains unavoidably cause leakage. Therefore, in this document, the time related strain behaviour of the assemblies is taken into account and the test pressures derived from the isochronous stress-strain-diagram are used.

12.2 Fusion compatibility

Pipes made from PA-U 11 shall be heat fusion jointed only to either pipes or components made from PA-U 11, or both.

Pipes made from PA-U 12 shall be heat fusion jointed only to either pipes or components made from PA-U 12, or both.

Pipes made from PA-U are not fusion compatible either with pipes or components made from other polymers, or both.

Test methods for assuring fusibility are given in ISO 16486-3 and ISO 16486-5.

13 Components performance

The components shall withstand the mechanical, thermal, and chemical demands to be expected. The components shall be resistant to the fluids to be conveyed. Components conforming to any of the product standards listed in the bibliography or with national standards, as applicable, may be used with components conforming to this document provided that they conform to the requirements for joint dimensions and to the relevant requirements of this document.

Valves shall be used with components conforming to this document provided that they conform additionally to the relevant requirements of this document.

14 Classification of components

The classification of pipes shall be based on the pipe series, S, or the standard dimension ratio, SDR, or the nominal pressure, PN, as applicable.

The classification of fittings shall be based on the corresponding pipe together with the pipe series S or the standard dimension ratio, SDR, or the nominal pressure, PN, as applicable.

Valves shall be classified in accordance with the requirements of ISO 16486-4.

15 Design and installation

For the design and installation of thermoplastic piping systems for industrial applications, see Annex B.

16 Declaration of conformity

The manufacturer shall declare conformity to this document by marking the component in accordance with Clause 16 and, under request, issue a statement of conformity.

17 Marking

17.1 General

Marking elements shall be printed or formed directly on the component or be on a label in such a way that after storage, weathering, handling and installation, legibility is maintained.

NOTE The manufacturer is not responsible for marking of the component becoming-illegible due to actions caused during installation and use, such as painting, scratching, covering, or by use of detergents, etc., unless agreed upon or specified by the manufacturer.

Marking shall not initiate cracks or other types of defects which adversely influence the performance of the component.

If printing is used, the colouring of the printed information shall differ from the basic colouring of the component.

The size of the marking shall be such that the marking is legible without magnification.

17.2 Minimum required marking of pipes

The minimum required marking of pipes shall conform to Table 1.

Pipes shall be marked at intervals of maximum 1 m, at least once per pipe.

Table 1 — Minimum required marking of pipes

Aspects	Marking or symbol[a]
Number of the International Standard	
Manufacturer's name and/or trade mark	Name or symbol
Nominal outside diameter, d_n	e.g. 110
Nominal wall thickness, e_n, or pipe series, S, or standard dimension ratio, SDR, or nominal pressure, PN	e.g. 10,0 or e.g. S 5 or SDR 11 or e.g. PN 10
Material type with MRS classification	e.g. PA-U11 180
Manufacturer's information	[b]

[a] Information on abbreviated terms can be found in Reference [16] and/or in national regulations.

[b] For providing traceability, the following details shall be given:

— production period, year and month, in figures or in code;

— name or code for the production site if the manufacturer is producing at different sites.

17.3 Minimum required marking of fittings

The minimum required marking of fittings shall conform to Table 2, except for fittings with $d_n \leq 32$ mm, for which the minimum required marking shall be directly on the fitting, as follows:

— manufacturer's name and/or trade mark;

— nominal outside diameter(s);

— material;

— nominal wall thickness, e_n, or pipe series S or SDR or PN, as applicable.

Table 2 — Minimum required marking of fittings

Aspects	Marking or symbol[a]
Number of the standard[a]	ISO 21036
Manufacturer's name and/or trade mark	Name or symbol
Nominal outside diameter(s), d_n	e.g. 63-32-63
Nominal wall thickness, e_n, or pipe series, S, or standard dimension ratio, SDR, or nominal pressure, PN	e.g. 10,0 or e.g. S 5 or e.g. SDR 11 or e.g. PN 18
Nominal size DN[b]	e.g. DN 50
Material type with MRS classification	e.g. PA-U11 180
Manufacturer's information	[c]

[a] Information on abbreviations can be found in Reference [17] and/or in national regulations. This information may either be marked directly on the fitting or on a label attached to the fitting or on the packaging.

[b] Applicable to flanges only.

[c] For providing traceability, the following details shall be given:

— production period, year and month, in figures or in code;

— name or code for the production site if the manufacturer is producing at different sites.

17.4 Minimum required marking of valves

Valves shall be marked in accordance with the requirements of ISO 16135 (see also ISO 16486-4), as applicable.

Annex A
(normative)

Industrial piping systems made from unplasticized polyamide (PA-U)

A.1 Material

A.1.1 General

This annex is applicable to the following types of unplasticized polyamides:

— unplasticized polyamide 11 (PA-U11 180);

— unplasticized polyamide 12 (PA-U12 180).

NOTE A comprehensive set of regression curves including ductile to brittle transition is only available for PA-U 180 (PA-U11 180 or PA-U12 180).

A.1.2 Material for components

The material shall be tested in accordance with 5.2 at 20 °C, 60 °C, and 80 °C, as well as at various hydrostatic (hoop) stresses in such a way that at each temperature, at least three failure times fall in each of the following time intervals:

— 10 h to 100 h;

— 100 h to 1 000 h;

— 1 000 h to 8 760 h;

— >8 760 h.

In tests lasting more than 8 760 h, any time which is reached at a certain stress and time at least on or above the relevant reference curve may be considered as failure time.

For PA-U 180, at 80 °C, there shall be no knee detected in the regression curve before 5 000 h.

The values of the minimum required hydrostatic strength [see reference curves given in Figure A.1 (PA-U 180)] in the temperature range of 10 °C to 80 °C shall be calculated using Formula (A.1) and Formula (A.2):

NOTE Testing has shown that for many compounds, no knee is detected before 1 year at 80 °C.

First branch: $$Log_{10}\ t = A_1 + \frac{B_1}{T} Log_{10}\ \sigma + \frac{C_1}{T} + D_1\ Log_{10}\ \sigma \quad \text{(A.1)}$$

Second branch: $$Log_{10}\ t = A_2 + \frac{C_2}{T} + D_2\ Log_{10}\ \sigma \quad \text{(A.2)}$$

where

t is the time, in hours;

T is the temperature, in kelvin;

σ is the hoop stress, in megapascal.

The lower value obtained from Formula (A.1) or Formula (A.2), respectively represents the expected minimum hoop strength.

First branch for PA-U 180:

A_1 = −34,909

B_1 = 24,234,068

C_1 = -8,855

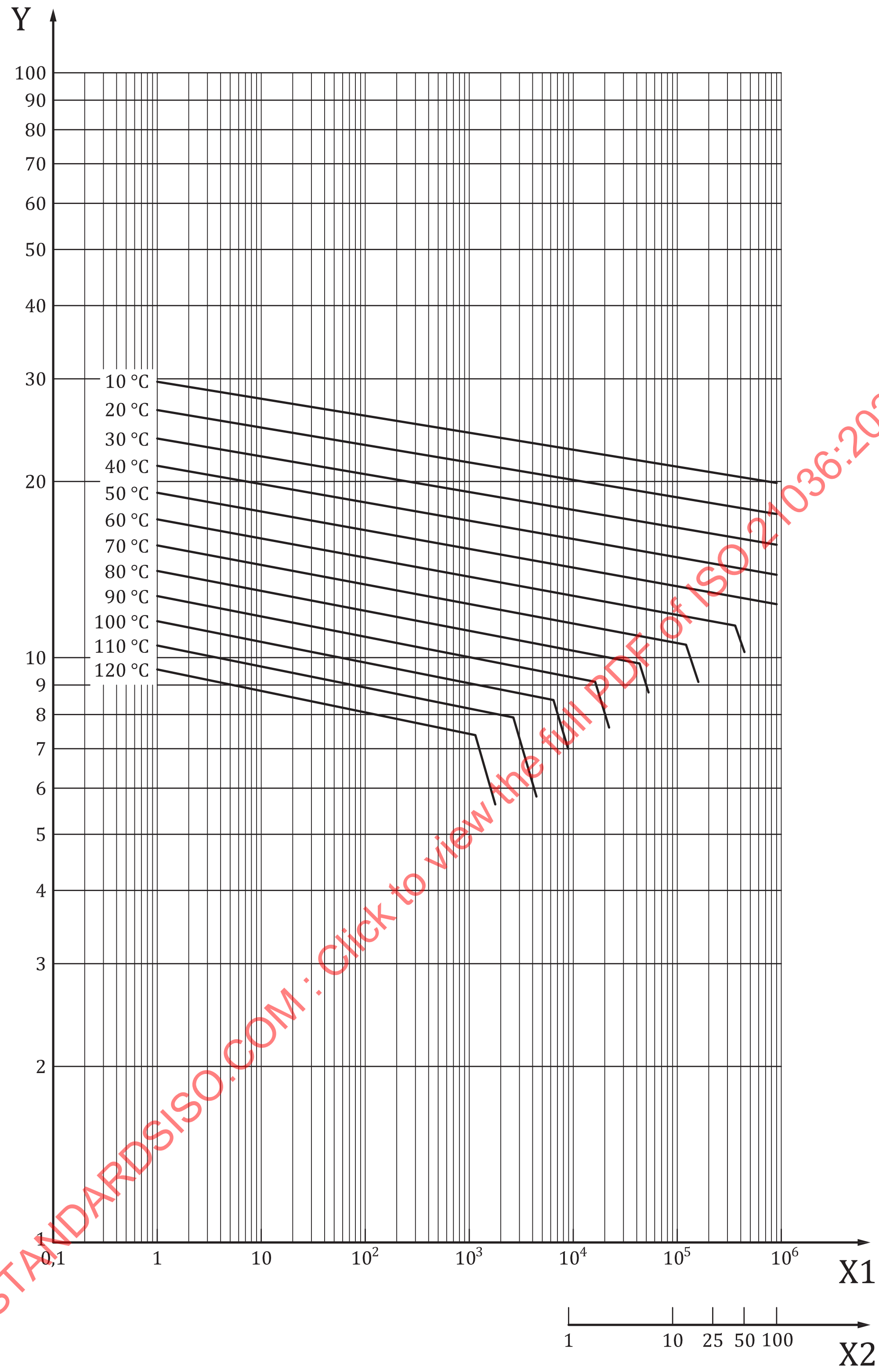
D_1 = -7,240,036

Second branch for PA-U 180:

A_2 = −12,752

B_2 = 6,753,180

D_2 = -618,358



Key

X_1 time to failure, in hours (h)

X_2 time to failure, in years

Y hoop stress, in megapascal (MPa)

Figure A.1 — Minimum required hydrostatic strength curves for PA-U 180

A.1.3 MRS-value

When evaluated in accordance with 5.2, the applicable PA-U 180-types shall have a minimum required strength, MRS, as given in Table A.1.

Table A.1 — MRS-values of PA-U 180-types

PA-U 180-type	MRS-value
PA-U11 180	≥18,0 MPa
PA-U12 180	≥18,0 MPa

A.1.4 Material characteristics

The material from which the components are manufactured shall conform to the requirements given in Table A.2 and Table A.3.

Table A.2 — Characteristics of the material in the form of granules

Characteristic	Requirements[a]	Test parameters		Test method
		Parameter	Value	
Compound density	PA-U 11 compound: (1 020 to 1 050) kg/m^3 PA-U 12 compound: (1 000 to 1 040) kg/m^3	Test temperature	23 °C	ISO 1183-1 or ISO 1183-2
Viscosity number	≥180 ml/g	Solvent	*m*-Cresol	ISO 307
Water content	≤0,10 %			ISO 15512:2019, Method B or E
Volatile content	≤ 350 mg/kg	Shall conform to EN 12099		EN 12099
Water content	≤ 300 mg/kg (Equivalent to < 0,03 % by mass)	Shall conform to ISO 15512		ISO 15512
Carbon black content[b]	(1,0 to 2,5) % (by mass)			ISO 6964
Carbon black dispersion[b]	≤ Grade 3 Rating of dispersion A1, A2, A3, or B	Preparation of test pieces Number of test pieces[c]	Free[d] Shall conform to ISO 18553	ISO 18553
Pigment dispersion[e]	Grade ≤3 Rating of appearance A1, A2, A3 or B	Preparation of test pieces Number of test pieces[c]	Free[d] Shall conform to ISO 18553	ISO 18553

[a] Conformity to these requirements shall be declared by the raw material producer.

[b] Only for black compound.

[c] The number of test pieces given indicate the number required to establish a value for the characteristic described in the table. The numbers of test pieces required for factory production control and process control should be listed in the manufacturer's quality plan. For guidance, see ISO/TS 16486-7.

[d] In case of dispute, the test pieces shall be prepared by the microtome method.

[e] Only for coloured compounds.

Table A.3 — Characteristics of the material in the form of pipe

Characteristic	Requirement[a]	Test parameters		Test method
		Parameter	Value	
Resistance to rapid crack propagation (Critical pressure, p_c)[b] ($e \geq 5$ mm) (Full-scale test)	$p_c \geq 1{,}5$ PN[c,d]	Test temperature	0 °C	In accordance with ISO 13478[e]
Resistance to slow crack growth for $e > 5$ mm (notch test)	No failure during the test period	Test temperature	80 °C	ISO 13479
		d_n	110 mm or 125 mm	
		SDR	11	
		Test pressure:		
		PA-U 11 160 and PA-U 12 160 c	18 bar	
		PA-U 11 180 and PA-U 12 180[c]	20 bar	
		Test period	500 h	
		Type of test	Water-in-water	
		Number of test pieces[f]	Shall conform to ISO 13479	

a Conformity to these requirements shall be proved by the compound producer.

b Only applicable for the conveyance of compressed gas in which case, PN is based on a C factor of 2.

c In this case, PN is based on a C factor of 2.

d The critical pressure, p_c shall be determined for each new PA-U compound and for every pipe dimension with $d_n > 90$ mm.

e The temperature of cooling for the crack initiation groove shall be appropriate to produce a high-speed crack or cracks emanating from the initiation. For some PA-U compounds a crack initiation groove temperature between 0 °C and −60 °C has been found to be suitable.

f The numbers of test pieces given indicate the numbers required to establish a value for the characteristic described.

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

A.1.5 Type of pipe

The following two types of pipe are covered:

— PA-U11 180 pipe (outside diameter d_n), including any identification;

— PA-U12 180 pipe (outside diameter d_n), including any identification.

A.2 General characteristics: Colour

Components made from PA-U should preferably be black. Other colours shall be agreed upon between manufacturer and purchaser or in accordance with national regulations.

A.3 Geometrical characteristics

A.3.1 Dimensions of pipes

A.3.1.1 Diameters and related tolerances

The mean outside diameter, d_{em}, and the related tolerances shall conform to Table A.4, appropriate to the tolerance grade, whereby the average value of the measurements of the outside diameter d_e made at a distance of d_n and $0{,}1d_n$, as well as from the end of the test pieces, shall be within the tolerance range for d_{em} as specified in Table A.4.

NOTE Pipes with tolerances of Grade A given in ISO 11922-1 are used for socket fusion and electrofusion joints where the peeling technique is used to prepare the pipe end for fusion. Pipes with tolerances of Grade B given in ISO 11922-1 are used for socket fusion joints where the peeling technique is not used.

A.3.1.2 Out-of-roundness

The out-of-roundness for straight lengths shall conform to Table A.4 when measured at the point of manufacture. If other values for the out-of-roundness than those given in Table A.4 are necessary, they shall be agreed upon between manufacturer and purchaser.

For coiled pipes, the maximum out-of-roundness shall be specified by agreement between manufacturer and purchaser.

Table A.4 — Mean outside diameters, related tolerances, and out-of-roundness of pipes

Dimensions in millimetres

Nominal outside diameter	Mean outside diameter		Maximum of absolute out-of-roundness[a]
d_n	$d_{em,min}$	$d_{em,max}$	Grade N[b]
16	16,0	16,3	1,2
20	20,0	20,3	1,2
25	25,0	25,3	1,2
32	32,0	32,3	1,3
40	40,0	40,4	1,4
50	50,0	50,4	1,4
63	63,0	63,4	1,5
75	75,0	75,5	1,6
90	90,0	90,6	1,8
110	110,0	110,7	2,2
125	125,0	125,8	2,5
140	140,0	140,9	2,8
160	160,0	161,0	3,2
180	180,0	181,1	3,6
200	200,0	201,2	4,0
225	225,0	226,4	4,5
250	250,0	251,5	5,0
280	280,0	281,7	9,8
315	315,0	316,9	11,1
355	355,0	357,2	12,5
400	400,0	402,4	14,0
450	450,0	452,7	[c]
500	500,0	503,0	[c]
560	560,0	563,4	[c]
630	630,0	633,8	[c]

[a] Measurement of out-of-roundness shall be made at the point of manufacture in accordance with ISO 3126.

[b] Grade N shall be in accordance with ISO 11922-1.

[c] The maximum out-of-roundness shall be specified by agreement.

A.3.1.3 Wall thicknesses and related tolerances

The wall thickness, e, and the related tolerances shall conform to Table A.5.

Table A.5 — Wall thicknesses and related tolerances

Dimensions in millimetres

Nominal outside diameter[b] d_n	Minimum wall thickness[a] e_{min}						
	SDR 7,4	**SDR 9**	**SDR 11**	**SDR 13,6**	**SDR 17**	**SDR 21**	**SDR 26**
16	2,2	—	—	—	—	—	—
20	2,8	2,3	—	—	—	—	—
25	3,5	2,8	2,3	—	—	—	—
32	4,4	3,6	2,9	2,4	—	—	—
40	5,5	4,5	3,7	3,0	2,4	2,0	—
50	6,9	5,6	4,6	3,7	3,0	2,4	2,0
63	8,6	7,1	5,8	4,7	3,8	3,0	2,5
75	10,3	8,4	6,8	5,6	4,5	3,6	2,9
90	12,3	10,1	8,2	6,7	5,4	4,3	3,9
110	15,1	12,3	10,0	8,1	6,6	5,3	4,2
125	17,1	14,0	11,4	9,2	7,4	6,0	4,8
140	19,2	15,7	12,7	10,3	8,3	6,7	5,4
160	21,9	17,9	14,6	11,8	9,5	7,7	6,2
180	24,6	20,1	16,4	13,3	10,7	8,6	6,9
200	27,4	22,4	18,2	14,7	11,9	9,6	7,7
225	30,8	25,2	20,5	16,6	13,4	10,8	8,6
250	34,2	27,9	22,7	18,4	14,8	11,9	9,6
280	—	31,3	25,4	20,6	16,6	13,4	10,7
315	—	35,2	28,6	23,2	18,7	15,0	12,1
355	—	—	32,2	26,1	21,1	16,9	13,6
400	—	—	36,4	29,4	23,7	19,1	15,3
450	—	—	—	33,1	26,7	21,5	17,2
500	—	—	—	36,8	29,7	23,9	19,1
560	—	—	—	—	33,2	26,7	21,4
630	—	—	—	—	—	30,0	24,1

[a] For wall thickness >30 mm, butt fusion jointing parameters are evaluated individually.

[b] For diameters >250 mm, mechanical fittings and electrofusion methods are evaluated.

A.3.2 Dimensions of fittings

A.3.2.1 General

This annex is applicable for the following types of fittings:

— butt fusion fittings;

— socket fusion fittings;

— electrofusion fittings;

— flange adaptors and loose backing flanges;

— mechanical fittings.

A.3.2.2 Butt fusion fittings

A.3.2.2.1 Outside diameters

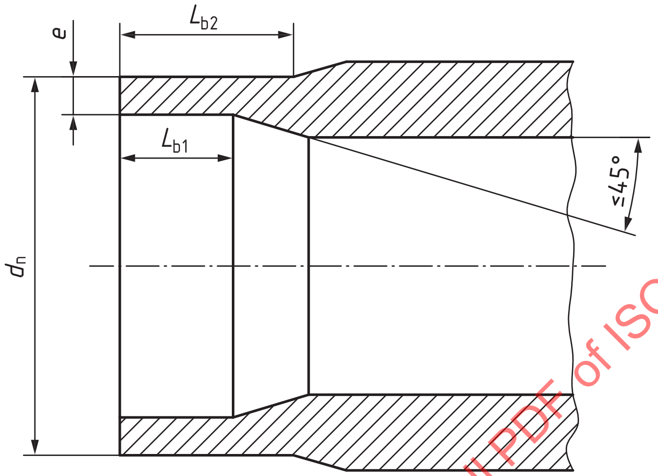
The mean outside diameter, d_{em}, of the spigot end (see Figure A.2) over the length, L_{b2} (see Table A.6) shall conform to A.3.1.1, except between the plane of the entrance face and the plane parallel to it, located at a distance not greater than $0{,}01d_n + 1$ mm where a reduction of the outside diameter is permissible (e.g. for circumferential reversion).

A.3.2.2.2 Out-of-roundness

The out-of-roundness of the spigot end (see Figure A.2) over the length, L_{b2} (see Table A.6) shall conform to A.3.1.2.

A.3.2.2.3 Wall thickness of the spigot end

The wall thickness, e, of the spigot end (see Figure A.2) over the length, L_{b1}, (see Table A.6) shall conform to A.3.1.3 except between the plane of the entrance face and the plane parallel to it, located at a distance not greater than $0{,}01d_n + 1$ mm where a thickness reduction is permissible (e.g. for chamfered edge).



Key

L_{b1} minimum inside tubular length of the fusion end, which comprises the initial depth of the spigot end which is necessary for butt fusion

L_{b2} minimum outside tubular length of the fusion end, which comprises the initial length of the fusion end

Figure A.2 — Dimensions of spigot end for butt fusion fittings

Table A.6 — Dimensions of spigot ends for butt fusion fittings

Dimensions in millimetres

Nominal outside diameter d_n	Inside tubular length L_{b1}[a] min.	Outside tubular length L_{b2}[a] min.
16	4	10
20	4	10
25	4	10
32	5	10
40	5	10
50	5	12
63	6	12
75	6	12
90	7	12
110	8	12
125	8	15

NOTE The minimum tubular lengths given in this table are too short for electrofusion joints. For this jointing method, a tubular length conforming to the depth of penetration according to Table A.7 is necessary.

[a] For bends, a reduction of the tubular length(s) is permissible.

Table A.6 *(continued)*

Nominal outside diameter d_n	Inside tubular length L_{b1}[a] min.	Outside tubular length L_{b2}[a] min.
140	9	15
160	9	20
180	10	20
200	11	20
225	12	25
250	13	25
280	14	30
315	15	30
355	16	30
400	18	30
450	20	35
500	20	35
560	20	40
630	20	40

NOTE The minimum tubular lengths given in this table are too short for electrofusion joints. For this jointing method, a tubular length conforming to the depth of penetration according to Table A.7 is necessary.

[a] For bends, a reduction of the tubular length(s) is permissible.

A.3.2.2.4 Wall thickness of fitting body

The wall thickness, *e*, of the fitting body shall be at least equal to the minimum wall thickness of the corresponding pipe (see A.3.1.3).

A.3.2.2.5 Other dimensions

Other dimensions of butt fusion fittings shall be specified by the manufacturer.

A.3.2.3 Electrofusion fittings

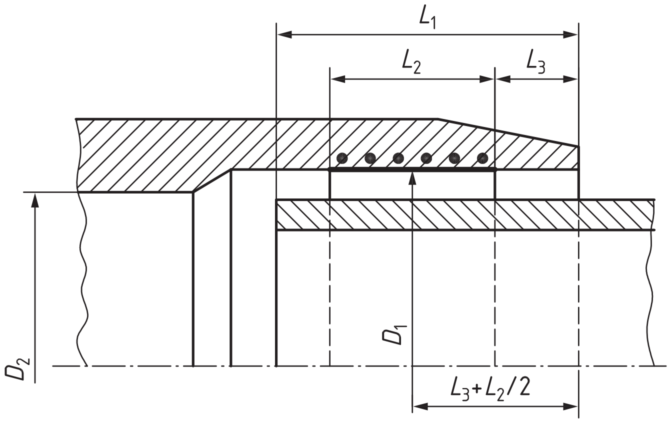
A.3.2.3.1 Dimensions of sockets of electrofusion fittings

The dimensions of sockets of electrofusion fittings (see Figure A.3) shall conform to Table A.7.

The mean inside diameter of the fitting in the middle of the fusion zone, D_1, shown in Figure A.3 shall not be less than d_n. The manufacturer shall declare the actual maximum and minimum values of D_1 and L_1 for determining suitability for clamping and joint assembly.

In the case of a fitting having sockets of different sizes (e.g. reduction), each socket shall conform to the requirements of the corresponding nominal diameter.

In the case of using spigot end fittings, the outside tubular length of the fusion end shall allow the assembly with an electrofusion fitting.



Key

D_1 mean inside diameter in the fusion zone measured in a plane parallel to the plane of the mouth at a distance of $L_3 + 0{,}5L_2$ from that face

D_2 bore, which is the minimum diameter of the flow channel through the body of the fitting

L_1 depth of penetration of the pipe or male end of a spigot end fitting. In case of a coupling without stop, it is not greater than half the total length of the fitting

L_2 heated length within a socket as declared by the manufacturer, to be the nominal length of the fusion zone

L_3 distance between the mouth of the fitting and the start of the fusion zone as declared by the manufacturer to be the nominal unheated entrance length of the fitting ($L_3 \geq 5$ mm)

Figure A.3 — Dimensions of electrofusion socket fittings

Table A.7 — Dimensions of sockets of electrofusion fittings

Dimensions in millimetres

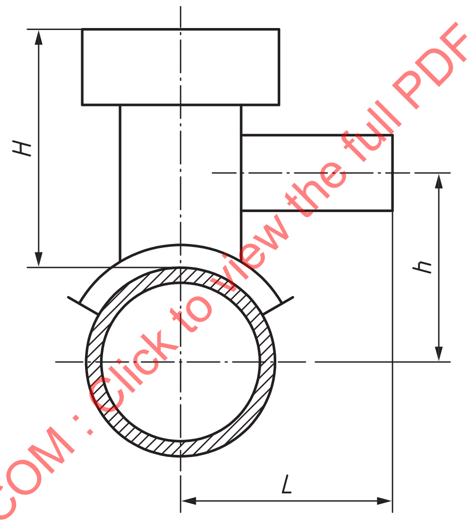
Nominal diameter of fitting d_n	Depth of penetration L_1 min.	Depth of penetration L_1 max.	Length of the fusion zone L_2 min.
16	20	41	10
20	20	41	10
25	20	41	10
32	20	44	10
40	20	49	10
50	20	55	10
63	23	63	11
75	25	70	12
90	28	79	13
110	32	82	15
125	35	87	16
140	38	92	18
160	42	98	20
180	46	105	21
200	50	112	23
225	55	120	26
250	73	129	33
280	81	139	35

Table A.7 *(continued)*

Nominal diameter of fitting d_n	Depth of penetration L_1		Length of the fusion zone L_2
	min.	max.	min.
315	89	150	39
355	99	164	42
400	110	179	47
450	122	195	51
500	135	212	56
560	147	235	61
630	161	255	67

A.3.2.3.2 Dimensions of electrofusion saddle fittings

The manufacturer shall specify the overall dimensions of the electrofusion saddle fitting (see Figure A.4) in a technical file. These dimensions shall include the maximum height of the saddle, *H*, and for tapping tees, the height of the service pipe, *h*.



Key

H height of the saddle which comprises the distance from the top of the main to the top of the tapping tee or saddle

h height of the service pipe which comprises the distance from the axis of the main pipe to the axis of the service pipe

L width of the tapping tee which comprises the distance between the axis of the pipe and the plane of the mouth of the service tee

Figure A.4 — Dimensions of electrofusion saddle fittings

A.3.2.3.3 Other dimensions

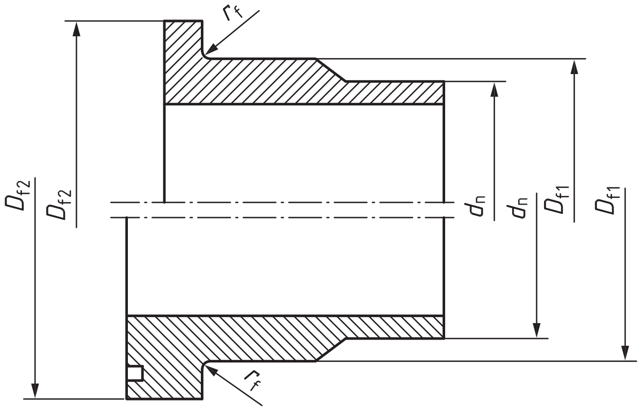
Other dimensions of electrofusion fittings shall be specified by the manufacturer.

A.3.2.4 Flange adaptors and loose backing flanges

A.3.2.4.1 Dimensions of flange adaptors for butt fusion

The dimensions of flange adaptors for butt fusion (see Figure A.5) shall conform to Table A.8.

The Figure A.5 is presenting the jointing face for flat seal in the upper section and the jointing face with O-ring groove in the lower section.



Key

D_{f1} outside diameter of chamfer on shoulder

D_{f2} outside diameter of flange adaptor

r_f radius of chamfer on shoulder

Figure A.5 — Dimensions of flange adaptors for butt fusion

Table A.8 — Dimensions of flange adaptors for butt fusion

Dimensions in millimetres

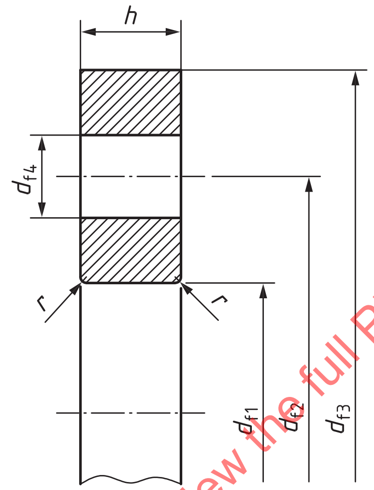
Nominal outside diameter of the corresponding pipe d_n	Outside diameter of chamfer on shoulder D_{f1}	Outside diameter of flange adaptor D_{f2}	Radius of chamfer on shoulder r_f
16	22	40	3
20	27	45	3
25	33	58	3
32	40	68	3
40	50	78	3
50	61	88	3
63	75	102	4
75	89	122	4
90	105	138	4
110	125	158	4
125	132	158	4
140	155	188	4
160	175	212	4
180	183	212	4
200	232	268	4
225	235	268	4
250	285	320	4
280	291	320	4
315	335	370	4
355	373	430	6
400	427	482	6
450	514	585	6

Table A.8 *(continued)*

Nominal outside diameter of the corresponding pipe d_n	Outside diameter of chamfer on shoulder D_{f1}	Outside diameter of flange adaptor D_{f2}	Radius of chamfer on shoulder r_f
500	530	585	6
560	615	685	6
630	642	685	6

A.3.2.4.2 Dimensions of loose backing flanges for use with flange adaptors for butt fusion

The dimensions of loose backing flanges for use with flange adaptors for butt fusion (see Figure A.6) shall conform to Table A.9.



Key

d_{f1} inside diameter of flange
d_{f2} pitch circle diameter of bolt holes
d_{f3} outside diameter of flange
d_{f4} diameter of bolt holes
r radius of flange
h thickness of backing flange

NOTE The thickness, h, of the loose backing flange is dependent on the material used.

Figure A.6 — Dimensions of loose backing flanges for use with flange adaptors for butt fusion