
**Plastics piping systems for the supply
of gaseous fuels for maximum
operating pressures up to and
including 2 MPa (20 bar) —
Polyamide (PA) —**

**Part 1:
General**

*Systèmes de canalisations en matières plastiques pour la distribution
de combustibles gazeux pour des pressions maximales de service
inférieures ou égales à 2 MPa (20 bar) — Polyamide (PA) —*

Partie 1: Généralités



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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 22621-1 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 4, *Plastics pipes and fittings for the supply of gaseous fuels*.

ISO 22621 consists of the following parts, under the general title *Plastics piping systems for the supply of gaseous fuels for maximum operating pressures up to and including 2 MPa (20 bar) — Polyamide (PA)*:

- *Part 1: General*
- *Part 2: Pipes*
- *Part 3: Fittings*

Fitness for purpose of the system is to form the subject of a future part 5.

Introduction

As polyamide material is used for piping systems for the supply of gaseous fuels both at low and high pressure, ISO/TC 138/SC 4 experts decided to split the standardization programme into two series of International Standards, with one series (ISO 15439) covering low pressures up to 0,4 MPa (4 bar), and the other (ISO 22621) high pressures up to 2 MPa (20 bar).

Thin wall thickness pipes and solvent cement joints are used typically for pressures up to 0,4 MPa (4 bar), while thicker wall thickness pipes and butt fusion, electrofusion and mechanical joints are typically used for pressures up to 2 MPa (20 bar). For technical and safety reasons, it is not possible to mix the components of the two types of piping system (thin wall thickness pipes cannot be jointed by butt fusion or mechanical joints and vice versa). In particular, solvent cement joints must not be used for jointing for high pressure piping systems.

NOTE A list of standards related to polyamide pipes and fittings for the supply of gas is given in the Bibliography. See References [6] to [9].

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Plastics piping systems for the supply of gaseous fuels for maximum operating pressures up to and including 2 MPa (20 bar) — Polyamide (PA) —

Part 1: General

1 Scope

This part of ISO 22621 specifies the general properties of polyamide (PA) compounds for the manufacture of pipes, fittings and valves made from these compounds, intended to be buried and used for the supply of gaseous fuels at maximum operating pressures (MOP) up to and including 20 bar¹.

It also specifies the test parameters for the test methods to which it refers.

This part of ISO 22621 establishes a calculation and design scheme on which to base the MOP of a piping system.

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 179-1:2000, *Plastics — Determination of Charpy impact properties — Part 1: Non-instrumented impact test*

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

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

ISO 472, *Plastics — Vocabulary*

ISO 527-1, *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*

1) 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1 N/mm²

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

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

ISO 1874-1, *Plastics — Polyamides (PA) moulding and extrusion materials — Part 1: Designation*

ISO 1874-2, *Plastics — Polyamides (PA) moulding and extrusion materials — Part 2: Preparation of test specimens and determination of properties*

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

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

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

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

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

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

ISO 13477, *Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Small-scale steady-state test (S4 test)*

ISO 13478:1997, *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 (notch test)*

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 15512:—²⁾, *Plastics — Determination of water content*

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

2) To be published. (Revision of ISO 15512:1999)

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 472, ISO 1043-1 and ISO 1874-1, and the following, apply.

3.1 Geometrical characteristics

3.1.1

nominal outside diameter

d_n

specified outside diameter of a component, which is identical to the minimum mean outside diameter, $d_{em,min}$, in millimetres

NOTE The nominal inside diameter of a socket is equal to the nominal outside diameter of the corresponding pipe.

3.1.2

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, rounded up to the nearest 0,1 mm

3.1.3

mean outside diameter

d_{em}

measured length of the outer circumference of a pipe, or the spigot end of a fitting, divided by π ($\approx 3,142$), rounded up to the nearest 0,1 mm

3.1.4

minimum mean outside diameter

$d_{em,min}$

minimum value for the mean outside diameter as specified for a given nominal size

3.1.5

maximum mean outside diameter

$d_{em,max}$

maximum value for the mean outside diameter as specified for a given nominal size

3.1.6

out-of-roundness

(pipe or fitting) difference between the measured maximum outside diameter and the measured minimum outside diameter in the same cross-sectional plane of a pipe or spigot end of a fitting

3.1.7

out-of-roundness

(socket) difference between the measured maximum inside diameter and the measured minimum inside diameter in the same cross-sectional plane of a socket

3.1.8

nominal wall thickness

e_n

wall thickness, in millimetres, corresponding to the minimum wall thickness, e_{min}

3.1.9

wall thickness at any point

e

measured wall thickness at any point around the circumference of a component, rounded up to the nearest 0,1 mm

3.1.10

minimum wall thickness at any point

$e_{\min}$

minimum value for the wall thickness at any point around the circumference of a component, as specified

3.1.11

standard dimension ratio

SDR

ratio of the nominal outside diameter, d_n , of a pipe to its nominal wall thickness, e_n

3.2 Materials

3.2.1

compound

homogenous mixture of base polymer (PA) and additives, i.e. antioxidants, pigments, UV stabilisers and others, at a dosage level necessary for the processing and use of components conforming to the requirements of this part of ISO 22621

3.2.2

virgin material

material in a form such as granules or powder that has not been previously processed other than for compounding and to which no rework material or recyclable material has been added

3.2.3

rework material

material from a manufacturer's own production (of compounds and of pipes, fittings or valves) that has been reground or pelletized for reuse by that same manufacturer

3.3 Material characteristics

3.3.1

lower confidence limit of the predicted hydrostatic strength

σ_{LPL}

quantity, in megapascals, 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 $\sigma_{\text{LPL}} = \sigma_{(T, t, 0,975)}$

3.3.2

minimum required strength

MRS

value of σ_{LPL} at 20 °C and 50 years, 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 The R 10 and R 20 series are the Renard number series as defined in ISO 3 [1] and ISO 497 [2].

3.3.3

overall service (design) coefficient

C

overall 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, σ_{LPL}

3.3.4 design stress

σ_s

allowable stress, in megapascals, for a given application or set of service conditions

NOTE It is derived by dividing the MRS by the coefficient, C , then rounding to the next lower value in the R 10 or R 20 series, as applicable:

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

3.4 Related to service conditions

3.4.1 gaseous fuel

any fuel which is in a gaseous state at a temperature of 15 °C, at a pressure of one bar (0,1 MPa)

3.4.2 maximum operating pressure MOP

maximum effective pressure of the gas in the piping system, expressed in bar, which is allowed in continuous use

NOTE The MOP takes into account the physical and the mechanical characteristics of the components of a piping system and the influence of the gas on these characteristics.

4 Symbols and abbreviated terms

4.1 Symbols

C overall service (design) coefficient

d_e outside diameter at any point

d_{em} mean outside diameter

$d_{em,max}$ maximum mean outside diameter

$d_{em,min}$ minimum mean outside diameter

d_n nominal outside diameter

e wall thickness at any point

e_{min} minimum wall thickness at any point

e_n nominal wall thickness

σ_s design stress

σ_{LPL} lower confidence limit of the predicted hydrostatic strength

NOTE 1 The symbols d_e and e correspond to d_{ey} and e_y given in other International Standards such as ISO 11922-1.

NOTE 2 Additional symbols specific to Annex D are defined therein.

4.2 Abbreviations

MOP maximum operating pressure

MRS minimum required strength

PA polyamide

R series of preferred numbers, conforming to the Renard series

SDR standard dimension ratio

5 Material

5.1 Material of the components

The material from which the components, i.e. the pipes, fittings and valves, are made shall be polyamide (PA) in accordance with ISO 1874-1.

5.2 Compound

5.2.1 Additives

The compound shall be made of the polyamide base polymer to which are added only those additives that are needed to facilitate the manufacture of pipes and fittings conforming to the applicable parts of ISO 22621.

All additives shall be used according to national regulations.

5.2.2 Colour

The colour of the compound shall be yellow or black.

5.2.3 Identification compound

When applicable, the compound used for identification stripes shall be manufactured from a PA polymer manufactured from the same type of base polymer as used in the compound for pipe production.

When applicable, the compound used for an identification layer shall be of the same base polymer and of the same MRS as the compound used for pipe production.

5.2.4 Rework material

Rework material shall not be used.

5.2.5 Characteristics

The compounds from which the components are manufactured shall be in accordance with Tables 1 and 2.

Unless otherwise specified in the applicable test method, the test pieces shall be conditioned for at least 16 h at 23 °C and 50 % relative humidity in accordance with ISO 291 before testing in accordance with Table 2.

Table 1 — Characteristics of the compound in the form of granules

Characteristic	Requirement ^a	Test parameters		Test method
		Parameter	Value	
Density	PA 11 compound: (1 020 to 1 050) kg/m ³ PA 12 compound: (1 000 to 1 040) kg/m ³	Test temperature	23 °C	ISO 1183-1 ISO 1183-2
Viscosity number	≥ 180 ml/g	Solvent	m-Cresol	ISO 307
Water content	≤ 0,10 %			ISO 15512, Method B
Carbon black content ^a	(0,5 to 1,0) % (by mass)			ISO 6964
Pigment or carbon black dispersion	A.3			Annex A
^a Only for black compound.				

Table 2 — Characteristics of compound in form of pipe/bar

Characteristic	Requirement ^a	Test parameters		Test method
		Parameter	Value	
Chemical resistance	Change in mean hoop stress at burst between specimens tested in reagent and in the corresponding control fluid ≤ 20 % or Change in tensile strength at yield of injection moulded bar specimens tested in reagent and in the corresponding control fluid ≤ 20 %	According to Annex B		Annex B
Resistance to weathering	The weathered test pieces shall have the following characteristics:	Preconditioning (weathering): cumulative solar radiation	≥ 3,5 GJ/m ²	ISO 16871
a) Elongation at break	a) Elongation at break: ≥ 160 %	Testing speed	25 mm/min	a) ISO 6259-1, ISO 6259-3 ^a or ISO 527-1, ISO 527-2 ^b
b) Hydrostatic strength	b) No failure during the test period of any test piece	End caps Orientation Conditioning time Type of test Circumferential (hoop) stress: PA 11 160 and PA 12 160 ^c PA 11 180 and PA 12 180 ^c Test period Test temperature Test temperature	Type A Free 6 h Water-in-water 10,0 MPa 11,5 MPa 165 h 80 °C 23 °C	b) ISO 1167-1, ISO 1167-2 c) ISO 13954 Joint: Condition 1, Table D.2
c) Cohesive resistance for electrofusion joint	Length of initiation rupture ≤ $L_2/3$ in brittle failure	Test temperature	23 °C	c) ISO 13954 Joint: Condition 1, Table D.2

Table 2 (continued)

Characteristic	Requirement ^a	Test parameters		Test method
		Parameter	Value	
Resistance to rapid crack propagation (Critical pressure, p_c) ($e \geq 5$ mm)	$p_c \geq 1,5$ MOP with $p_c = 7,8 p_{c,S4} + 6,8$ ^d	Test temperature	0 °C	ISO 13477
Longitudinal reversion	≤ 3 % pipe shall retain its original appearance	Heating fluid Test temperature Length of test piece Duration of exposure time	Air 150 °C 200 mm According to ISO 2505	ISO 2505
Resistance to slow crack growth for $e > 5$ mm (notch test)	No failure during the test period	Test temperature d_n SDR Test pressure: PA 11 160 and PA 12 160 °C PA 11 180 and PA 12 180 °C Test period Type of test	80 °C 110 mm or 125 mm 11 18 bar 20 bar 500 h Water-in-water	ISO 13479
Charpy impact strength	$a_{cN} \geq 10$ kJ/m ² for PA 11 and PA 12 compounds	Test specimens Test temperature	Notched injection moulded specimens prepared according to ISO 1874-2 0 °C	ISO 179-1/1eA

NOTE 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1 N/mm²

^a For test pieces in the form of pipe.

^b For test pieces in the form of injection moulded bar prepared according to ISO 1874-2.

^c For material classification and designation, see 5.4.

^d Alternatively, the full-scale test method according to Annex C may be used. The relation between the full-scale test and the S4 test is defined by the formula $p_{C,FS} + p_{atm} = 7,8 (p_{C,S4} + p_{atm})$. In this case: $p_C = p_{C,FS}$. In case of dispute, the full-scale test is decisive.

5.3 Fusion compatibility

Components made from PA 11 shall be heat fusion jointed only to components made from PA 11.

Components made from PA 12 shall be heat fusion jointed only to components made from PA 12.

Components made from polyamide are not fusion compatible with components made from other polymers.

NOTE Test methods for assuring fusibility are given in ISO 22621-3 and ISO 22621-5³⁾.

3) Under preparation.

5.4 Classification and designation

PA compounds shall be classified by MRS in accordance with Table 3.

The long-term hydrostatic strength of the compound shall be evaluated in accordance with ISO 9080, with pressure tests performed in accordance with ISO 1167-1 to find σ_{LPL} . The MRS value shall be determined from the σ_{LPL} .

The classification in accordance with ISO 12162 shall be given and demonstrated by the compound producer.

Where fittings are manufactured from the same compound as pipes, then the compound classification shall be the same as for pipes.

Table 3 — Classification and designation of compounds

σ_{LPL} (20 °C, 50 years, 0,975) MPa	MRS MPa	Compound designation
$16,00 \leq \sigma_{LPL} \leq 17,99$	16	PA11 160 PA12 160
$18,00 \leq \sigma_{LPL} \leq 19,99$	18	PA11 180 PA12 180

5.5 Maximum operating pressure MOP

The MOP is calculated [using Equation (2)] as follows:

$$MOP = \frac{20 \times MRS}{C \times (SDR-1)} \quad (2)$$

The minimum value of the overall service (design) coefficient, C , for pipes, fittings and valves for the supply of gaseous fuels shall be 2, or a higher value according to national regulations.

The MRS is determined at 20 °C and for 50 years but other temperatures and times may be used according to Annex E.

Annex A (normative)

Assessment of degree of pigment or carbon black dispersion in polyamide compounds

A.1 Apparatus

A.1.1 Microscope with a 200×10 times magnification with a field of view of $(1 \pm 0,1)$ mm diameter, equipped with Vernier scale to measure linear dimensions and capable of phase contrast illumination.

A.1.2 Hotplate capable of being maintained at (180 ± 5) °C.

A.1.3 Metal shims of 38 mm length, 19 mm width and 0,03 mm thickness.

A.2 Procedure

A.2.1 Place two clean microscope slides on a hotplate maintained at (180 ± 5) °C.

A.2.2 Place three specimens of pin-head size (of mass approximately 5 mg), each cut from a separate pellet or from a separate part of a moulded or extruded article, approximately 19 mm apart on one of the hot microscope slides.

A.2.3 Place a shim at each end and cover the whole with the other hot microscope slide. Press out the specimens by applying even pressure for 1 to 2 min to the whole area of the face of the upper slide. After the specimens have been placed on the slides, they shall not remain on the hotplate for more than 3 min.

A.2.4 When the slides are cool enough to be handled, examine the three specimens through the microscope.

Alternatively, for polyamide in the form of extrusions or moulded articles or granules, examine three randomly selected microtome sections with a thickness of about 0,03 mm and a minimum area of $0,7 \text{ mm}^2$ at a 200×10 times magnification for compounds, omitting the process of pressing the material between hot microscope slides.

A.2.5 Compare the whole of each specimen with Figures A.1 and A.2 for number and size of agglomerates. Record any lack of uniformity of the background.

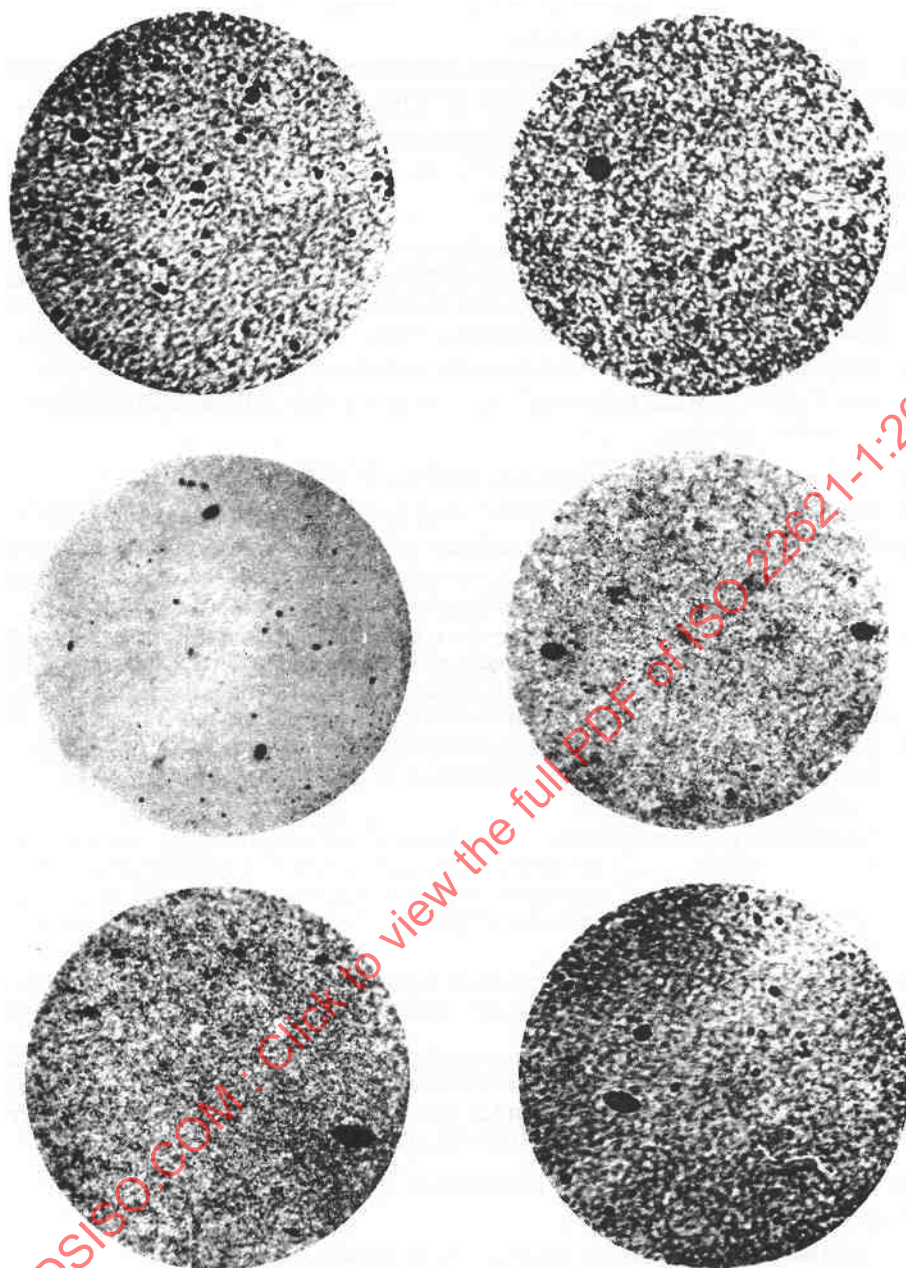


Figure A.1 — Satisfactory pigment or carbon black dispersion

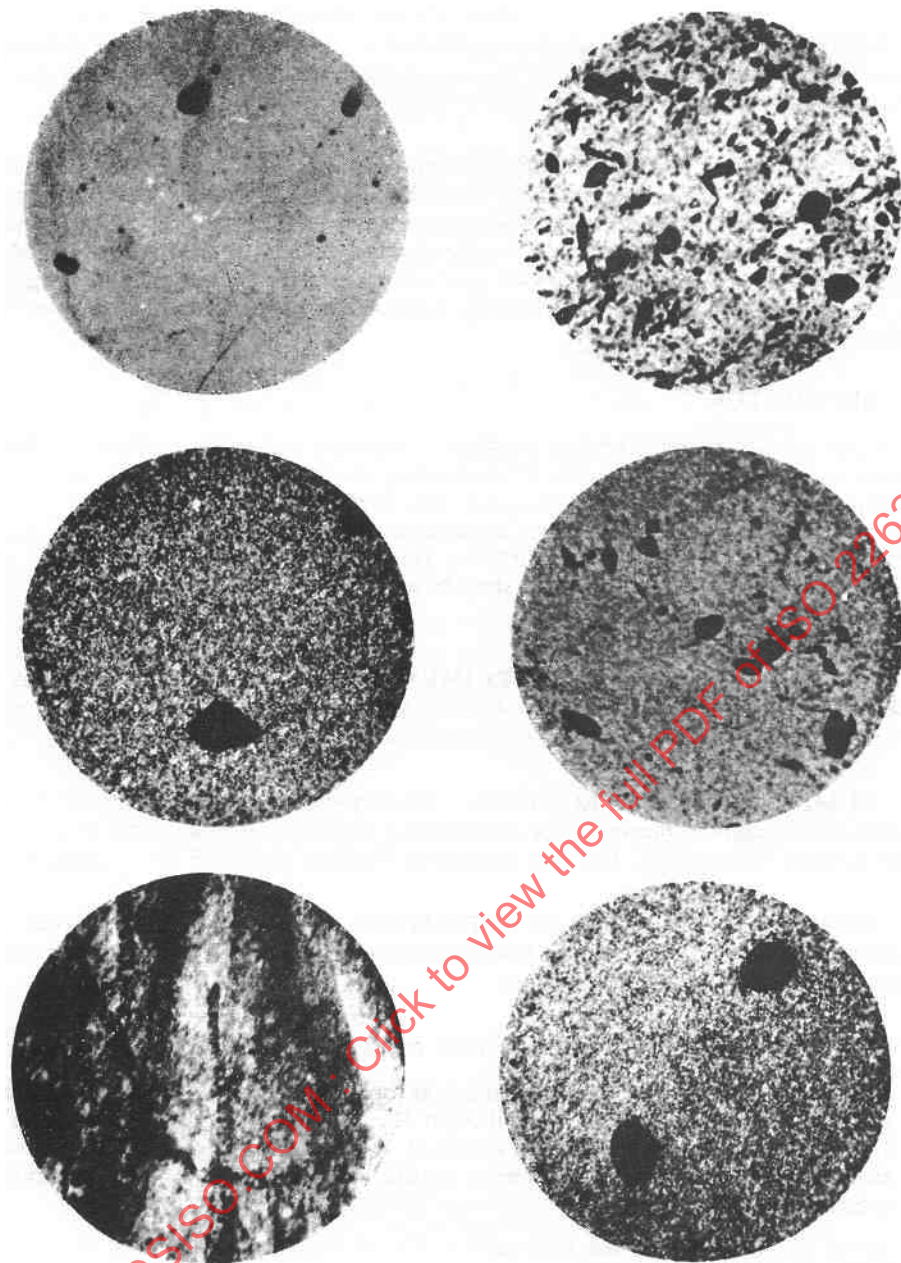


Figure A.2 — Unsatisfactory pigment or carbon black dispersion

A.3 Requirements

The degree of pigment or carbon black dispersion in the PA compound shall be considered satisfactory if

- a) the specimens show a uniform background free from white streaks, and
- b) the number of agglomerates in the specimens are not greater than those shown in Figure A.1 and their size is not greater than 15 microns in any one direction.

A.4 Test report

The test report shall include the following information:

- a) reference to this part of ISO 22621 (i.e. "ISO 22621-1");
- b) complete identification of the compound, including producer, type of material and production date;
- c) a statement that the degree of pigment or carbon black dispersion is satisfactory or unsatisfactory;
- d) lack of uniformity of background;
- e) any agglomeration larger than 15 microns in size;
- f) any factors which may have affected the results, such as any incidents or operating details not specified in this part of ISO 22621;
- g) date of the test.

Annex B (normative)

Chemical resistance

B.1 Principle

Chemical resistance is based on the determination either of the mean hoop stress at burst on a specimen in the form of a pipe, or the tensile strength at yield on a specimen in the form of an injection moulded bar between the corresponding specimens tested in reagent and in the relevant control fluid.

B.2 Reagents

B.2.1 A solution of methanol in water with a volume fraction of 10 %.

B.2.2 Undiluted pentane.

B.2.3 A mixture of 70 % (by mass) tetrahydrothiophene and 30 % (by mass) *t*-butyl mercaptan in paraffin oil with a volume fraction of 5 %.

CAUTION — Tetrahydrothiophene and *t*-butyl mercaptan are extremely malodorous materials which should be handled with great care.

B.2.4 A mixture of liquid hydrocarbons with the volume fractions as given in Table B.1 to which is added 0,5 g of phenol for 100 ml of the mixture.

Table B.1 — Volume fractions of liquid hydrocarbons

Liquid hydrocarbon	Volume fraction %
Benzene	10
Toluene	20
Xylene	25
Cyclohexane	25
Kerosene	10
Styrene	10

B.3 Control fluids

B.3.1 Water for reagent B.2.1.

B.3.2 Undiluted paraffin oil for reagent B.2.3.

B.3.3 Air for reagents B.2.2 and B.2.4.

NOTE All reagents and control fluids are commercial grade.

B.4 Test pieces

Test pieces shall be as follows:

- a) 35 test pieces of (250 ± 10) mm long taken from a pipe of d_n 32, SDR 11 when the chemical resistance is based on the change in hoop stress at burst;
- b) 35 test pieces prepared according to ISO 1874-2 when the chemical resistance is based on the change in tensile strength at yield.

B.5 Conditioning of test pieces and reagents

The test pieces and reagents shall be conditioned at $(23 \pm 2)^\circ\text{C}$ for not less than 24 h immediately before testing.

B.6 Procedure

B.6.1 Determination of the hoop stress at burst

B.6.1.1 Determine and record the hoop stress at burst at $(23 \pm 2)^\circ\text{C}$ for five test pieces in accordance with Annex F.

B.6.1.2 Subdivide the remaining 30 test pieces into six sets of five test pieces. Fully immerse each set in each of the four reagents and in each of the two control fluids B.3.1 and B.3.2, making sure the test pieces do not touch each other or the walls of the container, for a minimum of 72 h at a temperature maintained at $(23 \pm 2)^\circ\text{C}$.

B.6.1.3 Remove each test piece from the reagent and wipe with a dry, clean cloth.

B.6.1.4 Within 5 min of removal from the reagent or control fluid, carry out the test in accordance with Annex F and determine the hoop stress at burst of each of the immersed test pieces.

B.6.1.5 Repeat steps B.6.1.3 and B.6.1.4 above until determinations have been carried out on all test pieces.

B.6.2 Determination of the tensile strength at yield

B.6.2.1 Determine and record the tensile strength at yield at $(23 \pm 2)^\circ\text{C}$ for five test pieces prepared in accordance with ISO 1874-2 and tested in accordance with ISO 527-1 and ISO 527-2.

B.6.2.2 Subdivide the remaining 30 test pieces into six sets of five test pieces. Fully immerse each set in each of the four reagents and in each of the two control fluids B.3.1 and B.3.2, making sure the test pieces do not touch each other or the walls of the container, for a minimum of 72 h at a temperature maintained at $(23 \pm 2)^\circ\text{C}$.

B.6.2.3 Remove each test piece from the reagent and wipe with a dry, clean cloth.

B.6.2.4 Within 5 min of removal from the reagent or control fluid, carry out the test in accordance with ISO 527-1 and ISO 527-2 and determine the tensile strength at yield of each of the immersed test pieces.

B.6.2.5 Repeat steps B.6.2.3 and B.6.2.4 above until determinations have been carried out on all test pieces.

B.7 Test report

The test report shall include the following information:

- a) reference to this part of ISO 22621 (i.e. "ISO 22621-1");
- b) the procedure used for assessing the chemical resistance: hoop stress at burst or tensile strength at yield;
- c) for the procedure based on hoop stress at burst:
 - 1) complete identification of the pipe, including manufacturer, nominal diameter d_n , type of material and production date;
 - 2) mean outside diameter, d_{em} , of the pipe;
 - 3) minimum wall thickness, e_{min} , of the pipe;
 - 4) type of end caps;
 - 5) mean hoop stress at burst of non-immersed test pieces;
 - 6) mean hoop stress at burst of immersed test pieces for each reagent and its associated control fluid;
- d) for the procedure based on tensile strength at yield:
 - 1) mean tensile strength at yield of non-immersed test pieces;
 - 2) mean tensile strength at yield of immersed test pieces for each reagent and its associated control fluid;
- e) any factors which may have affected the results, such as any incidents or any operating details not specified in this part of ISO 22621;
- f) date of the test.

Annex C
(normative)

Resistance to rapid crack propagation (RCP) — Full-scale test (FST)

For the determination of the resistance to RCP by an FST method, the test method as specified in ISO 13478:1997, 10.1, shall be used with the following deviation:

the temperature of cooling for the crack-initiation groove shall be 0 °C.

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Annex D (normative)

Preparation of test assemblies by electrofusion

D.1 Scope

This annex specifies a method for preparing test piece assemblies from PA pipes or spigot-ended fittings and electrofusion fittings.

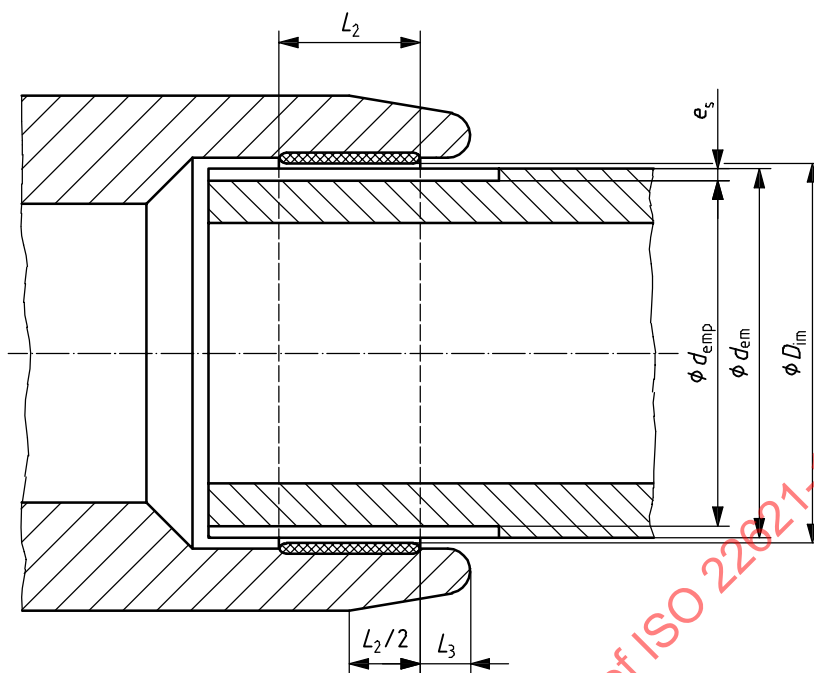
D.2 Symbols

For the purposes of this annex, the following symbols apply.

D.2.1 General

D_{im}	mean inside diameter of the fusion zone of a fitting in the radial plane located a distance of $L_3 + 0,5L_2$ from the face of the fitting socket
$D_{im,max}$	maximum theoretical value of D_{im} as declared by the fitting manufacturer
$D_{i,max}$	maximum inside diameter of the fusion zone of the fitting
$D_{i,min}$	minimum inside diameter of the fusion zone of the fitting
d_e	outside diameter of a pipe or fitting spigot
d_{em}	mean outside diameter of a pipe or fitting spigot in conformance with ISO 22621-2 and ISO 22621-3, as applicable, and calculated from the measured circumference
d_{emp}	mean outside diameter of a pipe or fitting spigot after preparation for assembly with the outer layer removed by scraping or peeling and calculated from the circumference measured in a radial plane coincident with the centre of the fusion zone at a distance of $L_3 + 0,5L_2$ from the face of the fitting socket after assembly
L_2	nominal length of the fusion zone as indicated by the fitting manufacturer
L_3	nominal distance from the face of the fitting socket to the leading edge of the fusion zone
e_s	depth of scraping or the thickness of material removed from the pipe surface by peeling

See Figure D.1.



Key

L_2 nominal length of fusion zone

L_3 length of unheated section of socket

$D_{im} = (D_{i,max} + D_{i,min})/2$

$d_{em} = C/\pi$, where C is the circumference of unscraped pipe

d_{emp} (by analogy) = C_p/π , where C_p is circumference of pipe to be assembled with fitting

$e_s = (d_{em} - d_{emp})/2$

Figure D.1 — Electrofusion socket

D.2.2 Clearances

C_1 clearance between fitting bore and outside diameter of unscraped pipe:

$$C_1 = D_{im} - d_{em}$$

C_2 clearance between fitting bore and outside diameter of scraped pipe:

$$C_2 = C_1 + 2 e_s$$

C_2 may be obtained by machining the unscraped pipe to bring its mean outside diameter, d_{em} , to the value d_{emp} calculated from

$$d_{emp} = D_{im} - C_2$$

C_3 maximum theoretical clearance between fitting bore and outside diameter of unscraped pipe:

$$C_3 = D_{im,max} - d_e$$

C_4 maximum theoretical clearance between fitting bore and outside diameter of scraped pipe

$$C_4 = C_3 + 2 e_s$$

C_4 may be obtained by machining the unscraped pipe to bring its mean outside diameter, d_{em} , to the value d_{emp} calculated from

$$d_{emp} = D_{im} - C_4$$

NOTE The clearance between saddle fittings and pipes is assumed to be zero.

D.2.3 Ambient temperature

T_a ambient temperature at which a joint is made

NOTE The ambient temperature can vary from the minimum temperature, T_{min} , to the maximum temperature, T_{max} , as specified either in the product standard or by agreement between the manufacturer and the purchaser.

T_R reference ambient temperature of $(23 \pm 2) ^\circ\text{C}$

T_{max} maximum permitted ambient temperature for joint assembly

T_{min} minimum permitted ambient temperature for joint assembly

D.2.4 Fusion parameters

D.2.4.1 Terms and definitions

For the purposes of this annex, the following terms and definitions apply.

D.2.4.1.1 reference time

t_R
theoretical fusion time indicated by the fitting manufacturer for the reference ambient temperature

D.2.4.1.2 fusion energy

electrical energy supplied during the fusion-jointing cycle as measured at the terminals of the fitting at a given ambient temperature, T_a , and for electrical parameters whose values lie within the tolerance ranges declared by the manufacturer

NOTE The fitting manufacturer is generally required to state in the technical file any variations in fusion energy input required as a function of the ambient temperature in the range T_{min} to T_{max} .

D.2.4.1.3 reference energy

energy supplied to a fitting having a nominal electrical resistance and using the nominal fusion parameters defined by the manufacturer at the reference ambient temperature, T_R

D.2.4.1.4 maximum energy

maximum value of the fusion energy supplied for jointing at a given ambient temperature, T_a

D.2.4.1.5 minimum energy

minimum value of the fusion energy supplied for jointing at a given ambient temperature, T_a

D.2.4.1.6**nominal energy**

nominal energy supplied for jointing at given ambient temperature, T_a

D.2.4.2 Determination of fusion-jointing electrical parameters using ISO 12176-2 voltage tolerances**D.2.4.2.1 Maximum energy input at T_a**

For control boxes using voltage control, the applied voltage is equal to

$$V_{\max} \sqrt{R/R_{\min}}$$

where

$V_{\max}$ is the maximum control-box output voltage, in volts (nominal + tolerance);

$R_{\min}$ is the manufacturer's minimum fitting resistance at T_R , in ohms, as declared;

R is the resistance, measured using a four-arm resistance bridge with the performance characteristics specified in Table D.1, of the fitting conditioned at the ambient temperature, T_a , specified for jointing.

D.2.4.2.2 Minimum energy input at T_a

For control boxes using voltage control, the applied voltage is equal to

$$V_{\min} = \sqrt{R/R_{\max}}$$

where

$V_{\min}$ is the minimum control-box output voltage, in volts (nominal – tolerance);

$R_{\max}$ is the manufacturer's maximum fitting resistance at T_R , in ohms, as declared;

R is the resistance, measured using a four-arm resistance bridge with the performance characteristics specified in Table D.1, of the fitting conditioned at the ambient temperature, T_a , specified for jointing.

The procedure for measuring the coil resistance implies the use of measuring equipment at the reference ambient temperature of $(23 \pm 2) ^\circ\text{C}$, conditioning of the fitting at $T_{\max}$ or $T_{\min}$ and measurement of the resistance of the coil of the fitting within 30 s of removal from the conditioning enclosure.

Table D.1 — Resistance-bridge performance characteristics

Range Ω	Resolution $\text{m}\Omega$	Accuracy %
0 to 1	0,1	0,25 of reading
0 to 10	1	0,25 of reading
0 to 100	10	0,25 of reading

D.3 Joint assembly

D.3.1 General

The joints shall be made using pipes and/or spigot-ended or electrofusion fittings conforming to ISO 22621. The preparation of the assembly for testing shall be carried out in accordance with the electrofusion fitting manufacturer's written procedures.

Unless a greater scraping depth is recommended by the manufacturer, the minimum scraping depth, e_s , shall be 0,2 mm.

D.3.2 Procedure

Carry out the following procedure, steps d) and f) in a temperature-controlled chamber able to maintain the temperature to within $\pm 2^\circ\text{C}$ and large enough to contain the fitting, the pipes and the holding apparatus. Fittings shall not be used within 170 h of manufacture.

- Measure, at the reference temperature, T_R , the parts to be joined to determine the dimensional characteristics defined in D.2.1 and illustrated in Figure D.1.
- Prepare the pipes to achieve the necessary clearance conditions, at the reference temperature, T_R , in accordance with D.2.2.
- Mount the fitting on the pipes in accordance with the manufacturer's instructions.
- Condition the assembly and the associated apparatus for at least 4 h at the applicable ambient temperature, T_a , as specified in Table D.2.
- After conditioning, measure the resistance of the heating coil and determine the values of the electrical parameters in accordance with Table D.2 and D.2.4.2. The procedure for measuring the coil resistance implies the use of measuring equipment at the reference ambient temperature, T_R , with the fitting at the conditioning temperature.
- Carry out the fusion jointing in accordance with the fitting manufacturer's instructions at the energy levels according to Table D.2.
- Leave the joint to cool until it reaches ambient temperature.
- Proceed to the tests as given in the relevant product standards.

Table D.2 — Conditions for pipe and fitting preparation

Set of conditions	Ambient temperature, T_a (see D.2.3)	Pipe configuration	Clearance ^a (see D.2.2)	Energy (see D.2.4.1)	Assembly load ^b
1	T_R	coiled or straight pipe as supplied	C_2	Reference	Usual
2.1	$T_{\max}$	straight pipe	C_4	Nominal	Usual
2.2	$T_{\min}$	straight pipe	C_4	Minimum	Minimum
3.1	$T_{\min}$	straight pipe	C_2	Nominal	Usual
3.2	$T_{\max}$	straight pipe	C_2	Maximum	Maximum
4	$T_{\max}$	straight pipe	C_4	Minimum	Minimum
5	$T_{\min}$	coiled or straight pipe as supplied	C_2	Maximum	Maximum

NOTE Sets of conditions 1 to 5 are applicable to the energy profiles illustrated in Figures D.2 and D.3.

^a In the case of saddles, the clearance shall be considered to be zero.

^b Applicable to joints with saddles, where the load can be controlled.