INTERNATIONAL STANDARD

# ISO 22621-1

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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

*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*

Reference number
ISO 22621-1:2007(E)

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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].

**INTERNATIONAL STANDARD** **ISO 22621-1:2007(E)**

# 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*

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

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 pyknometer 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*

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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 $\pi$ ($\approx$ 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**

$e_{\mathrm{min}}$

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, $d_{\mathrm{n}}$, of a pipe to its nominal wall thickness, $e_{\mathrm{n}}$

## 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**

$\sigma_{\mathrm{LPL}}$

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

### 3.3.2
**minimum required strength**

**MRS**

value of $\sigma_{\mathrm{LPL}}$ at 20 °C and 50 years, rounded down to the next lower value in the R 10 series when $\sigma_{\mathrm{LPL}}$ is less than 10 MPa, or to the next lower value in the R 20 series when $\sigma_{\mathrm{LPL}}$ 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, $\sigma_{\mathrm{LPL}}$

### 3.3.4
**design stress**

$\sigma_s$

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 |
| $\sigma_s$ | design stress |
| $\sigma_{LPL}$ | 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:<br>(1 020 to 1 050) kg/$m^3$<br>PA 12 compound:<br>(1 000 to 1 040) kg/$m^3$ | Test temperature | 23 °C | ISO 1183-1<br>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 %<br>or<br>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):<br>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)<br>ISO 6259-1, ISO 6259-3 [a]<br>or<br>ISO 527-1, ISO 527-2 [b] |
| b) Hydrostatic strength | b) No failure during the test period of any test piece | End caps<br>Orientation<br>Conditioning time<br>Type of test<br>Circumferential (hoop) stress:<br>PA 11 160 and PA 12 160 [c]<br>PA 11 180 and PA 12 180 [c]<br>Test period<br>Test temperature | Type A<br>Free<br>6 h<br>Water-in-water<br><br>10,0 MPa<br>11,5 MPa<br>165 h<br>80 °C | b)<br>ISO 1167-1, ISO 1167-2 |
| c) Cohesive resistance for electrofusion joint | Length of initiation rupture ⩽ $L_2/3$ in brittle failure | Test temperature | 23 °C | c) ISO 13954<br>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, $p_c$)<br>($e \geqslant 5$ mm) | $p_c \geqslant 1{,}5$ MOP<br>with $p_c = 7{,}8\ p_{c,s4} + 6{,}8$ [d] | Test temperature | 0 °C | ISO 13477 |
| Longitudinal reversion | $\leqslant 3$ %<br>pipe shall retain its original appearance | Heating fluid<br>Test temperature<br>Length of test piece<br>Duration of exposure time | Air<br>150 °C<br>200 mm<br>According to ISO 2505 | ISO 2505 |
| Resistance to slow crack growth for $e > 5$ mm<br>(notch test) | No failure during the test period | Test temperature<br>$d_n$<br>SDR<br>Test pressure:<br>PA 11 160 and PA 12 160 [c]<br>PA 11 180 and PA 12 180 [c]<br>Test period<br>Type of test | 80 °C<br>110 mm or 125 mm<br>11<br><br>18 bar<br>20 bar<br>500 h<br>Water-in-water | ISO 13479 |
| Charpy impact strength | $a_{cN} \geqslant 10$ kJ/m$^2$<br>for PA 11 and PA 12 compounds | Test specimens<br>Test temperature | Notched injection moulded specimens prepared according to ISO 1874-2<br>0 °C | ISO 179-1/1eA |

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

[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 22621-5[3].

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[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 $\sigma_{\mathrm{LPL}}$. The MRS value shall be determined from the $\sigma_{\mathrm{LPL}}$.

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**

| $\sigma_{\mathrm{LPL}}$ **(20 °C, 50 years, 0,975)** MPa | **MRS** MPa | **Compound designation** |
|---|---|---|
| $16{,}00 \leqslant \sigma_{\mathrm{LPL}} \leqslant 17{,}99$ | 16 | PA11 160<br>PA12 160 |
| $18{,}00 \leqslant \sigma_{\mathrm{LPL}} \leqslant 19{,}99$ | 18 | PA11 180<br>PA12 180 |

## 5.5 Maximum operating pressure MOP

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

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

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 ± 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 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.

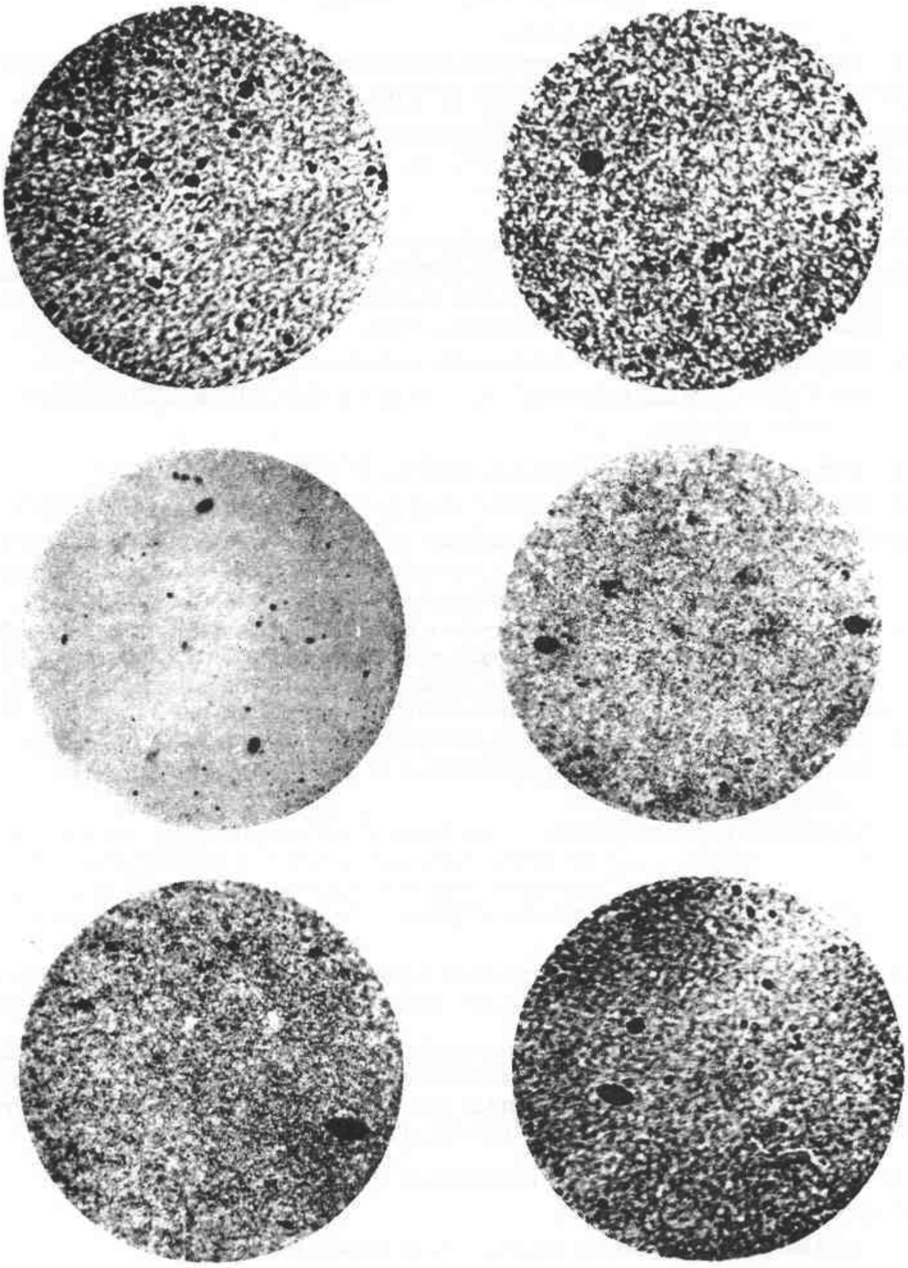


Figure A.1 — Satisfactory pigment or carbon black dispersion

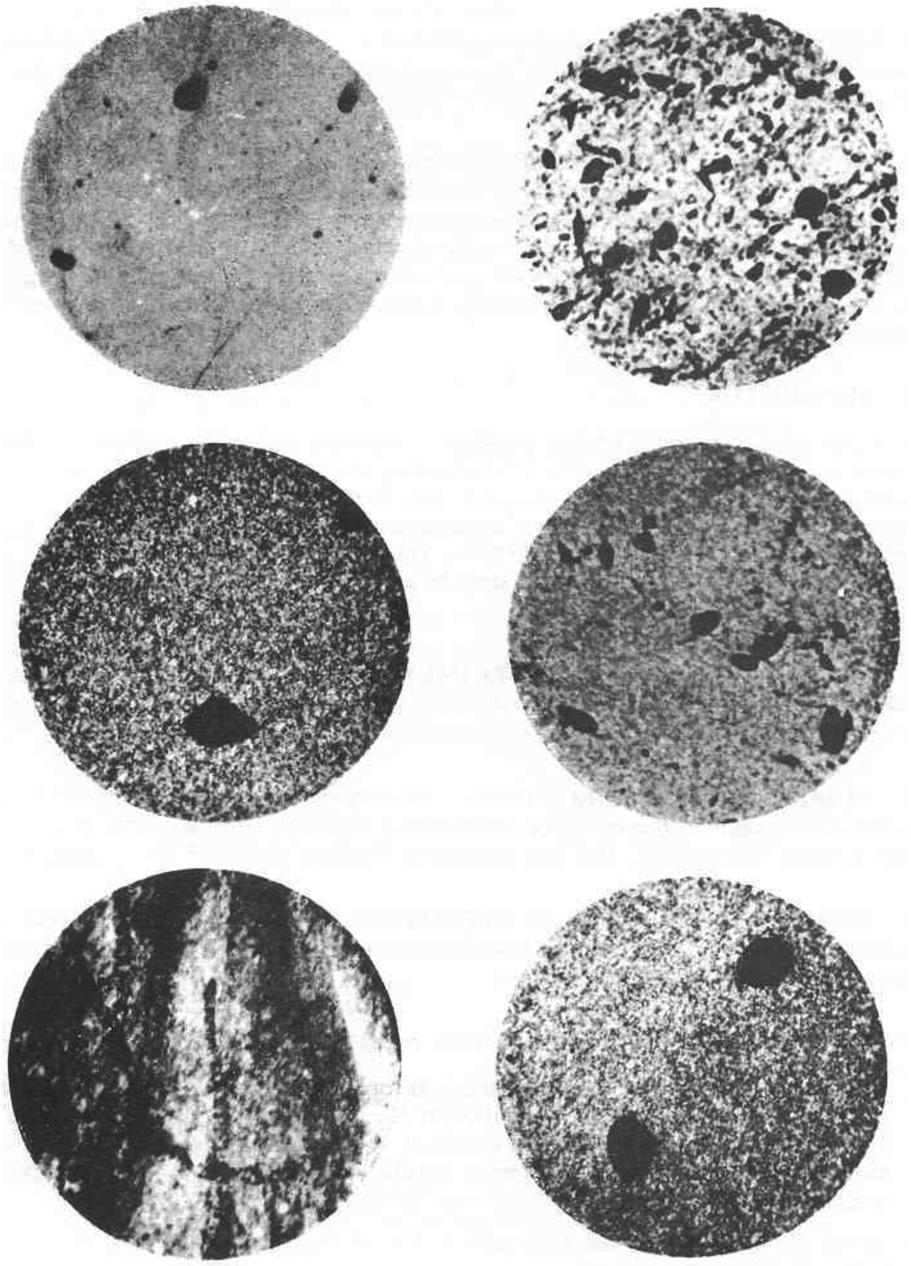


Figure A.2 — Unsatisfactory pigment or carbon black dispersion

## 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 ± 2) °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 ± 2) °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 ± 2) °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 ± 2) °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 ± 2) °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.

# 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.

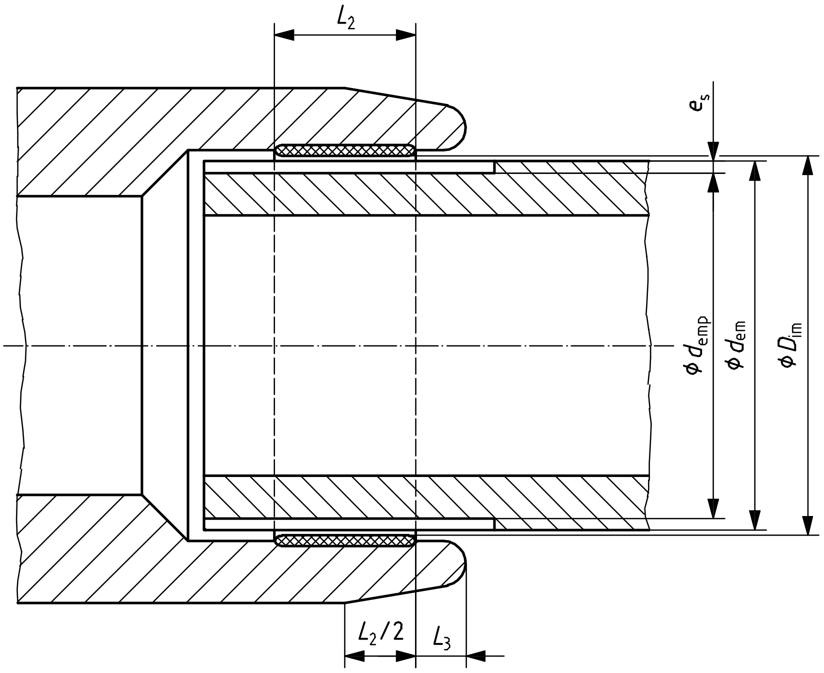
## D.2 Symbols

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

### D.2.1 General

| | |
|---|---|
| $D_{\mathrm{im}}$ | 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 |
| $D_{\mathrm{im,max}}$ | maximum theoretical value of $D_{\mathrm{im}}$ as declared by the fitting manufacturer |
| $D_{\mathrm{i,max}}$ | maximum inside diameter of the fusion zone of the fitting |
| $D_{\mathrm{i,min}}$ | minimum inside diameter of the fusion zone of the fitting |
| $d_{\mathrm{e}}$ | outside diameter of a pipe or fitting spigot |
| $d_{\mathrm{em}}$ | 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 |
| $d_{\mathrm{emp}}$ | 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 |
| $e_{\mathrm{s}}$ | 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) $= C_p/\pi$, 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 ± 2) °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 ± 2) °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**<br>Ω | **Resolution**<br>mΩ | **Accuracy**<br>% |
|---|---|---|
| 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 ± 2 °C and large enough to contain the fitting, the pipes and the holding apparatus. Fittings shall not be used within 170 h of manufacture.

a) 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.

b) Prepare the pipes to achieve the necessary clearance conditions, at the reference temperature, $T_R$, in accordance with D.2.2.

c) Mount the fitting on the pipes in accordance with the manufacturer's instructions.

d) 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.

e) 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.

f) Carry out the fusion jointing in accordance with the fitting manufacturer's instructions at the energy levels according to Table D.2.

g) Leave the joint to cool until it reaches ambient temperature.

h) 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 |

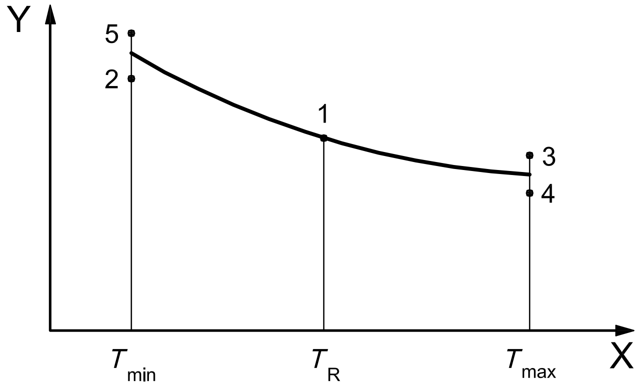
NOTE Sets of conditions 1 to 5 are applicable to the energy profiles illustrated in Figures D.2 and D.3.

[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.

## D.4 Diagrammatic representation of variation in fusion energy with ambient temperature

Figures D.2 and D.3 illustrate different forms of energy profile.

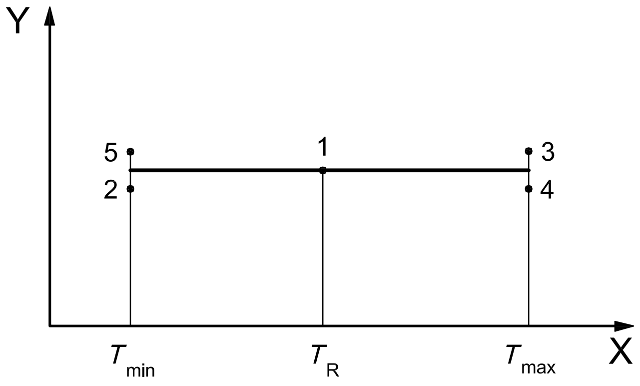


**Key**

X temperature

Y fusion energy

Figure D.2 — Profile with continuous adjustment of energy



**Key**

X temperature

Y fusion energy

Figure D.3 — Constant-energy profile

# Annex E
(informative)

# Design guidance

The part of ISO 22621 specifies the physical properties of buried PA pipes for the supply of gaseous fuels. It lays down dimensional requirements and maximum operating pressures related to the overall service (design) coefficient and operating temperatures.

Guidance is given regarding the calculation of pipe design stress, $\sigma_\text{s}$, and pipe SDR and wall thickness. The MRS of the pipe material (determined at 20 °C and 50 years life parameters using ISO 9080) is divided by the overall service (design) coefficient, $C$:

$$\sigma_\text{s} = \frac{\text{MRS}}{C}$$

For gas systems, a minimum value of $C$ of 2,0 is allocated for the calculation.

## E.1 Pipe design stress, $\sigma_\text{s}$

ISO 12162 describes the “overall service (design) coefficient” or “C factor”, detailing the contents of this coefficient and giving the minimum values to be used for it.

According to ISO 12162:1995, Clause 5, the minimum coefficient is to be established for static water pressure at 20 °C for 50 years, taking into account the following considerations:

a) additional stress and other unquantifiable effects which are considered to arise in the application;

b) influence of temperature, time and environment inside or outside of the pipe, if different from the 20 °C, 50 years life parameters specified in ISO 9080, this influence having either positive or negative effects;

c) standards relating to MRS for temperatures other than 20 °C.

Minimum values are given in ISO 12162:1995, Table 2.

The symbol for design stress given in ISO 12162 is $\sigma_\text{s}$; however, the abbreviation HDS (hydrostatic design stress) has also widespread use internationally. In order to satisfy the requirements of the full international arena, and as a compromise, an alternative symbol is therefore suggested: $\sigma_\text{HDS}$.

## E.2 MRS of material

International developments for gas pipe systems are more and more focused on operating conditions that deviate substantially from the well established 20 °C temperature and 50 years design life parameters that form the basis of the determination of MRS. Greater flexibility is needed in dealing with requirements that deviate from the standard 20 °C and 50 years.

This could be achieved by the introduction of a universal function of the MRS parameter, i.e. $\text{MRS}_{\theta,\text{t}}$ for use in pipe design calculations whilst retaining the value of $\text{MRS}_{\theta,\text{t}}$ at 20 °C for 50 years in water as the usual basis for classification of material. The value at 20 °C for 50 years would be published as the MRS for the material in accordance with ISO 12162, as it is currently.

The $\mathrm{MRS}_{\theta,t}$ should be equal to the value of $\sigma_{\mathrm{LPL}}$ determined and categorized for the temperature, $\theta$, and required lifetime, $t$, in water, in accordance with ISO 9080, using the 3 or 4 coefficient stress rupture/time equation. This differs from the historical approach where de-rating coefficients acting on the MRS are used to establish the effect of temperature only on the strength of the pipe material.

The categorization of $\mathrm{MRS}_{\theta,t}$ should be in accordance with the following series, with the boundaries of categories as given in Table E.1:

— R20 series for $\mathrm{MRS}_{\theta,t} \geqslant 10$ MPa;

— R10 series for $\mathrm{MRS}_{\theta,t} < 10$ MPa.

**Table E.1 — Boundaries of categorization for $\mathrm{MRS}_{\theta,t}$**

| **Range of $\sigma_{\mathrm{LPL}}$ at $\theta$ and $t$** MPa | $\mathrm{MRS}_{\theta,t}$ MPa |
|---|---|
| $16{,}00 \leqslant \sigma_{\mathrm{LPL}} \leqslant 17{,}99$ | 16 |
| $18{,}00 \leqslant \sigma_{\mathrm{LPL}} \leqslant 19{,}99$ | 18 |

## E.3 *C* factor

The current $C$ factor is related to the pipe material and the anticipated installation and operating conditions. There is, however, no clear distinction between the relative effect on the coefficient of material performance and application conditions. This should be corrected, with individual factors introduced to separately cover material and application aspects. The proportion of the factor related to application conditions should not be considered in relation to this part of ISO 22621, where the focus should be solely on material.

In this way, the material-related factor, $C_{\mathrm{M}}$, will be less than the value of 2,0 currently allocated in this part of ISO 22621 and will be within the experience of ISO/TC 138/SC 4 to determine. It reflects the properties of the components of a piping system other than those represented in the $\sigma_{\mathrm{LPL}}$ (e.g. extrusion, batch-to-batch variation). In this way, the minimum factor should be 1,25 (the same as for water).

The application-related component, $C_{\mathrm{A}}$, should be left to the gas distribution engineer to incorporate via appropriate design codes and national regulations, and should be dependent on the location of the pipeline, the MOP, the type of gas being conveyed, etc. Care should be taken regarding the differences between (hydro)static and dynamic loading.

Internal fluids such as gases and aggressive condensates when absorbed can have the effect of reducing the material strength upon which the design stress is based, the influence of gas being much less severe than condensate. For natural gas, it is therefore proposed that the component of $C_{\mathrm{A}}$ related to the type of gas be 1,0 (the same as for water). For LPG gas, the gas-related component of $C_{\mathrm{A}}$ should be 1,1 — 10 % greater than that of natural gas, which difference is in line with values already in use by the gas industry in the ISO codes of practice. The factor for manufactured gas should take into consideration the analysis of the gas with special reference to liquid hydrocarbons and should be at least 1,2. However, this component needs to be the subject of further discussion.

## E.4 Design equations

Equation (E.1) gives the design stress including the above features:

$$\sigma_{\mathrm{HDS},\theta,t} = \frac{\mathrm{MRS}_{\theta,t}}{C_{\mathrm{A}} \times C_{\mathrm{M}}} \tag{E.1}$$

where

$\sigma_{\mathrm{HDS},\theta,\mathrm{t}}$ is the hydrostatic design stress for the material in contact with the fluid being transmitted at a specified temperature, $\theta$ and for a time, $t$

$\mathrm{MRS}_{\theta,\mathrm{t}}$ is the $\sigma_{\mathrm{LPL}}$ of the material calculated for a specified temperature, $\theta$ and for a time, $t$, and suitably categorized from data produced in water in accordance with ISO 9080.

$C_{\mathrm{M}}$ reflects the material related properties of the components of a piping system, other than those represented in the $\sigma_{\mathrm{LPL}}$ (e.g. for PA the material design coefficient, $C_{\mathrm{M}}$, should be 1,25).

$C_{\mathrm{A}}$ is the application design coefficient to be applied by the gas distribution engineer.

The pipe wall thickness, $e_{\mathrm{n}}$, is then determined from Equations (E.2) and (E.3):

$$e_{\mathrm{n}} = \frac{d_{\mathrm{n}}}{\mathrm{SDR}} \tag{E.2}$$

and

$$\mathrm{SDR} = \frac{20\sigma_{\mathrm{HDS},\theta,\mathrm{t}}}{\mathrm{MOP}} + 1 = \frac{20\mathrm{MRS}_{\theta,\mathrm{t}}}{\mathrm{MOP} \times C_{\mathrm{A}} \times C_{\mathrm{M}}} + 1 \tag{E.3}$$

using standardized SDR values.

Pipe diameter ($d_{\mathrm{n}}$) and maximum operating pressure (MOP) are features of the flow requirements of the distribution system and are assumed to be set by the pipeline operator.

A value of $C_{\mathrm{A}}$ of 1,6 when applied in conjunction with the $C_{\mathrm{M}}$ value for natural gas of 1,25 gives an overall factor ($C_{\mathrm{A}} \times C_{\mathrm{M}}$) of 2,0, the minimum value for $C$ already having been specified in this part of ISO 22621.

## E.5 Summary

Material-related design factors are to be covered by the MRS classification in accordance with ISO 9080 and a value of 1,25 is proposed for the material design coefficient, $C_{\mathrm{M}}$, for PA piping systems. For greater flexibility in the use of the MRS, $\mathrm{MRS}_{\theta,\mathrm{t}}$ is introduced, where the temperature, $\theta$, and the lifetime, $t$, may differentiate from the usual values of 20 °C and 50 years. This policy retains the well established MRS basis for the classification of polyamide materials in accordance with ISO 12162.

Application-related design factors, which are covered in $C_{\mathrm{A}}$, are to be left at the option of the gas distribution engineer and should be specified in the relevant codes of practice.

# Annex F
(normative)

# Hoop stress at burst

## F.1 Principle

This test method determines the maximum internal stress that the material is able to withstand for a short time due to pressure surge.

## F.2 Apparatus

This shall be in accordance with ISO 1167-1, except for **pressurizing equipment**, which shall be capable of producing a pressure in the pipe sufficient to result in bursting.

## F.3 Test pieces

### F.3.1 Preparation of test pieces

The preparation of test pieces shall be in accordance with the relevant clause of ISO 1167-2.

Before testing, each test specimen shall have its ends squared and cleaned. It shall have no burrs, notches or other markings which could cause premature failure.

Measure and record test piece component parameters, e.g. preparation conditions, dimensions, as necessary.

### F.3.2 Number of test pieces

Prepare five test pieces.

## F.4 Procedure

**F.4.1** Connect a test piece to the apparatus and ensure that all air is excluded.

**F.4.2** Pressurize the test piece at such a rate that failure will occur between 1 min and 3 min after applying pressure.

For a test series all test pieces should be pressurized at the same rate.

**F.4.3** Record the pressure required to burst the test piece and the time to failure. The test piece shall be considered to have failed when it leaks, weeps or ruptures. In the event of a failure at an end connection or within one diameter of an end connection up to a maximum of 75 mm, a further test piece shall be selected and the test shall be repeated.

**F.4.4** Calculate the hoop stress at burst using the following equation:

$$\sigma = P\,(d_{\mathrm{em}} - e_{\mathrm{min}})/20e_{\mathrm{min}}$$

where

$\sigma$ is the hoop stress to be induced by the pressure at burst, expressed in megapascals;

$P$ is the pressure at burst, expressed in bars;

$d_{\text{em}}$ is the mean outside diameter of the test piece, expressed in millimetres;

$e_{\text{min}}$ is the minimum wall thickness of the free length of the test piece, expressed in millimetres.

## F.5 Test report

The test report shall include the following information:

a) the hoop stress at burst for each test piece;

b) the mean hoop stress at burst for the five test pieces.

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[9] ASTM D 2513-01ae1, *Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing, and Fittings*

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4) Under preparation or to be published.

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