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**Plastics piping systems for the supply  
of gaseous fuels for maximum operating  
pressure up to and including 0,4 MPa  
(4 bar) — Polyamide (PA) —**

**Part 1:  
General**

*Systèmes de canalisations en matières plastiques pour la distribution  
de combustibles gazeux pour une pression maximale de service  
inférieure ou égale à 0,4 MPa (4 bar) — Polyamide (PA) —*

*Partie 1: Généralités*



Reference number  
ISO 15439-1:2007(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 15439-1 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 15439 consists of the following parts, under the general title *Plastics piping systems for the supply of gaseous fuels for maximum operating pressure up to and including 0,4 MPa (4 bar) — Polyamide (PA)*:

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



## Introduction

A list of standards related to polyamide pipes and fittings for the supply of gas is given in the Bibliography. See [1] to [8].

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# Plastics piping systems for the supply of gaseous fuels for maximum operating pressure up to and including 0,4 MPa (4 bar) — Polyamide (PA) —

## Part 1: General

### 1 Scope

This part of ISO 15439 specifies the general properties of polyamide (PA) compounds for the manufacturing of pipes, fittings and valves made from such compounds, intended to be buried and used for the supply of gaseous fuels for maximum operating pressure up to and including 4 bar.

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

This part of ISO 15439 specifies a calculation and design scheme on which the maximum operating pressure (MOP) of piping systems is based.

### 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*

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 15439-1:2007(E)

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 pycnometer method 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 — Polyamide (PA) moulding and extrusion materials — Part 1: Designation*

ISO 1874-2, *Plastics — Polyamide (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 12162:1995, *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 13480, *Polyethylene pipes — Resistance to slow crack growth — Cone test method*

ISO 15512:—<sup>1)</sup>, *Plastics — Determination of water content*

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

### 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 definitions

NOTE The symbols  $d_e$  and  $e$  correspond to  $d_{ey}$  and  $e_y$  given in other International Standards such as ISO 11922-1<sup>[9]</sup>.

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



**3.1.1****nominal outside diameter** $d_n$ 

specified outside diameter of a component, 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**

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

**3.1.7****nominal wall thickness** $e_n$ 

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

**3.1.8****wall thickness at any point** $e$ 

measured wall thickness at any point around the circumference of a component, rounded up to the nearest 0,05 mm

**3.1.9****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

**3.1.10****standard dimension ratio****SDR**

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

## 3.2 Definitions of materials

### 3.2.1

#### compound

homogenous mixture of base polymer (PA) and additives, i.e. anti-oxidants, pigments, UV-stabilizers and others, at a dosage level necessary for the processing and use of components conforming to the requirements of this part of ISO 15439

### 3.2.2

#### virgin material

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

### 3.2.3

#### rework material

material from a manufacturer's own production, which has been reground or pelletized for re-use by that same manufacturer

NOTE This definition applies to either the production of compounds or the production of pipe fittings or valves.

## 3.3 Definitions related to material characteristics

### 3.3.1

#### lower confidence limit of the predicted hydrostatic strength

$\sigma_{LPL}$   
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 It is given by  $\sigma_{LPL} = \sigma_{(T, t, 0,975)}$

### 3.3.2

#### minimum required strength

##### MRS

value of  $\sigma_{LPL}$  at 20 °C and 50 years, rounded down to the next lower value in the R 10 series when  $\sigma_{LCL}$  is less than 10 MPa, or to the next lower value in the R 20 series when  $\sigma_{LPL}$  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<sup>[10]</sup> and ISO 497<sup>[11]</sup>.

### 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,

$\sigma_{LPL}$

### 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, as in Equation (1), then rounding to the next lower value in the R 10 or R 20 series, as applicable:

$$\sigma_s = \frac{MRS}{C} \quad (1)$$

### 3.4 Definitions related to service conditions

#### 3.4.1

##### **gaseous fuel**

any fuel that is in a gaseous state at a temperature of 15 °C, at a pressure of one bar

#### 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 and which 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

### 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 designated 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 15439.

All additives shall be used according to the national regulations.

#### 5.2.2 Colour

The colour of the compound shall be yellow, black or natural. The natural colour is admitted only for compounds intended to be used for manufacturing fittings and valves.

#### 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 conform to the requirements given in Table 1 and Table 2.

Unless otherwise specified by 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	Requirements	Test parameters		Test method
Density	PA 11 compound: (1 020 to 1 050) kg/m <sup>3</sup> PA 12 compound: (1 000 to 1 040) kg/m <sup>3</sup>	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 15512:1999, Method B
Carbon black content <sup>a</sup>	(0,5 to 1,0) % (by mass)			ISO 6964
Pigment or carbon black dispersion	Clause A.3			Annex A
<sup>a</sup> Only for black compound.				

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

Characteristic	Requirements	Test parameters		Test method
Chemical resistance	Change in mean hoop stress at burst between specimens tested in reagent and in the corresponding control fluid $\leq 20\%$ OR Change in tensile yield strength of injection moulded bar specimens tested in reagent and in the corresponding control fluid $\leq 20\%$	Shall conform to Annex B		Annex B
Resistance to weathering	The weathered test pieces shall fulfil the following requirements	Preconditioning (weathering): Cumulative solar radiation	$\geq 3,5 \text{ GJ/m}^2$	ISO 16871
a) Elongation at break	$\geq 160\%$	Testing speed	25 mm/min	a) (ISO 6259-1, ISO 6259-3) <sup>a</sup> or (ISO 527-1, ISO 527-2) <sup>b</sup>
b) Hydrostatic strength (pipe)	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 PA 11 180 and PA 12 180 Test period Test temperature	Type A Free 6 h Water-in-water 10,0 MPa 11,5 MPa 165 h 80 °C	b) ISO 1167-1 ISO 1167-2
c) Hydrostatic strength (pipe/socket fitting assembly)	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 PA 11 180 and PA 12 180 Test period Test temperature	Type A Free 6 h Water-in-water 10,0 MPa 11,5 MPa 165 h 80 °C	ISO 1167-1 ISO 1167-4
Resistance to rapid crack propagation (critical pressure, $p_c$ ) ( $e \geq 5 \text{ mm}$ )	$p_c \geq 1,5 \text{ MOP}$ with $p_c = 7,8 p_{c,S4} + 6,8$ <sup>c</sup>	Test temperature	0 °C	ISO 13477
Longitudinal reversion	$\leq 3\%$ original appearance of the pipe shall remain	Heating fluid Test temperature Length of test piece Duration of exposure time	air 150 °C 200 mm shall conform to ISO 2505	ISO 2505
Resistance to slow crack growth for $e \leq 5 \text{ mm}$ (cone test)	$v \leq 10 \text{ mm/day}$			ISO 13480
Charpy impact strength	$a_{cN} \geq 10 \text{ kJ/m}^2$ for PA 11 and PA 12 compounds	Test specimens	Notched injection moulded specimens prepared according to ISO 1874-2	ISO 179-1 Method ISO 179-1/1eA
		Test temperature	0 °C	
<p>a For test pieces in the form of pipe.</p> <p>b For test pieces in the form of injection moulded bar prepared according to ISO 1874-2.</p> <p>c 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 <math>p_{C,FS} + p_{atm} = 7,8 (p_{C,S4} + p_{atm})</math>. In this case: <math>p_C = p_{C,FS}</math>. In case of dispute, the full-scale test is decisive.</p>				

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### 5.3 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 the  $\sigma_{LPL}$ . The MRS-value shall be determined from the  $\sigma_{LPL}$ .

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**

$\sigma_{LPL}$ (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

### 5.4 Maximum operating pressure MOP

The MOP is calculated using Equation (2):

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

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 D.

## Annex A (normative)

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

#### A.1 Apparatus

- A.1.1** Microscope with a magnification of  $\times (200 \pm 10)$  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  $(180 \pm 5)$  °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  $(180 \pm 5)$  °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 min 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 a microscope at a magnification of  $\times (200 \pm 10)$  with a field of view of  $(1 \pm 0,1)$  mm diameter.
- Alternatively, for polyamides in the form of extrusions or moulded articles or granules, examine three randomly selected microtome sections of about 0,03 mm thickness and 0,7 mm<sup>2</sup> minimum area at a magnification of  $\times (200 \pm 10)$  for compounds, omitting the process of pressing the material between hot microscope slides.
- A.2.5** Compare the whole of each specimen with Figure A.1 and Figure A.2 for number and size of agglomerates. Record also any lack of uniformity of the background.

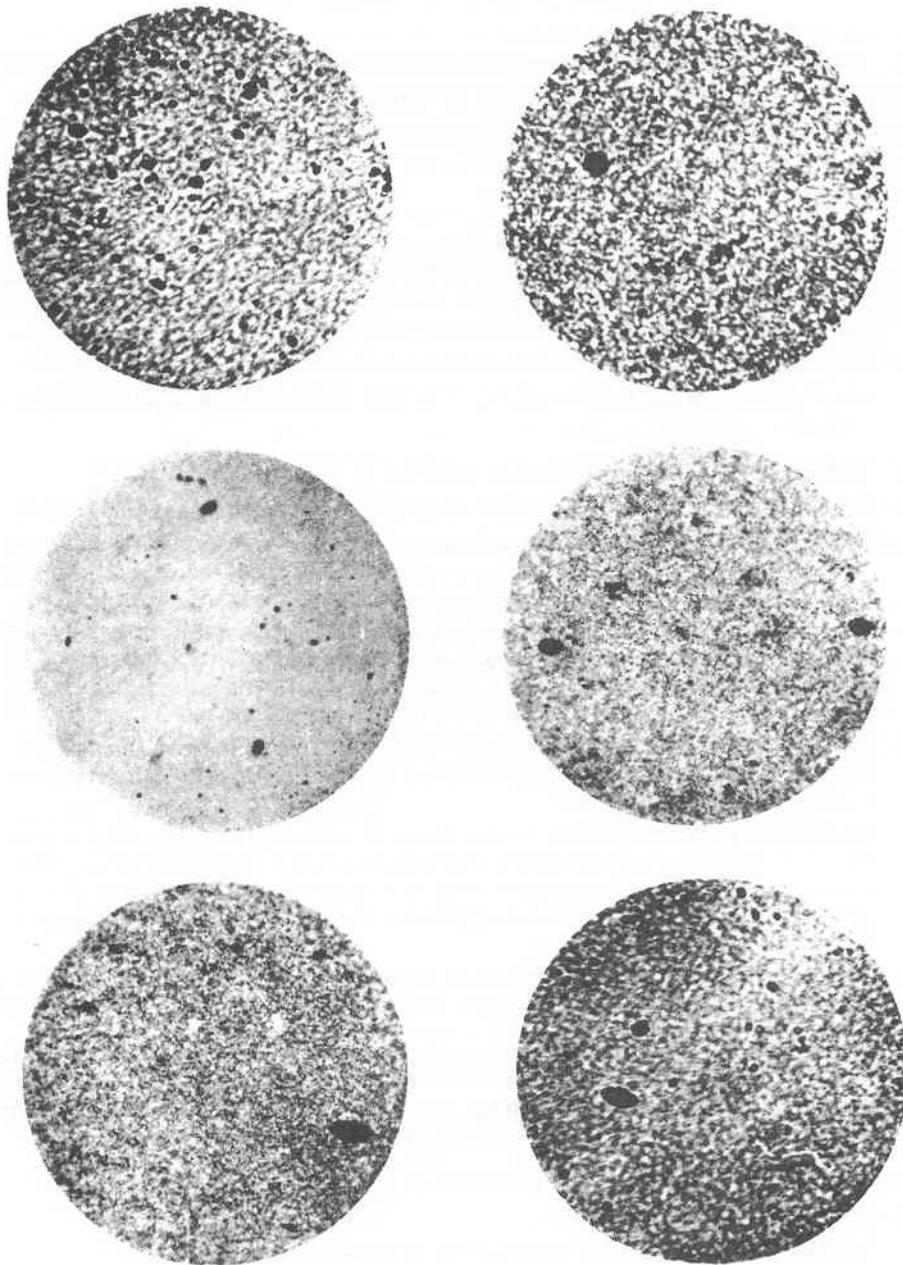
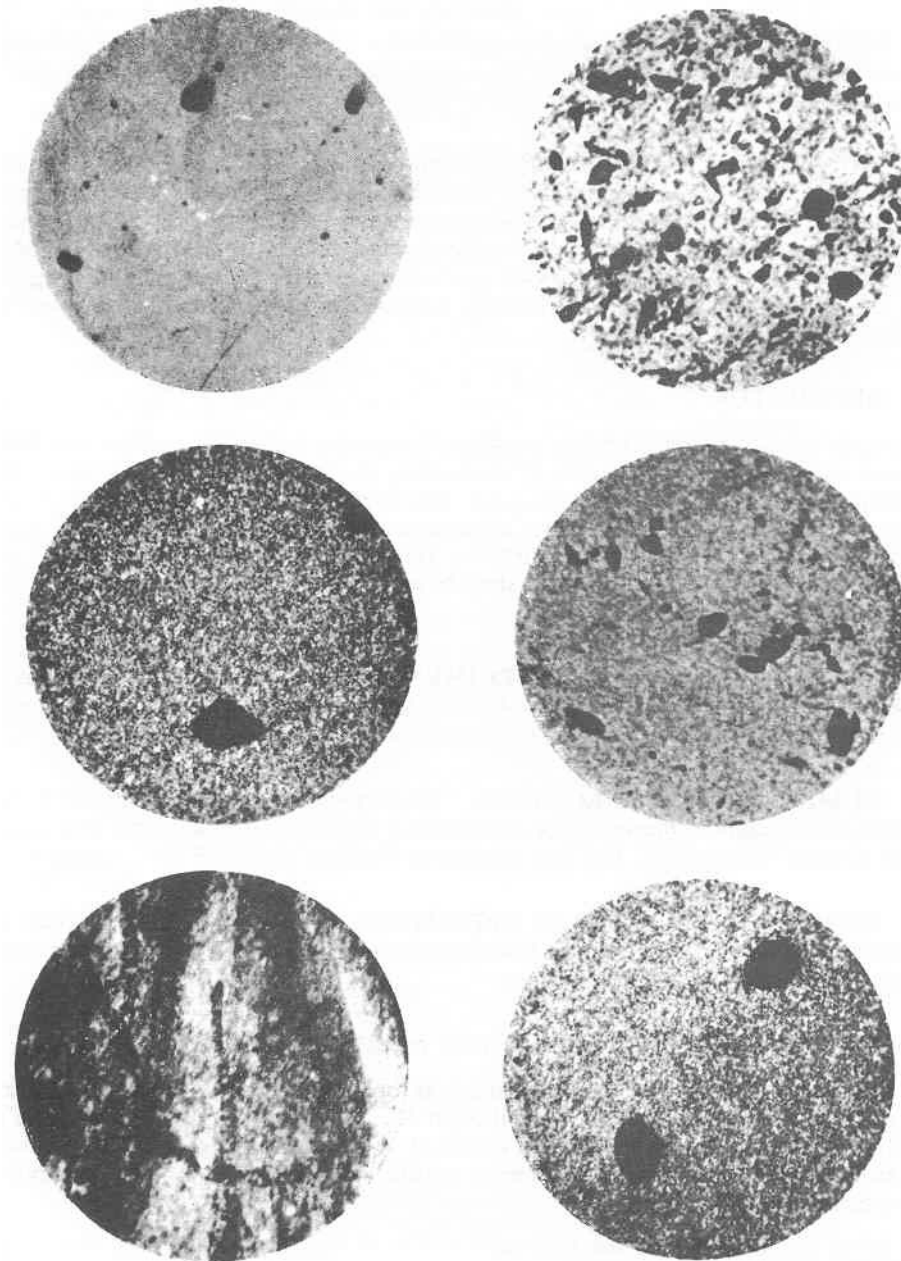


Figure A.1 — Satisfactory pigment or carbon black dispersion





**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;
- b) the number of agglomerates in the specimens is no greater than those shown in Figure A.1 and their size no greater than 15  $\mu$  in any one direction.

#### A.4 Test report

The test report shall include the following information:

- a) reference to this part of ISO 15439, i.e, ISO 15439-1:2007;
- b) complete identification of the compound, including producer, type of material and production date;
- c) if the degree of pigment or carbon black dispersion is satisfactory or unsatisfactory;
- d) any lack of uniformity of background;
- e) any agglomeration larger than 15  $\mu$  in size;
- f) any factors that may have affected the results, such as any incidents or any operating details not specified in this part of ISO 15439;
- g) the 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 pipe, or the tensile strength at yield on a specimen in the form of an injection moulded bar, the corresponding specimens being tested in a reagent (see Clause B.2) and in the relevant control fluid (see Clause B.3).

#### 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) *tert*-butyl mercaptan in paraffin oil with a volume fraction of 5 %.

**Caution — Tetrahydrothiophene and *tert*-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 by 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
Cyclo-hexane	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

Thirty-five test pieces of  $(250 \pm 10)$  mm long shall be taken from a pipe of  $d_n$  32, SDR 26 if the chemical resistance is based on the change in hoop stress at burst;

OR

thirty-five test pieces shall be prepared according to ISO 1874-2 if 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  $(23 \pm 2)$  °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  $(23 \pm 2)$  °C for five test pieces in accordance with Annex E.

**B.6.1.2** Subdivide the remaining 30 test pieces into six sets of five test pieces. Suspend a set of five pieces fully immersed in each of the four reagents and two control fluids, making sure the test pieces do not touch each other or the walls of the container, for a minimum of 72 h maintained at  $(23 \pm 2)$  °C.

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

**B.6.1.4** Within 5 min of removal from the reagent or control fluid, carry out the test in accordance with Annex E 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  $(23 \pm 2)$  °C for five test pieces 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. Suspend a set of five pieces fully immersed in each of the four reagents and two control fluids, making sure the test pieces do not touch each other or the walls of the container, for a minimum of 72 h maintained at  $(23 \pm 2)$  °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 15439, i.e, ISO 15439-1:2007;
- 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) a complete identification of the pipe, including manufacturer, nominal diameter  $d_n$ , type of material and production date;
  - 2) the mean outside diameter of the pipe  $d_{em}$ ;
  - 3) the minimum wall thickness of the pipe  $e_{min}$ ;
  - 4) the type of end caps;
  - 5) the mean hoop stress at burst of non-immersed test pieces;
  - 6) the 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) the mean tensile strength at yield of non-immersed test pieces;
  - 2) the 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 15439;
- f) the date of the test.

## **Annex C** (normative)

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

For the determination of the resistance to rapid crack propagation (RCP) by a full-scale method, the test method as specified in ISO 13478:1997 shall be used with the following deviation:

temperature of cooling for the crack-initiation groove (10.1 of ISO 13478:1997): 0 °C.

## Annex D (informative)

### Design guidance

#### D.1 General

This part of ISO 15439 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,  $\sigma_s$ , 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,  $C$ :

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

For gas systems, a minimum value of  $C$  of 2,0 is allocated by this part of ISO 15439 for the calculation.

#### D.2 Pipe design stress, $\sigma_s$

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 shall 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 that are considered to arise during application;
- b) influence of temperature, time and environment inside or outside 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  $\sigma_s$ , 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 version is therefore suggested:  $\sigma_{\text{HDS}}$ .

#### D.3 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 depart 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.  $\text{MRS}_{\theta,t}$  for use in pipe design calculations whilst retaining the value of  $\text{MRS}_{\theta,t}$  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  $MRS_{\theta,t}$  should be equal to the value of  $\sigma_{LPL}$  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  $MRS_{\theta,t}$  should be in accordance with the following series with the boundaries of categories as given in Table D.1.

- R20 series for  $MRS_{\theta,t} \geq 10$  MPa
- R10 series for  $MRS_{\theta,t} < 10$  MPa

**Table D.1 — Boundaries of categorization for  $MRS_{\theta,t}$**

Range of $\sigma_{LPL}$ at $\theta$ and $t$ MPa	$MRS_{\theta,t}$ MPa
$16,00 \leq \sigma_{LPL} \leq 17,99$	16
$18,00 \leq \sigma_{LPL} \leq 19,99$	18

#### D.4 The 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 15439, where the focus should be solely on material.

In this way, the material-related factor  $C_M$  will be less than the value of 2,0 currently allocated in this part of ISO 15439 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  $\sigma_{LPL}$  (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,  $C_A$ , 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 may 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  $C_A$  related to the type of gas be 1,0 (the same as for water). For LPG, the gas-related component of  $C_A$  should be 1,1 — 10 % greater than that of natural gas, a difference which 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.



## D.5 Design equations

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

$$\sigma_{\text{HDS},\theta,t} = \frac{\text{MRS}_{\theta,t}}{C_A \times C_M} \quad (\text{D.1})$$

where

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

$\text{MRS}_{\theta,t}$  is the  $\sigma_{\text{LPL}}$  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;

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

$C_A$  is the application design coefficient to be applied by the gas distribution engineer.

The pipe wall thickness  $e_n$  is then determined from the Equation (D.2) and Equation (D.3):

$$e_n = \frac{d_n}{\text{SDR}} \quad (\text{D.2})$$

and

$$\text{SDR} = \frac{20\sigma_{\text{HDS},\theta,t}}{\text{MOP}} + 1 = \frac{20\text{MRS}_{\theta,t}}{\text{MOP} \times C_A \times C_M} + 1 \quad (\text{D.3})$$

using standardized SDR values.

Pipe diameter  $d_n$  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  $C_A$  of 1,6 when applied in conjunction with the  $C_M$  value for natural gas of 1,25 gives an overall factor ( $C_A \times C_M$ ) of 2,0, the minimum value for  $C$  already specified.

## D.6 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  $C_M$  for PA piping systems. For greater flexibility in the use of the MRS, the  $\text{MRS}_{\theta,t}$  is introduced, where the temperature  $\theta$  and the lifetime  $t$  may differentiate from the usual values of 20 °C and 50 years. The 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  $C_A$ , should be left to the gas distribution engineer and should be specified in the relevant codes of practice.

## Annex E (normative)

### Hoop stress at burst

#### E.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.

#### E.2 Apparatus

Apparatus as specified in ISO 1167-1, except for the pressurizing equipment, which shall be capable of producing a pressure in the pipe sufficient to result in bursting.

#### E.3 Test pieces

##### E.3.1 Preparation of test pieces

The preparation of test pieces shall conform to 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 may cause premature failure.

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

##### E.3.2 Number of test pieces

Prepare five test pieces.

#### E.4 Procedure

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

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

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

**E.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.

**E.4.4** Calculate the hoop stress at burst using the following Equation:

$$\sigma = P (d_{em} - e_{min}) / 2 e_{min}$$

where

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

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

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

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

## **E.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.

## Bibliography

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