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Third edition
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Plastics piping systems for the supply of gaseous fuels — Unplasticized polyamide (PA-U) piping systems with fusion jointing and mechanical jointing —

Part 2: Pipes

Systèmes de canalisations en matières plastiques pour la distribution de combustibles gazeux — Systèmes de canalisations en polyamide non plastifié (PA-U) avec assemblages par soudage et assemblages mécaniques —

Partie 2: Tubes

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Foreword

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

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This document was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 4, *Plastics pipes and fittings for the supply of gaseous fuels,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 155, *Plastics piping systems and ducting systems,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 16486-2:2020), which has been technically revised.

The main changes are as follows:

— the references in the Introduction have been updated;

— a Note has been added in the Introduction providing information on the suitability of PA-U pipe systems for 100 % hydrogen and its admixtures with natural gas;

— the symbols that have been deleted in ISO 16486-1 (but that are used in this document) have been defined in this document;

— a reference to ISO 12176-5 has been added in the Note in Clause 9;

— the Bibliography has been extended.

A list of all parts in the ISO 16486 series can be found on the ISO website.

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

Introduction

This document specifies the requirements for a piping system and its components made from unplasticized polyamide (PA-U), which is intended to be used for the supply of gaseous fuels.

NOTE 1 Additional information about the suitability of PA-U pipe systems for hydrogen and its admixtures is given in ISO 16486-1:2023, Annex D.

Requirements and test methods for material and components of the piping system, are specified in ISO 16486-1, ISO 16486-3 and ISO 16486-4.

Characteristics for fitness for purpose of the system and generic fusion parameters are covered in ISO 16486-5.

Recommended practice for installation is given in ISO 16486-6, which will not be implemented as a European Standard under the Vienna Agreement.

NOTE 2 Recommended practice for installation is also given in CEN/TS 12007-6,[5] which has been prepared by Technical Committee CEN/TC 234, *Gas infrastructure*.

Assessment of conformity of the system is covered by ISO/TS 16486-7.

Training and assessment of fusion operators is covered by ISO/TS 16486-8.

ISO 16486-1, ISO 16486-2, ISO 16486-3, ISO 16486-5, ISO 16486-6, ISO/TS 16486-7 and ISO/TS 16486-8 have been prepared by ISO/TC 138/SC 4. ISO 16486-4 has been prepared by ISO/TC 138/SC 7.

Plastics piping systems for the supply of gaseous fuels — Unplasticized polyamide (PA-U) piping systems with fusion jointing and mechanical jointing —

Part 2: Pipes

1 Scope

This document specifies the physical and mechanical properties of pipes made from unplasticized polyamide (PA-U) in accordance with ISO 16486-1, intended to be buried and used for the supply of gaseous fuels.

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

The ISO 16486 series is applicable to PA-U piping systems, the components of which are connected by fusion jointing and/or mechanical jointing.

In particular, this document lays down dimensional characteristics and requirements for the marking of pipes.

Pipes conforming to this document are jointed typically by using mechanical, electrofusion or butt fusion techniques.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

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

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

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

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

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 11922-1, *Thermoplastics pipes for the conveyance of fluids — Dimensions and tolerances — Part 1: Metric series*

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

ISO 16486-1, *Plastics piping systems for the supply of gaseous fuels — Unplasticized polyamide (PA-U) piping systems with fusion jointing and mechanical jointing — Part 1: General*

EN 12106, *Plastics piping systems - Polyethylene (PE) pipes - Test method for the resistance to internal pressure after application of squeeze-off*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16486-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms related to geometrical characteristics

3.1.1
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

3.1.2
minimum mean outside diameter
$d_{em,min}$
minimum value for the mean outside diameter as specified for a given nominal size

3.1.3
maximum mean outside diameter
$d_{em,max}$
maximum value for the mean outside diameter as specified for a given nominal size

3.1.4
nominal wall thickness
e_n
wall thickness, in millimetres, corresponding to the minimum wall thickness, e_{min}

3.2 Terms related to material

3.2.1
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

3.3 Terms related to joints

3.3.1
squeeze-off
gas flow restricted by squeezing the pipe when compressed between two clamps in such a way that the distance between both clamps is less than twice the nominal wall thickness

3.4 Abbreviated terms

MVR melt volume-flow rate

SDR standard dimension ratio

4 Compound

The compound from which the pipes are made shall be in accordance with ISO 16486-1.

The pipes shall be made from virgin material. Rework material shall not be used.

5 General characteristics

5.1 Appearance

When viewed without magnification, the internal and external surfaces of pipes shall be smooth, clean and free from scoring, cavities and other surface defects which can affect pipe performance. The pipe ends shall be cut cleanly and square to the axis of the pipe.

5.2 Colour

The colour of the pipes shall be yellow or black.

NOTE In addition, black PA-U pipes can be identified by yellow or orange stripes, according to national preference.

5.3 Fusion compatibility

Pipes made from PA-U 11 shall be heat fusion jointed only to pipes and/or components made from PA-U 11.

Pipes made from PA-U 12 shall be heat fusion jointed only to pipes and/or components made from PA-U 12.

Pipes made from PA-U are not fusion compatible with pipes and/or components made from other polymers.

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

6 Geometrical characteristics

6.1 Measurement of dimensions

Dimensions shall be measured in accordance with ISO 3126 at (23 ± 2) °C, after being conditioned for at least 4 h. The measurement shall not be made less than 24 h after manufacture.

6.2 Mean outside diameters, out-of-roundness and their tolerances

The mean outside diameter of the pipe, d_{em}, and the out-of-roundness and their tolerances shall be in accordance with Table 1.

For maximum mean outside diameter, ISO 11922-1, Grade B tolerances, shall apply.

Table 1 — Mean outside diameters and out-of-roundness

Dimensions in millimetres

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

[a] Measurement of out-of-roundness shall be made at the point of manufacture according to ISO 3126.

[b] For coiled pipe with $d_n \leq 63$ mm, grade K according to ISO 11922-1 applies; for pipe with $d_n \geq 75$ mm, the maximum out-of roundness shall be specified by agreement.

[c] Grade N according to ISO 11922-1.

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

6.3 Wall thicknesses and tolerances

6.3.1 Minimum wall thickness

The minimum wall thickness, e_{min}, shall be in accordance with Table 2. Small diameter pipes are characterized by wall thickness. Large diameter pipes are characterized by their standard dimension ratio (SDR).

The use of any SDR derived from the pipe series S given according to ISO 4065 and ISO 161-1 is permitted.

NOTE In order to minimize the possibility of damage to small-diameter gas pipes by external influences, the use of pipes having a wall thickness of not less than 3,0 mm, even if higher than the minimal SDR value, can be considered.

Table 2 — Minimum wall thickness

Dimensions in millimetres

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

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

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

6.3.2 Tolerances on wall thickness at any point

The tolerances on the wall thickness at any point shall be in accordance with ISO 11922-1, Grade V. The maximum permissible variation between the nominal wall thickness, e_n, and the wall thickness at any point, e, shall be in accordance with Table 3.

Table 3 — Tolerances on wall thickness at any point

Dimensions in millimetres

Minimum wall thickness e_{min}		Permitted positive deviation	Minimum wall thickness e_{min}		Permitted positive deviation
>	≤		>	≤	
2,0	3,0	0,4	22,0	23,0	2,4
3,0	4,0	0,5	23,0	24,0	2,5
4,0	5,0	0,6	24,0	25,0	2,6
5,0	6,0	0,7	25,0	26,0	2,7
6,0	7,0	0,8	26,0	27,0	2,8
7,0	8,0	0,9	27,0	28,0	2,9
8,0	9,0	1,0	28,0	29,0	3,0
9,0	10,0	1,1	29,0	30,0	3,1
10,0	11,0	1,2	30,0	31,0	3,2
11,0	12,0	1,3	31,0	32,0	3,3
12,0	13,0	1,4	32,0	33,0	3,4
13,0	14,0	1,5	33,0	34,0	3,5
14,0	15,0	1,6	34,0	35,0	3,6
15,0	16,0	1,7	35,0	36,0	3,7
16,0	17,0	1,8	36,0	37,0	3,8
17,0	18,0	1,9			
18,0	19,0	2,0			
19,0	20,0	2,1			
20,0	21,0	2,2			
21,0	22,0	2,3			

7 Mechanical characteristics

7.1 Conditioning

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 4.

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

NOTE Pipes are used for the determination of the long-term hydrostatic strength of PA-U compounds and are saturated with water before starting the tests. Annex B provides examples for the water uptake over time in function of the sample thickness. The determination of water content is specified by ISO 62.

7.2 Requirements

The test pieces shall be tested in accordance with Table 4. When tested using the test method and parameters specified therein, the pipe shall have mechanical characteristics conforming to the requirements of Table 4. The requirements for pipe that has been subject to squeeze-off shall be as specified in Annex A.

Table 4 — Mechanical characteristics

Characteristic	Requirement	Test parameters		Test method(s)
		Parameter	Value	
Hydrostatic strength at 20 °C for 1 000 h	No failure of any test piece during test period	End caps	Type[a]	ISO 1167-1 ISO 1167-2
		Orientation	Free	
		Conditioning period	16 h	
		Type of test	Water-in-water	
		Test temperature	20 °C	
		Test period	1 000 h	
		Circumferential (hoop) stress:		
		PA-U 11 160 and PA-U 12 160[a]	19,0 MPa	
		PA-U 11 180 and PA-U 12 180[a]	20,0 MPa	
Hydrostatic strength at 80 °C for 165 h	No failure of any test piece during test period	End caps	Type[a]	ISO 1167-1 ISO 1167-2
		Orientation	Free	
		Conditioning period	16 h	
		Type of test	Water-in-water	
		Test temperature	80 °C	
		Test period	165 h	
		Circumferential (hoop) stress:		
		PA-U 11 160 and PA-U 12 160[a]	10,0 MPa	
		PA-U 11 180 and PA-U 12 180[a]	11,5 MPa	
Elongation at break for $e \leq 12$ mm	≥ 200 %	Test piece shape Speed of test Number of test pieces	Type 1 25 mm/min Shall conform to ISO 6259-1	ISO 6259-1 ISO 6259-3
Elongation at break for $e > 12$ mm	≥ 200 %	Test piece shape Speed of test Number of test pieces	Type 1 25 mm/min Shall conform to ISO 6259-1	
		Or		
		Test piece shape Speed of test Number of test pieces	Type 3 10 mm/min Shall conform to ISO 6259-1	

[a] For material classification and designation, see ISO 16486-1:2023, 5.4.

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

[c] Test pressure levels for other SDR are given in Table 5.

[d] $p_{c,s4,REF}$ is the value of the critical pressure determined in the S4 test on the pipe according to ISO 16486-1:2023, Table 2, from the batch whose full-scale critical pressure, p_c, was determined in ISO 16486-1.

[e] For pipes of $d_n < 90$ mm, the value of critical pressure, $p_{c,s4,REF}$, determined on a pipe of d_n 90 mm or d_n 110 mm according to ISO 16486-1:2023, Table 2, shall be taken as the reference value.

Table 4 *(continued)*

Characteristic	Requirement	Test parameters		Test method(s)
		Parameter	Value	
Resistance to slow crack growth for $e > 5$ mm (notch test)	No failure during the test period	Test temperature	80 °C	ISO 13479
		SDR	11	
		Type of test	Water-in-water	
		Test period	500 h	
		Test pressure:		
		PA-U 11 160 and PA-U 12 160[a]	18 bar[b,c]	
		PA-U 11 180 and PA-U 12 180[a]	20 bar[b,c]	
Resistance to rapid crack propagation (critical pressure, $p_{c,S4}$) (S4 test)	$p_{c,S4} \geq 0{,}9 p_{c,S4,REF}$[d,e]	Test temperature	0 °C	ISO 13477

[a] For material classification and designation, see ISO 16486-1:2023, 5.4.

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

[c] Test pressure levels for other SDR are given in Table 5.

[d] $p_{c,s4,REF}$ is the value of the critical pressure determined in the S4 test on the pipe according to ISO 16486-1:2023, Table 2, from the batch whose full-scale critical pressure, p_c, was determined in ISO 16486-1.

[e] For pipes of $d_n < 90$ mm, the value of critical pressure, $p_{c,s4,REF}$, determined on a pipe of d_n 90 mm or d_n 110 mm according to ISO 16486-1:2023, Table 2, shall be taken as the reference value.

In Table 5 test pressure levels are given for different SDR classes for information.

Table 5 — Test pressure levels

SDR	Test pressure bar[a]	
	PA-U 11 160 and PA-U 12 160[b]	PA-U 11 180 and PA-U 12 180[b]
7,40	28,12	31,25
9,00	22,50	25,00
11,00	18,00	20,00
13,60	14,28	15,87
17,00	11,25	12,50
21,00	9,00	10,00
26,00	7,20	8,00

These pressure levels are calculated to give nominal pipe hydrostatic levels of either 9 MPa (in PA-U 11 160 and PA-U 12 160 materials)[a] or 10 MPa (in PA-U 11 180 and PA-U 12 180 materials)[a], using the following formula:

$$p = \frac{20\sigma}{SDR - 1}$$

where

σ is the hydrostatic stress, in MPa;

SDR is the standard dimension ratio.

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

[b] For material classification and designation, see ISO 16486-1:2023, 5.4.

8 Physical characteristics

8.1 Conditioning

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 6.

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

8.2 Requirements

The test pieces shall be tested in accordance with Table 6. When tested using the test method and parameters specified therein, the pipe shall have physical characteristics conforming to the requirements of Table 6.

Table 6 — Physical characteristics

Characteristic	Requirement	Test parameters		Test method(s)
		Parameter	Value	
Viscosity number	≥ 180 ml/g	Solvent	*m*-Cresol	ISO 307
Melt volume-flow rate (MVR)[a,b]	As recommended by the material supplier	Temperature	235 °C	ISO 1133-2
		Load	10 kg	
Longitudinal reversion	≤3 % The pipe shall retain its original appearance	Heating fluid Test temperature Length of test piece Duration of exposure	Air 150 °C 200 mm According to ISO 2505	ISO 2505

[a] The water content of the sample shall be <0,1 %. This is essential because PA-U resin is sensitive to hydrolysis. Therefore, the test sample shall be dried prior to testing at 80 °C in a dry air or vacuum dryer for 3 h, or as recommended by the PA-U resin producer. The melt volume-flow rate (MVR) report shall include the water content of the sample prior to testing with the used methodology for its determination.

[b] The MVR can be measured by the pipe manufacturer for internal quality control, as an alternative for the viscosity number, e.g. to test deviations prior to and after working with the material. In practice, the MVR is extremely sensitive to any influence of water content, even if the water content is extremely low (see ISO 1133-2:2011, Table B.1, example for PA 6). It is recommended for PA-U to compare only MVR results from one test device.

9 Marking

All pipes shall be permanently and legibly marked with the minimum information specified in Table 7 so that the marking does not initiate cracks or other types of failure or weaken the pipe, and so that normal storage, weathering, handling, installation or use does not affect the legibility of the marking.

The length of coiled pipes may be indicated on the coil.

If printing is used, the colour of the printed information shall differ from the basic colour of the product. The frequency of the printing shall be at intervals not greater than 1 m.

The quality and size of the marking shall be so that it is easily legible without magnification.

NOTE Traceability data can be coded and found in line with ISO 12176-4 and ISO 12176-5.

Table 7 — Minimum information for marking

Information	Marking or symbol
Manufacturer or trademark	Name or symbol
Internal fluid	Gas
Dimensions	e.g. $d_n \times e_n$
SDR (for $d_n \geq 40$ mm)	e.g. SDR 17
Material and designation	e.g. PA-U 11 160[a]
Production period	Date, code
Reference to the ISO 16486 series	ISO 16486

[a] For material classification and designation, see ISO 16486-1:2023, 5.4.

Annex A
(normative)

Squeeze-off technique

A.1 General

In certain countries, the squeeze-off technique is used to restrict the flow of gas in PA-U piping systems while effecting maintenance and repair operations.[13],[14],[15]

The use of hydrogen in natural gas networks requires special consideration.[16]

If the end-user wishes to employ the technique, evidence shall be provided to the end-user that after squeeze-off, in accordance with the method recommended by the manufacturer of the pipes, the requirements for hydrostatic strength of the pipe at 20 °C for 1 000 h or 80 °C for 165 h according to Table 4 are fulfilled. These tests on squeezed-off pipes shall also fulfil the requirements of these hydrostatic tests on pipes in accordance with Table 4.

A.2 Test method

The evidence in accordance with Clause A.1 shall be obtained using a procedure in accordance with EN 12106.