
**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

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 16486-2 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*.

This first edition of ISO 16486-2 cancels and replaces the first edition of ISO 22621-2:2007 which has been technically revised.

ISO 16486 consists of the following parts, under the general title *Plastics piping systems for the supply of gaseous fuels — Unplasticized polyamide (PA-U) piping systems with fusion jointing and mechanical jointing*:

- Part 1: General
- Part 2: Pipes
- Part 3: Fittings
- Part 5: Fitness for purpose of the system
- Part 6: Code of practice for design, handling and installation

Introduction

Thin wall thickness unplasticized polyamide (PA-U) pipes and solvent cement joints are used typically for low pressures, while thicker wall thickness pipes and butt fusion, electrofusion or mechanical joints are typically used for high pressures.

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.

So for the time being, the standardization programme dealing with unplasticized polyamide (PA-U) piping systems for the supply of gaseous fuels is split into two series of International Standards, with one series (ISO 17467) covering piping systems the components of which are connected by solvent cement jointing and the other (ISO 16486) the components of which are connected by fusion jointing and/or mechanical jointing. When more experience will be gained from the field, it might be reasonable to merge the ISO 17467 series and the ISO 16486 series in one single series applicable to PA-U piping systems.

A similar series (ISO 17135) for fusion and mechanically jointed plasticized polyamide (PA-P) piping systems is in preparation.

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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

1 Scope

This part of ISO 16486 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.

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

In addition, it lays down dimensional characteristics and requirements for the marking of pipes.

Pipes conforming to this part of ISO 16486 are jointed typically by using mechanical, electrofusion or butt fusion (see Annex A) techniques, but not by solvent cement jointing.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 11922-1:1997, *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 16486-1:2012, *Plastics piping systems for the supply of gaseous fuels — Unplasticized polyamide (PA-U) piping systems with fusion jointing and mechanical jointing — Part 1: General*

3 Terms, definitions, symbols and abbreviated terms

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

4 Compound

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

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

5 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.

6 Geometrical characteristics

6.1 Measurement of dimensions

Dimensions shall be measured in accordance with ISO 3126 at $(23 \pm 2) ^\circ\text{C}$, 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 grade B tolerances, ISO 11922-1 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	
	$d_{em,min}$	$d_{em,max}$	Grade K ^b	Grade N
d_n				
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

Table 1 (continued)

Nominal outside diameter	Mean outside diameter		Maximum of absolute out-of-roundness ^a	
	$d_{em,min}$	$d_{em,max}$	Grade K ^b	Grade N
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

^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 applies; for pipe with $d_n \geq 75$ mm, 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 d_n	Minimum wall thickness						
	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	14,9	12,0	9,6

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 11922-1:1997, 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	18,0	19,0	2,0
3,0	4,0	0,5	19,0	20,0	2,1
4,0	5,0	0,6	20,0	21,0	2,2
5,0	6,0	0,7	21,0	22,0	2,3
6,0	7,0	0,8	22,0	23,0	2,4
7,0	8,0	0,9	23,0	24,0	2,5
8,0	9,0	1,0	24,0	25,0	2,6
9,0	10,0	1,1	25,0	26,0	2,7
10,0	11,0	1,2	26,0	27,0	2,8
11,0	12,0	1,3	27,0	28,0	2,9
12,0	13,0	1,4	28,0	29,0	3,0
13,0	14,0	1,5	29,0	30,0	3,1
14,0	15,0	1,6	30,0	31,0	3,2
15,0	16,0	1,7	31,0	32,0	3,3
16,0	17,0	1,8	32,0	33,0	3,4
17,0	18,0	1,9	33,0	34,0	3,5
			34,0	35,0	3,6
			35,0	36,0	3,7

7 Mechanical characteristics

7.1 Conditioning

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 4.

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.

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	6 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	

Table 4 (continued)

Characteristic	Requirement	Test parameters		Test method(s)
		Parameter	Value	
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	6 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	≥ 200 %	Test speed	25 mm/min	ISO 6259-1 ISO 6259-3
Melt volume rate (MVR) b	< 25 cm ³ /10 min or as recommended by the material supplier — whichever is the lower for PA-U 11 and PA-U 12 compounds	Temperature	235 °C	ISO 1133-2
		Load	10 kg	
Resistance to slow crack growth for <i>e</i> > 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 ^c	
		PA-U 11 180 and PA-U 12 180 ^a	20 bar ^c	
Resistance to rapid crack propagation (critical pressure, <i>p</i> _{C,S4}) (S4 test)	<i>p</i> _{C,S4} ≥ 0,9 <i>p</i> _{C,S4,REF} ^{de}	Test temperature	0 °C	ISO 13477
a For material classification and designation, see ISO 16486-1, 5.4. b It is essential that the water content of the sample be < 0,1 %, because PA-U resin is sensitive to hydrolyses. 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. c Test pressure levels for other SDR are given in Table 5. d <i>p</i>_{C,S4,REF} is the value of the critical pressure determined in the S4 test on the pipe according to ISO 16486-1, Table 2, from the batch whose full-scale critical pressure <i>p</i>_C was determined in ISO 16486-1. e For pipes of <i>d</i>_n < 90 mm, the value of critical pressure, <i>p</i>_{C,S4,REF}, determined on a pipe of <i>d</i>_n 90 mm or <i>d</i>_n 110 mm according to ISO 16486-1, Table 2, shall be taken as the reference value.				

Table 5 — Test pressure levels

SDR	Test pressure bar ^b	
	PA-U 11 160 and PA-U 12 160 ^a	PA-U 11 180 and PA-U 12 180 ^a
7,4	28,12	31,25
9	22,5	25
11	18,0	20
13,6	14,28	15,87
17	11,25	12,5
21	9,0	10
26	7,2	8

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 equation:

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

where

σ is the hydrostatic stress, in megapascals;

SDR is the standard dimension ratio.

^a For material classification and designation, see ISO 16486-1:2012, 5.4.

^b 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1 N/mm².

8 Physical characteristics

8.1 Conditioning

Unless otherwise specified by the applicable test method, the test pieces shall be conditioned at normal atmosphere 23/50 according to ISO 291 before testing.

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
Longitudinal reversion	≤ 3 % The pipe shall retain its original appearance.	Heating fluid	Air	ISO 2505
		Test temperature	150 °C	
		Length of test piece	200 mm	
		Duration of exposure	According to ISO 2505	

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.

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 this part of ISO 16486	ISO 16486-2
^a For material classification and designation, see ISO 16486-1:2012, 5.4.	

Annex A

(informative)

Butt fusion procedure for jointing PA-U pipes

A.1 General

The following butt fusion procedure is intended to be used for jointing PA-U pipes. Critical parameters in the butt fusion process are heater iron surface temperature, heat soak time and interfacial pressure during the initial contact of the molten pipe ends and during cooling and cooling time. The heat soak time and cooling time parameters vary as a function of pipe size and wall thickness. As a general guideline, the heat soak time for $d_n \leq 50$ mm should be sufficiently long to produce a melt bead of approximately 1,5 mm. For $d_n \geq 110$ mm, the melt bead width should be approximately 3 mm to 5 mm. The pipe should be held under pressure until cool to the touch.

A.2 Butt fusion procedure parameters

The following parameters should be used:

- a) interface pressure: $(0,3 \pm 0,1)$ MPa;
- b) heater surface temperature: (240 ± 20) °C.

A.3 Butt fusion procedure

A.3.1 Principle

The principle of the heat fusion is to heat two surfaces to a designated temperature, then fuse them together by application of a sufficient force. This force causes the melted materials to flow and mix, thereby resulting in fusion. When fused according to the proper procedures, the joint area becomes as strong as, or stronger than, the pipe itself in both tensile and pressure properties.

Field-site butt fusions may be carried out readily by trained operators using butt fusion machines that secure and precisely align the pipe ends for the fusion process.

The seven steps involved in performing a butt fusion joint are the following:

- a) clean the pipe ends;
- b) securely fasten the components to be joined;
- c) face the pipe ends;
- d) align the pipe profile;
- e) melt the pipe interfaces without pressure;
- f) join the two profiles together;
- g) hold under pressure until cooling.

A.3.2 Clean the pipe ends

Clean the inside and outside of the pipe to be joined by wiping with a clean lint-free cloth. Remove all foreign matter.