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

**Part 1:
General**

*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 1: Généralités



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 documents 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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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 second edition cancels and replaces the first edition (ISO 16486-1:2012), which has been technically revised. It also replaces ISO 16486-1:2012/Amd 1:2014.

The main changes compared to the previous edition are as follows:

- In subclause 5.2.5 characteristics include the need to saturate pipes for LTHS testing;
- In Table 1 the Carbon black content is changed to (1,0 to 2,5) % (by mass);
- In Table 2 former 6 hours has been changed to 16 hours for conditioning before hydrostatic strength testing in line with the phrasing in the table header;
- In subclause 5.2.6 change of compound refers to PPI TR-3 as guidance;
- A new informative Annex D – Continuous liquid hydrocarbon exposure from transported fluid or soil contamination – has been added;
- A new informative Annex E – Permeation resistance against different gases – has been added.

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

Requirements and test methods for components of the piping system are specified in ISO 16486-2, 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.

Assessment of conformity of the system is to form the subject of the future ISO/TS 16486-7¹⁾.

NOTE 1 Recommended practice for installation is also given in CEN/TS 12007-6, which has been prepared by Technical Committee CEN/TC 234, *Gas infrastructure*.

NOTE 2 A list of ASTM standards related to polyamide pipes and fittings for the supply of gas is given in the Bibliography^{[1][2][3][4]}.

Parts 1 (this document), 2, 3, 5 and 6 (and future Part 7) have been prepared by ISO/TC 138/SC 4. Part 4 has been prepared by ISO/TC 138/SC 7.

1) Under preparation. Stage at the time of publication: ISO/WD TS 16486-7:2020.

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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 1: General

1 Scope

This document specifies the general properties of unplasticized polyamide (PA-U) 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. 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.

This document establishes a calculation and design scheme on which to base the maximum operating pressure (MOP) of a PA-U piping system.

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 179-1, *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 1110, *Plastic — Polyamides — Accelerated conditioning of test specimens*

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 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 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*

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, designation and 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, *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*

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, *Plastics — Determination of water content*

ISO 16396-1, *Plastics — Polyamide (PA) moulding and extrusion materials — Part 1: Designation system, marking of products and basis for specifications*

ISO 16396-2, *Plastics — Polyamide (PA) moulding and extrusion materials — Part 2: Preparation of test specimens and determination of properties*

ISO 16486-5, *Plastics piping systems for the supply of gaseous fuels — Unplasticized polyamide (PA-U) piping systems with fusion jointing and mechanical jointing — Part 5: Fitness for purpose of the system*

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 16396-1 and the following apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

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* (3.1.4), $d_{em,min}$

Note 1 to entry: Expressed in millimetres.

3.1.2**outside diameter at any point** d_e

outside diameter measured through the cross-section at any point on a pipe, or the spigot end of a fitting, rounded up to the nearest 0,1 mm

3.1.3**mean outside diameter** d_{em}

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

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

minimum value for the *mean outside diameter* (3.1.3) as specified for a given nominal size

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

maximum value for the *mean outside diameter* (3.1.3) as specified for a given nominal size

3.1.6**nominal wall thickness** e_n

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

3.1.7**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

3.1.8**minimum wall thickness at any point** e_{min}

minimum value for the *wall thickness at any point* (3.1.7) around the circumference of a component, as specified

3.1.9**standard dimension ratio****SDR**

ratio of the *nominal outside diameter* (3.1.1), d_n , of a pipe to its nominal wall thickness, e_n

3.2 Materials**3.2.1****compound**

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

3.2.2**rework material**

material from a manufacturer's own production (of *compounds* [3.2.1] and of pipes, fittings or valves) that has been reground or pelletized for reuse by that same manufacturer

3.3 Material characteristics

3.3.1

lower confidence limit of the predicted hydrostatic strength

σ_{LPL}

quantity, with the dimensions of stress, which represents the 97,5 % lower confidence limit of the predicted hydrostatic strength at a temperature θ and time t

Note 1 to entry: The quantity is expressed in megapascals (MPa).

Note 2 to entry: Temperature, θ , is expressed in degrees Celsius and time, t , is expressed in years.

3.3.2

minimum required strength

MRS

value of σ_{LPL} (3.3.1) at 20 °C and 50 years, rounded down to the next smaller value of the R10 series or the R20 series

Note 1 to entry: The R10 series conforms to ISO 3[5] and the R20 series conforms to ISO 497[6].

3.3.3

categorized required strength at temperature θ and time t

$CRS_{\theta,t}$

value of σ_{LPL} (3.3.1) at temperature θ and time t , rounded down to the next smaller value of the R10 series or the R20 series

Note 1 to entry: $CRS_{\theta,t}$ at 20 °C and 50 years equals MRS (3.3.2).

Note 2 to entry: Temperature, θ , is expressed in degrees Celsius and time, t , is expressed in years.

Note 3 to entry: The R10 series conforms to ISO 3[5] and the R20 series conforms to ISO 497[6].

3.3.4

design coefficient

C

coefficient with a value greater than 1, which takes into consideration service conditions as well as properties of the components of a piping system other than those represented in the lower confidence limit

3.3.5

design stress

σ_s

$\sigma_{s,\theta,t}$

stress derived by dividing the MRS (3.3.2) or $CRS_{\theta,t}$ (3.3.3) by the *design coefficient* (3.3.4), C , i.e.

$\sigma_s = MRS/C$, or $\sigma_{s,\theta,t} = CRS_{\theta,t}/C$

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 1 to entry: 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

a_{cN}	charpy notched impact strength
C	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
L	length
P	pressure at burst
p_c	critical pressure
Σ	is the hoop stress to be induced by the pressure at burst
σ_{LPL}	lower confidence limit of the predicted hydrostatic strength
σ_s	design stress

NOTE 1 The symbols d_e and e correspond to d_{ey} and e_y given in other International Standards, e.g. ISO 11922-1[2].

4.2 Abbreviated terms

$CRS_{\theta,t}$	categorized required strength at temperature, θ , and time, t
MOP	maximum operating pressure
MRS	minimum required strength
PA-U	unplasticized polyamide
R	series of preferred numbers, conforming to the Renard series
RT	room temperature
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 unplasticized polyamide (PA-U) in accordance with ISO 16396-1.

5.2 Compound

5.2.1 Additives

The compound shall be made of the PA-U 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 16486.

5.2.2 Colour

The colour of the compound shall be yellow or black.

The carbon black used in the production of black compound shall have an average (primary) particle size of 10 nm to 25 nm.

5.2.3 Identification compound

When applicable, the compound used for identification stripes shall be manufactured from a PA-U 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](#).

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

Long-term hydrostatic strength data shall be generated on saturated polyamide pipe specimens representing the most severe case to prevent rising humidity content of the pipe over test duration and resulting effects on the analysis of time to failure test results. The saturation process in water can be accelerated according to ISO 1110. Data shall show the uptake of water until saturation over time according to ISO 15512.

NOTE In ISO 16486-2:2020, Annex B, information is given about the saturation performance of pipes in water.

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

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

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

Characteristic	Requirement ^a	Test parameters		Test method
		Parameter	Value	
Chemical resistance	Change in mean hoop stress at burst between specimens tested in reagent and in the corresponding control fluid ≤20 % or Change in tensile strength at yield of injection moulded bar specimens tested in reagent and in the corresponding control fluid ≤20 %	In accordance with Annex B		In accordance with Annex B
Resistance to weathering	The weathered test pieces shall have the following characteristics:	Preconditioning (weathering): cumulative solar radiation	≥7,0 GJ/m ²	ISO 16871
a) Elongation at break after weathering	Elongation at break: ≥160 %	Testing speed	25 mm/min	a) ISO 6259-1, ISO 6259-3 ^a or ISO 527-1, ISO 527-2 ^b

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

^a For test pieces taken from samples in the form of pipe/bar.

^b For test pieces in the form of injection moulded bar prepared according to ISO 16396-2.

^c For material classification and designation, see [5.4](#).

^d The critical pressure, p_c shall be determined for each new PA-U compound and for every pipe dimension with $d_n > 90$ mm.

^e The temperature of cooling for the crack initiation groove shall be appropriate to produce a high-speed crack or cracks emanating from the initiation. For some PA-U compounds a crack initiation groove temperature between 0 °C and -60 °C has been found to be suitable.

^f The critical pressure, $p_{c,S4}$, shall be determined on a pipe produced from the same batch of PA-U compound and the same lot of pipes, as the pipe submitted to the full-scale test.

^g The value of $p_{c,S4}$ determined in this test is the reference value, $p_{c,S4,REF}$, to be referred to in the requirement of the S4 test specified in ISO 16486-2.

Table 2 (continued)

Characteristic	Requirement ^a	Test parameters		Test method
		Parameter	Value	
b) Hydrostatic strength after weathering	No failure during the test period of any test piece	End caps	Type A	b) ISO 1167-1, ISO 1167-2
		Orientation	Free	
		Conditioning time	16 h	
		Type of test	Water-in-water	
		Circumferential (hoop) stress:		
		PA-U 11 160 and PA-U 12 160 ^c	10,0 MPa	
		PA-U 11 180 and PA-U 12 180 ^c	11,5 MPa	
		Test period	165 h	
		Test temperature	80 °C	
c) Cohesive resistance for electrofusion joint after weathering of pipe	Length of initiation rupture $\leq L_2/3$ in brittle failure	Test temperature	23 °C	c) ISO 13954 Joint: Condition 1, ISO 16486-5, Table B.3
Resistance to rapid crack propagation (Critical pressure, p_c) ^d ($e \geq 5$ mm) (Full-scale test)	$p_c \geq 1,5$ MOP	Test temperature	0 °C	In accordance with ISO 13478 ^e
Resistance to rapid crack propagation (critical pressure, $p_{c,S4}$) ^f (S4 test)	^g	Test temperature	0 °C	ISO 13477
Longitudinal reversion	≤ 3 % pipe shall retain its original appearance	Heating fluid Test temperature Length of test piece Duration of exposure time	Air 150 °C 200 mm According to ISO 2505	ISO 2505
NOTE 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm ² . ^a For test pieces taken from samples in the form of pipe/bar. ^b For test pieces in the form of injection moulded bar prepared according to ISO 16396-2. ^c For material classification and designation, see 5.4. ^d The critical pressure, p_c shall be determined for each new PA-U compound and for every pipe dimension with $d_n > 90$ mm. ^e The temperature of cooling for the crack initiation groove shall be appropriate to produce a high-speed crack or cracks emanating from the initiation. For some PA-U compounds a crack initiation groove temperature between 0 °C and –60 °C has been found to be suitable. ^f The critical pressure, $p_{c,S4}$, shall be determined on a pipe produced from the same batch of PA-U compound and the same lot of pipes, as the pipe submitted to the full-scale test. ^g The value of $p_{c,S4}$ determined in this test is the reference value, $p_{c,S4,REF}$, to be referred to in the requirement of the S4 test specified in ISO 16486-2.				

Table 2 (continued)

Characteristic	Requirement ^a	Test parameters		Test method
		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
		d_n	110 mm or 125 mm	
		SDR	11	
		Test pressure:		
		PA-U 11 160 and PA-U 12 160 c	18 bar	
		PA-U 11 180 and PA-U 12 180 ^c	20 bar	
		Test period	500 h	
		Type of test	Water-in-water	
Charpy impact strength	$a_{cN} \geq 10 \text{ kJ/m}^2$ for PA-U 11 and PA-U 12 compounds	Test specimens	Notched injection moulded specimens prepared according to ISO 16396-2	ISO 179-1
		Test temperature	0 °C	

NOTE 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm².

^a For test pieces taken from samples in the form of pipe/bar.

^b For test pieces in the form of injection moulded bar prepared according to ISO 16396-2.

^c For material classification and designation, see 5.4.

^d The critical pressure, p_c shall be determined for each new PA-U compound and for every pipe dimension with $d_n > 90$ mm.

^e The temperature of cooling for the crack initiation groove shall be appropriate to produce a high-speed crack or cracks emanating from the initiation. For some PA-U compounds a crack initiation groove temperature between 0 °C and -60 °C has been found to be suitable.

^f The critical pressure, $p_{c,S4}$, shall be determined on a pipe produced from the same batch of PA-U compound and the same lot of pipes, as the pipe submitted to the full-scale test.

^g The value of $p_{c,S4}$ determined in this test is the reference value, $p_{c,S4,REF}$, to be referred to in the requirement of the S4 test specified in ISO 16486-2.

5.2.6 Change of compound formulation

Any change in dosage levels or manufacturing process of the compound affecting the performance can require a new qualification of the compound.

NOTE 1 Guidance for the assessment of conformity of the compound and the system is to form the subject of a future ISO/TS 16486-7.

NOTE 2 Further guidance can be found in line with Reference [8].

5.3 Fusion compatibility

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

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

Components made from PA-U are not fusion compatible with components made from other polymers.

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

5.4 Classification and designation

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

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

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

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

Table 3 — Classification and designation of compounds

σ_{LPL} (20 °C, 50 years, 0,975) MPa	MRS MPa	Compound designation
$16 \leq \sigma_{LPL} < 18$	16	PA-U 11 160 PA-U 12 160
$18 \leq \sigma_{LPL} < 20$	18	PA-U 11 180 PA-U 12 180

5.5 Maximum operating pressure (MOP)

The MOP is the lower value when calculated using [Formula \(1\)](#) and [Formula \(2\)](#):

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

The minimum value of the design coefficient, C , for pipes, fittings and valves for the supply of gaseous fuels shall be 2.

$$MOP = \frac{p_c}{1,5} \quad (2)$$

p_c is the full-scale critical pressure determined in accordance with ISO 13478 at 0 °C.

The critical pressure determined for a pipe with a given wall thickness may be used for pipes made from the same compound with a smaller wall thickness.

5.6 Effects of transport of liquid hydrocarbons and hydrogen

[Annex D](#) gives information about continuous liquid hydrocarbon exposure from transported fluid or soil contamination. [Annex E](#) shows the permeation resistance against different gases.

Annex A (normative)

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

A.1 Apparatus

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

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

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

A.2 Procedure

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

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

A.2.3 Place a shim at each end and cover the whole with the other hot microscope slide. Press out the specimens by applying even pressure for 1 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 the microscope.

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

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

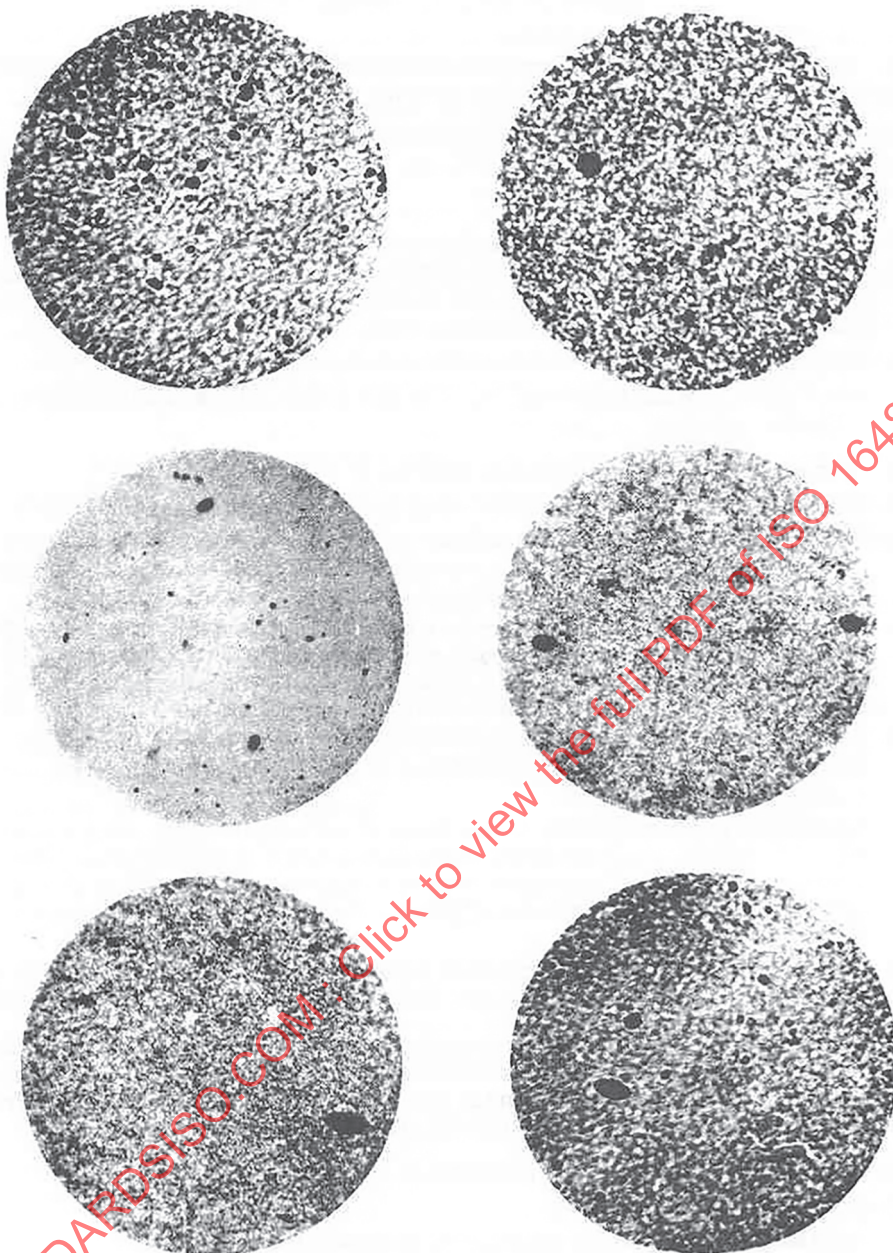


Figure A.1 — Satisfactory pigment or carbon black dispersion

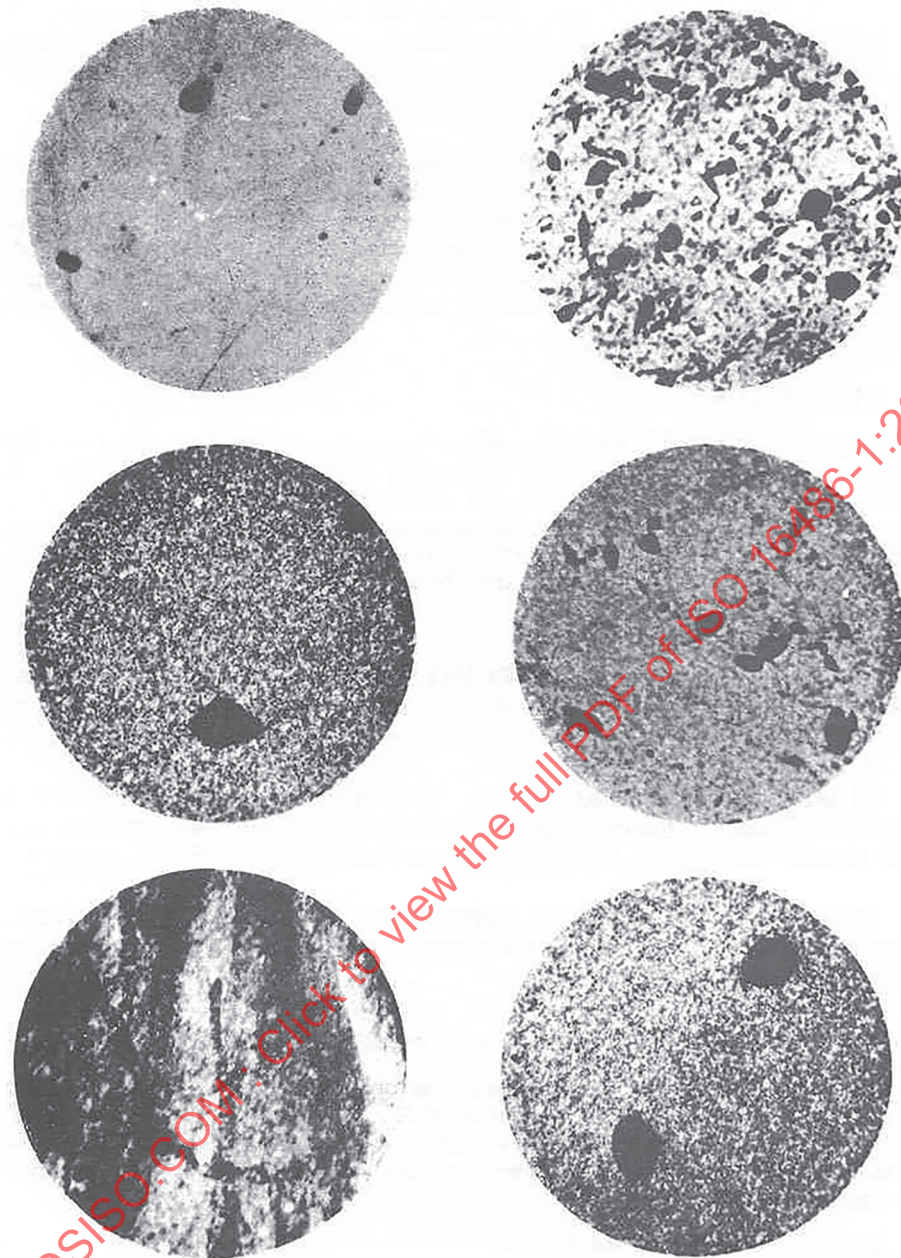


Figure A.2 — Unsatisfactory pigment or carbon black dispersion

A.3 Requirements

The degree of pigment or carbon black dispersion in the PA-U 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 document (i.e. "ISO 16486-1:2020");
- b) complete identification of the compound, including producer, type of material and production date;
- c) the test method used;
- d) a statement that the degree of pigment or carbon black dispersion is satisfactory or unsatisfactory;
- e) lack of uniformity of background;
- f) any agglomeration larger than 15 microns in size;
- g) any factors which may have affected the results, such as any incidents or operating details not specified in this document;
- h) any unusual features observed;
- i) date of the test.

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Annex B (normative)

Chemical resistance

B.1 Principle

Evaluation of 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.

NOTE This test method is from Australia^[9].

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 16396-2 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 C](#).

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 C](#) 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 16396-2 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 document (i.e. "ISO 16486-1:2020");
- 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, and
 - 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, and
 - 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 document;
- f) any unusual features observed;
- g) date of the test.

Annex C **(normative)**

Hoop stress at burst

C.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.

C.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.

C.3 Test pieces

C.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.

C.3.2 Number of test pieces

Prepare five test pieces.

C.4 Procedure

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

C.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.

C.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.

C.4.4 Calculate the hoop stress at burst using the [Formula \(C.1\)](#):

$$\sigma = P (d_{\text{em}} - e_{\text{min}}) / 2e_{\text{min}} \quad (\text{C.1})$$

where

- σ 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_{em} is the mean outside diameter of the test piece, expressed in millimetres;
- e_{min} is the minimum wall thickness of the free length of the test piece, expressed in millimetres.

C.5 Test report

The test report shall include the following information:

- a) reference to this document (i.e. "ISO 16486-1:2020");
- b) complete identification of the pipe, including manufacturer, nominal diameter, d_n , type of material and production date,
- c) the test method used;
- d) mean outside diameter, d_{em} , of the pipe,
- e) minimum wall thickness, e_{min} , of the pipe,
- f) type of end caps,
- g) mean hoop stress at burst of non-immersed test pieces, and
- h) mean hoop stress at burst of immersed test pieces for each reagent and its associated control fluid
- i) any factors which may have affected the results, such as any incidents or any operating details not specified in this document;
- j) any unusual features observed;
- k) date of the test.