
**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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Published in Switzerland

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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 16486-1 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*.

This first edition of ISO 16486-1 cancels and replaces the first edition of ISO 22621-1:2007 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.

NOTE A list of standards related to polyamide pipes and fittings for the supply of gas is given in the Bibliography. See References [6] to [9].

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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 part of ISO 16486 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.

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

This part of ISO 16486 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, 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 179-1:2010, *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 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 system and basis for specification*

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, *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 13478:2007, *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 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 1874-1, and the following apply.

3.1 Geometrical characteristics

3.1.1

nominal outside diameter

d_n

specified outside diameter of a component, which is identical to the minimum mean outside diameter, $d_{em,min}$, in millimetres

NOTE The nominal inside diameter of a socket is equal to the nominal outside diameter of the corresponding pipe.

3.1.2

outside diameter at any point

d_e

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

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

measured length of the outer circumference of a pipe, or the spigot end of a fitting, divided by 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 as specified for a given nominal size

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

maximum value for the mean outside diameter as specified for a given nominal size

3.1.6**out-of-roundness**

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

3.1.7**out-of-roundness**

(socket) difference between the measured maximum inside diameter and the measured minimum inside diameter in the same cross-sectional plane of a socket

3.1.8**nominal wall thickness** e_n

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

3.1.9**wall thickness at any point** e

measured wall thickness at any point around the circumference of a component, rounded up to the nearest 0,1 mm

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

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

3.1.11**standard dimension ratio****SDR**

ratio of the nominal outside diameter, d_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 and others, at a dosage level necessary for the processing and use of components conforming to the requirements of this part of ISO 16486

3.2.2**virgin material**

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

3.2.3

rework material

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

3.3 Material characteristics

3.3.1

lower confidence limit of the predicted hydrostatic strength

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 The quantity is expressed in megapascals (MPa).

NOTE 2 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} at 20 °C and 50 years, rounded down to the next smaller value of the R10 series or the R20 series

NOTE The R10 series conforms to ISO 3^[1] and the R20 series conforms to ISO 497^[2].

3.3.3

categorized required strength at temperature θ and time t

$CRS_{\theta,t}$

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

NOTE 1 $CRS_{\theta,t}$ at 20 °C and 50 years equals MRS.

NOTE 2 Temperature, θ , is expressed in degrees Celsius and time, t , is expressed in years.

NOTE 3 The R10 series conforms to ISO 3^[1] and the R20 series conforms to ISO 497^[2].

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 or $CRS_{\theta,t}$ by the design coefficient 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 The MOP takes into account the physical and the mechanical characteristics of the components of a piping system and the influence of the gas on these characteristics.

4 Symbols and abbreviated terms

4.1 Symbols

C	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
σ_s	design stress
σ_{LPL}	lower confidence limit of the predicted hydrostatic strength
p_c	critical pressure

NOTE 1 The symbols d_e and e correspond to d_{ey} and e_y given in other International Standards such as ISO 11922-1^[3].

NOTE 2 Additional symbols specific to Annex C are defined therein.

4.2 Abbreviated terms

CRS _{θ,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
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 1874-1.

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.

All additives shall be used according to national regulations.

5.2.2 Colour

The colour of the compound shall be yellow or black.

5.2.3 Identification compound

When applicable, the compound used for identification stripes shall be manufactured from a PA-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.

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
Carbon black content ^a	(0,5 to 1,0) % (by mass)			ISO 6964
Pigment or carbon black dispersion	A.3			Annex A
^a Only for black compound.				

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

Characteristic	Requirement ^a	Test parameters		Test method
		Parameter	Value	
Chemical resistance	Change in mean hoop stress at burst between specimens tested in reagent and in the corresponding control fluid ≤ 20 % or Change in tensile strength at yield of injection moulded bar specimens tested in reagent and in the corresponding control fluid ≤ 20 %	According to Annex B		Annex B

Table 2 (continued)

Characteristic	Requirement ^a	Test parameters		Test method
		Parameter	Value	
Resistance to weathering	The weathered test pieces shall have the following characteristics:	Preconditioning (weathering): cumulative solar radiation	$\geq 3,5 \text{ GJ/m}^2$	ISO 16871
a) Elongation at break	a) Elongation at break: $\geq 160 \%$	Testing speed	25 mm/min	a) ISO 6259-1, ISO 6259-3 ^a or ISO 527-1, ISO 527-2 ^b
b) Hydrostatic strength	b) No failure during the test period of any test piece	End caps Orientation Conditioning time Type of test Circumferential (hoop) stress: PA-U 11 160 and PA-U 12 160 ^c PA-U 11 180 and PA-U 12 180 ^c Test period Test temperature 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) Cohesive resistance for electrofusion joint	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 ($e \geq 5 \text{ mm}$) (Full-scale test)	$p_c \geq 1,5 \text{ MOP}$	Test temperature	0 °C	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	$\leq 3 \%$ 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

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 d_n SDR Test pressure: PA-U 11 160 and PA-U 12 160 c PA-U 11 180 and PA-U 12 180 ^c Test period Type of test	80 °C 110 mm or 125 mm 11 18 bar 20 bar 500 h Water-in-water	ISO 13479
Charpy impact strength	$a_{cN} \geq 10$ kJ/m ² for PA-U 11 and PA-U 12 compounds	Test specimens	Notched injection moulded specimens prepared according to ISO 1874-2	ISO 179-1/1eA
		Test temperature	0 °C	
NOTE 1 bar = 0,1 MPa = 10 ⁵ Pa; 1 MPa = 1 N/mm ² .				
^a For test pieces in the form of pipe.				
^b For test pieces in the form of injection moulded bar prepared according to ISO 1874-2.				
^c For material classification and designation, see 5.4.				
^d 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[10].				

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 [11] and ISO 16486-5 [12].

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
$16,00 \leq \sigma_{LPL} < 18$	16	PA-U 11 160 PA-U 12 160
$18,00 \leq \sigma_{LPL} < 20$	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, or a higher value according to national regulations.

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

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

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

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 mm² 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.

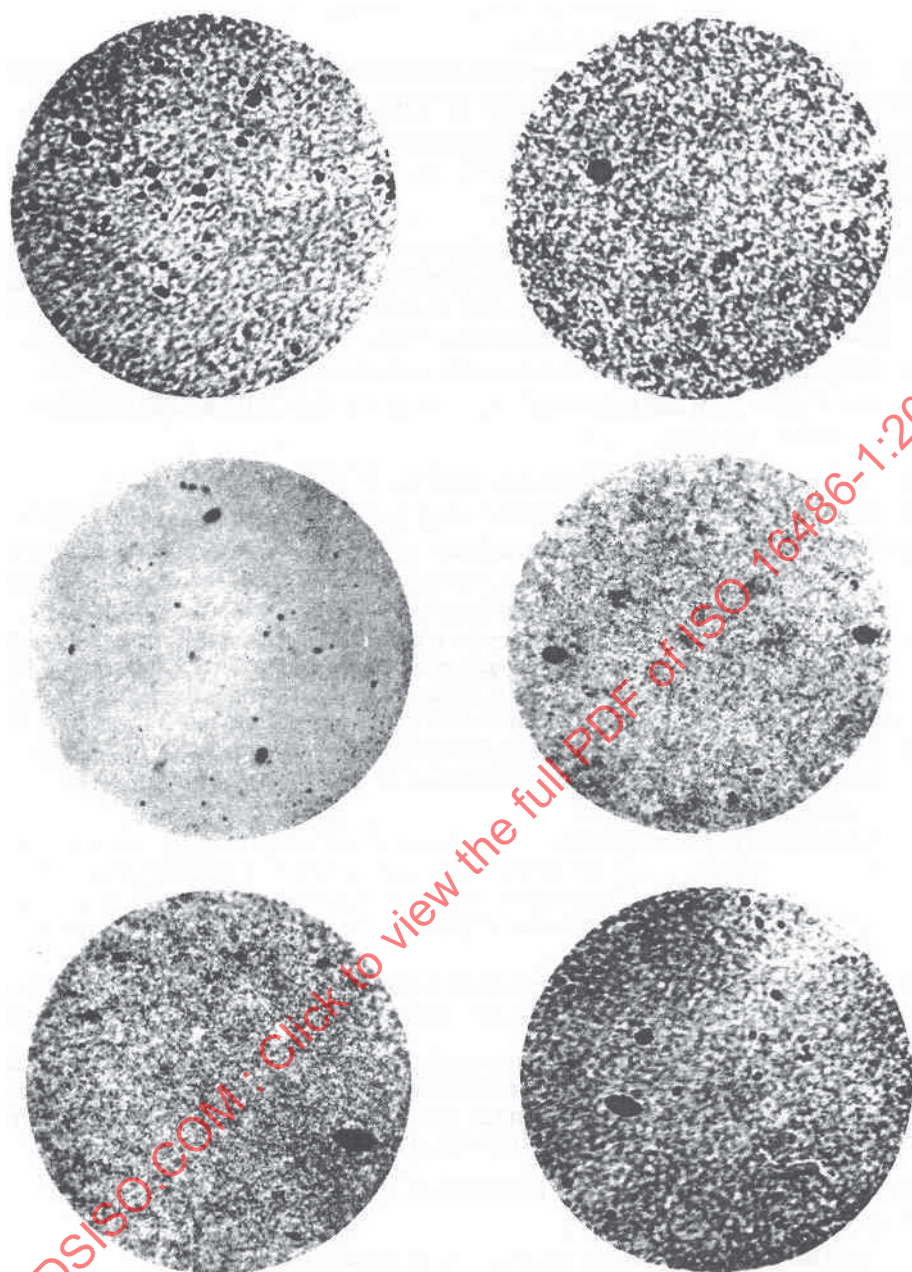


Figure A.1 — Satisfactory pigment or carbon black dispersion

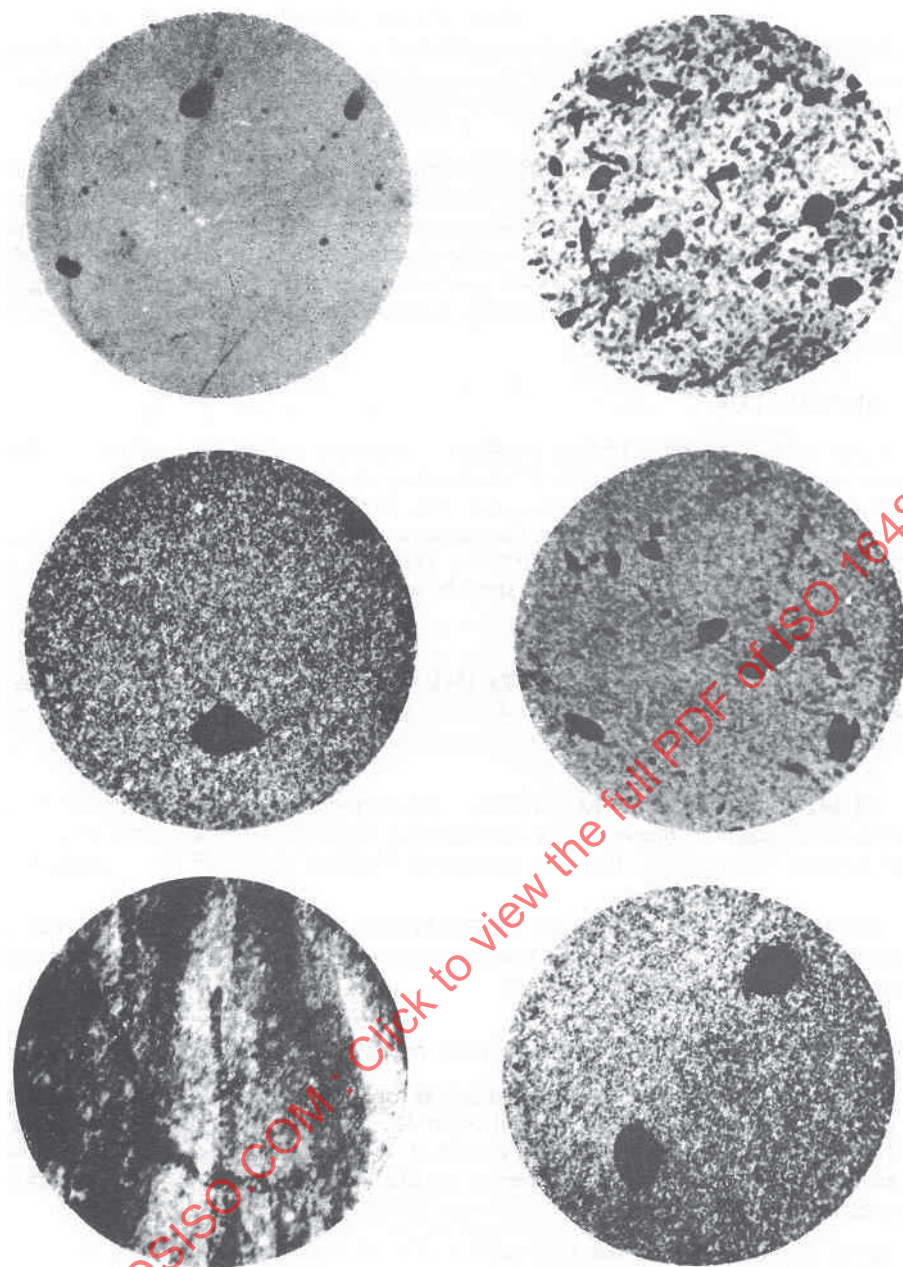


Figure A.2 — Unsatisfactory pigment or carbon black dispersion

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 part of ISO 16486 (i.e. "ISO 16486-1");

- b) complete identification of the compound, including producer, type of material and production date;
- c) a statement that the degree of pigment or carbon black dispersion is satisfactory or unsatisfactory;
- d) lack of uniformity of background;
- e) any agglomeration larger than 15 microns in size;
- f) any factors which may have affected the results, such as any incidents or operating details not specified in this part of ISO 16486;
- g) date of the test.

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Annex B (normative)

Chemical resistance

B.1 Principle

Chemical resistance is based on the determination either of the mean hoop stress at burst on a specimen in the form of a pipe, or the tensile strength at yield on a specimen in the form of an injection moulded bar between the corresponding specimens tested in reagent and in the relevant control fluid.

B.2 Reagents

B.2.1 A solution of methanol in water with a volume fraction of 10 %.

B.2.2 Undiluted pentane.

B.2.3 A mixture of 70 % (by mass) tetrahydrothiophene and 30 % (by mass) *t*-butyl mercaptan in paraffin oil with a volume fraction of 5 %.

CAUTION — Tetrahydrothiophene and *t*-butyl mercaptan are extremely malodorous materials which should be handled with great care.

B.2.4 A mixture of liquid hydrocarbons with the volume fractions as given in Table B.1 to which is added 0,5 g of phenol for 100 ml of the mixture.

Table B.1 — Volume fractions of liquid hydrocarbons

Liquid hydrocarbon	Volume fraction %
Benzene	10
Toluene	20
Xylene	25
Cyclohexane	25
Kerosene	10
Styrene	10

B.3 Control fluids

B.3.1 Water for reagent B.2.1.

B.3.2 Undiluted paraffin oil for reagent B.2.3.

B.3.3 Air for reagents B.2.2 and B.2.4.

NOTE All reagents and control fluids are commercial grade.