BRITISH STANDARD

BS ISO 4437:2007

Buried polyethylene (PE) pipes for the supply of gaseous fuels — Metric series — Specifications

ICS 75.200; 83.140.30

British Standards

National foreword

This British Standard is the UK implementation of ISO 4437:2007.

The UK participation in its preparation was entrusted by Technical Committee PRI/88, Plastics piping systems, to Subcommittee PRI/88/2, Plastics piping for pressure applications.

A list of organizations represented on this committee can be obtained on request to its secretary.

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INTERNATIONAL STANDARD

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Buried polyethylene (PE) pipes for the supply of gaseous fuels — Metric series — Specifications

Canalisations enterrées en polyéthylène (PE) pour réseaux de distribution de combustibles gazeux — Série métrique — Spécifications

Reference number
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Contents

Page

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 4437 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 third edition cancels and replaces the second edition (ISO 4437:1997), which has been technically revised as follows. A clear distinction has been made between requirements on compounds and requirements on pipes. Substantial changes have been made in introducing specifications for pipes, including additional layers, and in amending the relationship of the S4 critical pressure to the maximum operating pressure and FS critical pressure. An informative annex (Annex B) has been added, giving an alternative design approach using a pre-set, overall service (design) coefficient. Normative references have been updated and changed as appropriate. It also incorporates the Technical Corrigendum ISO 4437:1997/Cor.1:1999.

Buried polyethylene (PE) pipes for the supply of gaseous fuels — Metric series — Specifications

1 Scope

This International Standard specifies the general properties of the polyethylene (PE) compounds for the manufacture of pipes, the physical and mechanical properties of the pipes made from these compounds, and the requirements for the marking of such pipes, intended to be used for the supply of gaseous fuels.

It deals with three types of pipe:

— PE pipes (outside diameter d_n) including any identification stripes;

— PE pipes with co-extruded layers on either or both the outside and/or inside of the pipe (total outside diameter d_n) as specified in Annex C, where all layers have the same MRS rating;

— PE pipes (outside diameter d_n) with a peelable, contiguous thermoplastics additional layer on the outside of the pipe ("coated pipe") as specified in Annex D.

This International Standard also gives guidance on a calculation and design scheme on which the maximum operating pressure (MOP) of the pipes is based. The pipes are intended to be buried.

NOTE For above-ground application of pipes conforming to this International Standard, the pipes need always to be protected by a casing pipe.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3, *Preferred numbers — Series of preferred numbers*

ISO 161-1, *Thermoplastics pipes for the conveyance of fluids — Nominal outside diameters and nominal pressures — Part 1: Metric series*

ISO 497, *Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers*

ISO 1133, *Plastics — Determination of the melt mass-flow rate (MFR) and the melt volume-flow rate (MVR) of thermoplastics*

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 (all parts), *Plastics — Methods for determining the density of non-cellular plastics*

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

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

ISO 4065, *Thermoplastics pipes — Universal wall thickness table*

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 8085-3, *Polyethylene fittings for use with polyethylene pipes for the supply of gaseous fuels — Metric series — Specifications — Part 3: Electrofusion fittings*

ISO 9080, *Plastics piping and ducting systems — Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation*

ISO 11357-6, *Plastics — Differential scanning calorimetry (DSC) — Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT)* [1)]

ISO 11413, *Plastics pipes and fittings — Preparation of test piece assemblies between a polyethylene (PE) pipe and an electrofusion fitting*

ISO 11414:1996, *Plastics pipes and fittings — Preparation of polyethylene (PE) pipe/pipe or pipe/fitting test piece assemblies by butt fusion*

ISO 11922-1:1997, *Thermoplastics pipes for the conveyance of fluids — Dimensions and tolerances — Part 1: Metric series*

ISO 12162:1995, *Thermoplastics materials for pipes and fittings for pressure applications — Classification and designation — Overall service (design) coefficient*

ISO 13477, *Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Small-scale steady-state test (S4 test)*

ISO 13478, *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 (notch test)*

ISO 13480, *Polyethylene pipes — Resistance to slow crack growth — Cone test method*

ISO 13953, *Polyethylene (PE) pipes and fittings — Determination of the tensile strength and failure mode of test pieces from a butt-fused joint*

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*

1) To be published. (Revision of ISO 11357-6:2002)

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

ISO 18553, *Method for the assessment of the degree of pigment or carbon black dispersion in polyolefin pipes, fittings and compounds*

ASTM D3849, *Standard test method for carbon black — Morphological characterization of carbon black using electron microscopy*

EN 12099, *Plastics piping systems — Polyethylene piping materials and components — Determination of volatile content*

3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

3.1
nominal outside diameter
d_n
numerical designation of size which is common to all components in a thermoplastics piping system other than flanges and components designated by thread size

NOTE 1 It is a convenient round number for reference purposes.

NOTE 2 For metric pipes conforming to ISO 161-1, the nominal outside diameter, expressed in millimetres, is the minimum mean outside diameter, $d_{em,min}$.

3.2
mean outside diameter
d_{em}
measured length of the outer circumference of the pipe divided by π, rounded up to the nearest 0,1 mm

NOTE The value for π is taken to be 3,142.

3.3
minimum mean outside diameter
$d_{em,min}$
minimum mean outside diameter of the pipe

3.4
maximum mean outside diameter
$d_{em,max}$
maximum mean outside diameter of the pipe

3.5
out-of-roundness
ovality
difference between the measured maximum outside diameter and the measured minimum outside diameter in the same cross-sectional plane of the pipe

3.6
nominal wall thickness
e_n
wall thickness, in millimetres, tabulated in ISO 4065, corresponding to the minimum wall thickness $e_{y,min}$ at any point e_y

3.7
wall thickness at any point
e_y
measured wall thickness at any point around the circumference of the pipe, rounded up to the nearest 0,1 mm

3.8
minimum wall thickness
$e_{y,min}$
minimum wall thickness of the pipe

3.9
standard dimension ratio
SDR
ratio of the nominal outside diameter of the pipe to its nominal wall thickness

$$\text{SDR} = \frac{d_n}{e_n}$$

3.10
lower confidence limit of predicted hydrostatic strength
σ_{LPL}
quantity with the dimension of stress, which represents the 97,5 % lower confidence limit of the predicted hydrostatic strength for a single value at a temperature T and a time t

NOTE It is denoted as $\sigma_{LPL} = \sigma_{(T,t,0,975)}$.

3.11
minimum required strength
MRS
value of σ_{LPL} at a temperature of 20 °C and a time of 50 years ($\sigma_{(20,50\text{years},0,975)}$), rounded down to the next smaller value of the R10 series or of the R20 series conforming to ISO 3, ISO 497 and ISO 12162, depending on the value of σ_{LPL}

3.12
gaseous fuel
any fuel which is in the gaseous state at a temperature of 15 °C and a pressure of 1 bar

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

3.13
maximum operating pressure
MOP
maximum effective pressure of the gas in a piping system, expressed in bar, which is allowed for continuous use

NOTE 1 It takes into account the physical and the mechanical characteristics of the components of the piping system and the influence of the gas on these characteristics.

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

3.14
compound
homogeneous extruded mixture of base polymer (PE) and additives, i.e. antioxidants, pigments, UV-stabilizers and others, at a dosage level necessary for the processing and use of components conforming to the requirements of this International Standard

3.15
rework material
unused material from a manufacturer's retained production that has been reground, granulated or pelletized for reuse by that same manufacturer

4 PE compound

4.1 Technical data

The technical data concerning the materials used, relevant to the performance of the pipe, shall be made available to the purchaser of the compound by the compound manufacturer.

4.2 Change in compound quality

Any change in dosage levels or processing of the compound affecting the performance of the pipe may require a new qualification of the compound.

NOTE Guidelines can be found in Bibliographic references [4] and [6].

4.3 Identification compound

Where applicable, the compound used for identification stripes shall be made from the same base resin as one of the pipe compounds for which fusion compatibility of pipes is proven by the pipe manufacturer.

4.4 Rework material

Clean rework material may be used, provided that it is derived from the same pipe and/or fitting compound as used for the relevant production.

4.5 Characteristics of PE compound

The PE compound shall be in accordance with Tables 1 and 2.

4.6 Fusion compatibility of PE compound

The compound manufacturer shall demonstrate fusion compatibility for the compounds of his own product range by checking that the requirement for tensile strength given in Table 3 is fulfilled for butt-fusion joints prepared using the parameters specified in ISO 11414:1996, Annex A, at an ambient temperature of (23 ± 2) °C.

4.7 Classification

PE compounds shall be classified by MRS in accordance with Table 4.

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

The long-term hydrostatic strength of the compound shall be evaluated in accordance with ISO 9080, with pressure tests performed at least three temperatures, where two of the temperatures are fixed to 20 °C and 80 °C, and the third temperature free between 30 °C and 70 °C. At 80 °C, there shall be no knee detected in the regression curve at $t < 5\,000$ h.

Table 1 — Characteristics of PE compound

Characteristic	Unit	Requirement	Test parameter	Test method
Density [a]	kg/m^3	$\geqslant$ 930	23 °C	ISO 1183
Melt flow rate	g/10 min	± 20 % of the nominated value or ± 0,1 g/10 min, whichever is the greatest	condition T [b]	ISO 1133
Thermal stability	min	> 20	200 °C [c]	ISO 11357-6
Volatile content [d]	mg/kg	$\leqslant$ 350		EN 12099
Water content [d, e]	mg/kg	$\leqslant$ 300		ISO 15512
Carbon black content [f]	% (mass fraction)	2,0 % to 2,5 %		ISO 6964
Carbon black or pigment dispersion	Grade	$\leqslant$ 3		ISO 18553
	Rating of appearance	A1,A2,A3 or B		
Carbon black particle size [f]	nm	10 to 25		ASTM D3849

[a] For the base polymer only.

[b] The condition used for determining the MFR shall be related to the conditions used by the manufacturer.

[c] Testing may be carried out at 210 °C provided there is clear correlation with the results at 200 °C. In case of dispute, the reference temperature shall be 200 °C.

[d] This test method may be used for quality control purposes.

[e] Only applicable if the compound does not conform to the requirement for volatile content. In case of dispute, the requirement for water content shall be decisive. The requirement applies to the compound producer at the stage of compound manufacturing and to the compound user at the stage of processing (if the water content exceeds the limit, drying is required prior to use).

[f] Only applicable for black compounds.

Table 2 — Characteristics of PE compound — Tested in pipe form

Characteristic	Unit	Requirement	Test parameter	Test method
Resistance to gas constituents	h	⩾ 20	80 °C 2 MPa	Annex A
Resistance to rapid crack propagation (RCP): S4 test ($e \geqslant 15$ mm)	bar	$p_c \geqslant 1{,}5 \times \text{MOP}$ with $p_c = 3{,}6 \times p_{cS4} + 2{,}6$ (in bar) [a]	0 °C	ISO 13477
Resistance to slow crack growth	h	⩾ 500	80 °C; 8,0 bar [b] 80 °C; 9,2 bar [c]	ISO 13479
Resistance to weathering (for non-black compounds only)	—	After weathering	$E \geqslant 3{,}5$ GJ/m^2 [e]	ISO 16871
		Hydrostatic strength of pipe [d]	80 °C; ⩾1 000 h	ISO 1167-1 ISO 1167-2
		Elongation at break of pipe	⩾ 350 %	ISO 6259-1 ISO 6259-3
		De-cohesion of an electrofusion joint — percentage brittle failure	23 °C; ⩽ 33,3 %	ISO 13954 ISO 11413 [f] Jointing condition 1 ISO 8085-3

[a] The full-scale/S4 correlation factor is equal to 3,6 and is defined by the formula:

$$p_{cFS} + p_{atm} = 3{,}6\ (p_{cS4} + p_{atm})$$

where p_{cFS} is the full-scale test critical pressure, p_{atm} is the atmospheric pressure, and p_{cS4} is the small-scale, steady-state (S4) test critical pressure.

NOTE Attention is drawn to the fact that the correlation factor could be modified.

If the requirement is not met, then retest using the full-scale test ISO 13478. In this case, critical pressure $p_c = p_{c,FS}$.

[b] Test parameter for PE 80, d_n 110 mm or 125 mm, SDR 11.

[c] Test parameter for PE 100, d_n 110 mm or 125 mm, SDR 11.

[d] Test parameter for PE 80: 4,0 MPa. Test parameter for PE 100: 5,0 MPa.

[e] The value of 3,5 GJ/m^2 represents the yearly exposure to sunlight near the 50th degree of latitude. This value might not be appropriate for other global locations, in which case, national standards and regulations will apply.

[f] ISO 11413:1996 does not take into account peelable pipe. It is intended that its next revision will cover this aspect.

Table 3 — Characteristic of PE compound — Tested in butt-fusion joint form

Characteristic	Unit	Requirement	Test parameter	Test method
Tensile strength for butt fusion (d_n: 110 mm or 125 mm — SDR 11)	—	Test to failure: Ductile — Pass Brittle — Fail	23 °C	ISO 13953

Table 4 — Classification of PE compounds

Designation	σ (20 °C, 50 years, 0,975) MPa	**MRS** MPa
PE 80	8,00 to 9,99	8,0
PE 100	$\geqslant$ 10,00	10,0

5 Pipes [2)]

5.1 Appearance

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

5.2 Geometrical characteristics

5.2.1 General

The dimensions of the pipe shall be measured not less than 24 h after manufacture in accordance with ISO 3126 after having being conditioned at (23 ± 2) °C for at least 4 h.

5.2.2 Mean outside diameter and out-of-roundness (ovality) and their tolerances

The mean outside diameter $d_{\text{e,m}}$, the out-of-roundness (ovality) and their tolerances shall be in accordance with Table 5.

Grade B tolerances in accordance with ISO 11922-1 shall apply.

5.2.3 Wall thicknesses and their tolerances

The minimum wall thickness $e_{\text{y,min}}$ shall be in accordance with Table 6. Small pipe diameters are characterized by wall thickness. Large pipe diameters are characterized by SDR. All SDR values may be used, taken from series stated in ISO 4065 and ISO 161-1.

NOTE The minimum required wall thickness for pipes with a nominal diameter of 75 mm or lower does not, in all cases, conform with ISO 4065.

The tolerance on the wall thickness at any point shall conform to of ISO 11922-1:1997, Grade V. The maximum permitted positive deviation between the minimum wall thickness $e_{\text{y,min}}$ and the wall thickness at any point e_{y} shall conform to Table 7.

2) Specifications for pipes with co-extruded and peelable layers are given in Annexes C and D.

5.2.4 Circumferential reversion

The circumferential reversion of pipes ("tow-in") with a d_n equal to or greater than 250 mm shall be determined between 24h and 48h after manufacturing and after a conditioning in water at 80 °C. The conditioning shall be in accordance with ISO 1167-1 and 1167-2. The pipe test pieces shall be $3d_n$ in length. With the test piece at (23 ± 2) °C, circumferential measurement shall be made to establish d_{em}. The difference between d_{em} measurement made at distance of $1,0d_n$ and $0,1d_n$, respectively, from the end of the test piece shall not be greater than the d_{em} tolerance range (grade B) specified in Table 5.

Table 5 — Mean outside diameters and out-of-roundness

Dimensions in millimetres

Nominal outside diameter d_n	$d_{em,min}$	$d_{em, max}$	Maximum of absolute out-of-roundness (ovality) [a]	
		Grade B	Grade K [b]	Grade 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
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	—	15,6
500	500,0	503,0	—	17,5
560	560,0	563,4	—	19,6
630	630,0	633,8	—	22,1

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

[b] For coiled pipe with $d_n \leqslant 63$ mm, grade K applies; for pipe with $d_n \geqslant 75$ mm, the maximum out-of roundness shall be specified by agreement.

Table 6 — Minimum wall thickness

Dimensions in millimetres

Nominal outside diameter d_n	Minimum wall thickness $e_{y,min}$						
	SDR 9	SDR 11 [a]	SDR 13,6	SDR 17 [a]	SDR 17,6 [b]	SDR 21	SDR 26
16	3,0	2,3 [d]	—	—	—	—	—
20	3,0	2,3 [d]	—	—	—	—	—
25	3,0	2,3 [d]	2,0 [c]	—	—	—	—
32	3,6	3,0	2,4 [d]	2,0 [c]	2,0 [c]	—	—
40	4,5	3,7	3,0	2,4 [d]	2,3 [d]	2,0 [c]	—
50	5,6	4,6	3,7	3,0	2,9 [d]	2,4 [d]	2,0 [c]
63	7,1	5,8	4,7	3,8	3,6	3,0	2,5 [d]
75	8,4	6,8	5,6	4,5	4,3	3,6	2,9 [d]
90	10,1	8,2	6,7	5,4	5,2	4,3	3,5
110	12,3	10,0	8,1	6,6	6,3	5,3	4,2
125	14,0	11,4	9,2	7,4	7,1	6,0	4,8
140	15,7	12,7	10,3	8,3	8,0	6,7	5,4
160	17,9	14,6	11,8	9,5	9,1	7,7	6,2
180	20,1	16,4	13,3	10,7	10,3	8,6	6,9
200	22,4	18,2	14,7	11,9	11,4	9,6	7,7
225	25,2	20,5	16,6	13,4	12,8	10,8	8,6
250	27,9	22,7	18,4	14,8	14,2	11,9	9,6
280	31,3	25,4	20,6	16,6	15,9	13,4	10,7
315	35,2	28,6	23,2	18,7	17,9	15,0	12,1
355	39,7	32,2	26,1	21,1	20,2	16,9	13,6
400	44,7	36,4	29,4	23,7	22,8	19,1	15,3
450	50,3	40,9	33,1	26,7	25,6	21,5	17,2
500	55,8	45,5	36,8	29,7	28,4	23,9	19,1
560	—	50,9	41,2	33,2	31,9	26,7	21,4
630	—	57,3	46,3	37,4	35,8	30,0	24,1

[a] Preferred series.

[b] SDR 17,6 series might be removed at the next revision of this International Standard.

[c] For practical reasons, electrofusion and butt fusion of pipe of 2,0 mm wall thickness is not recommended.

[d] Minimum wall thickness values greater than limits of 2,3 mm, 2,4 mm and 2,9 mm may be imposed for practical reasons in accordance with national requirements. See manufacturer's technical files or national specifications for advice.

Table 7 — Tolerances on wall thickness at any point

Dimensions in millimetres

Minimum wall thickness $e_{y,min}$ >	Minimum wall thickness $e_{y,min}$ ⩽	Permitted positive deviation	Minimum wall thickness $e_{y,min}$ >	Minimum wall thickness $e_{y,min}$ ⩽	Permitted positive deviation
2,0	3,0	0,4	30,0	31,0	3,2
3,0	4,0	0,5	31,0	32,0	3,3
4,0	5,0	0,6	32,0	33,0	3,4
5,0	6,0	0,7	33,0	34,0	3,5
6,0	7,0	0,8	34,0	35,0	3,6
7,0	8,0	0,9	35,0	36,0	3,7
8,0	9,0	1,0	36,0	37,0	3,8
9,0	10,0	1,1	37,0	38,0	3,9
10,0	11,0	1,2	38,0	39,0	4,0
11,0	12,0	1,3	39,0	40,0	4,1
12,0	13,0	1,4	40,0	41,0	4,2
13,0	14,0	1,5	41,0	42,0	4,3
14,0	15,0	1,6	42,0	43,0	4,4
15,0	16,0	1,7	43,0	44,0	4,5
16,0	17,0	1,8	44,0	45,0	4,6
17,0	18,0	1,9	45,0	46,0	4,7
18,0	19,0	2,0	46,0	47,0	4,8
19,0	20,0	2,1	47,0	48,0	4,9
20,0	21,0	2,2	48,0	49,0	5,0
21,0	22,0	2,3	49,0	50,0	5,1
22,0	23,0	2,4	50,0	51,0	5,2
23,0	24,0	2,5	51,0	52,0	5,3
24,0	25,0	2,6	52,0	53,0	5,4
25,0	26,0	2,7	53,0	54,0	5,5
26,0	27,0	2,8	54,0	55,0	5,6
27,0	28,0	2,9	55,0	56,0	5,7
28,0	29,0	3,0	56,0	57,0	5,8
29,0	30,0	3,1	57,0	58,0	5,9

5.3 Mechanical characteristics

When tested in accordance with the test methods as specified in Table 8 using the indicated parameters, the pipe shall have mechanical characteristics conforming to the requirements given in Table 8.

NOTE For information about providing evidence that after using the squeeze-off technique, the long term strength of the pipe will still conform to this International Standard. Guidelines are given in Annex E.

Table 8 — Mechanical characteristics of the pipe

Characteristic	Unit	Requirement	Test parameter	Test method
Hydrostatic strength	h	Failure time $\geqslant$ 100 h	20 °C PE 80; 9,0 MPa PE 100; 12,4 Mpa	ISO 1167-1 [a] ISO 1167-2 [a]
		Failure time $\geqslant$ 165 h [b]	80ºC PE 80; 4,5 MPa PE 100; 5,4 MPa	
		Failure time $\geqslant$ 1 000 h	PE 80; 4,0 MPa PE 100; 5,0 MPa	
Elongation at break	%	$\geqslant$ 350	—	ISO 6259-1 ISO 6259-3
Resistance to rapid crack propagation (RCP) [c]	bar	$p_c \geqslant 1{,}5 \times \text{MOP}$ with $p_c = 3{,}6 \times p_{c,S4} + 2{,}6$ (in bar) [c]	0 °C	ISO 13477
Resistance to slow crack growth: Cone test ($e_n \leqslant$ 5 mm)	mm/day	< 10	80 °C	ISO 13480
Resistance to slow crack growth [d]: Notch test ($e_n >$ 5 mm)	h	$\geqslant$ 500	80 °C	ISO 13479

[a] End caps type A.

[b] Brittle failures shall be conclusive. If a ductile failure occurs before the required time a lower stress may be selected. The minimum test time corresponding to the selected stress, shall be obtained from the line through the recommended stress/time points (see Table 9).

[c] RCP tests are applicable to PE pipes intended to be used in distribution systems with 0,1 < MOP $\leqslant$ 4 bar and $d_n \geqslant$ 250 mm, or in distribution systems with MOP > 4 bar and $d_n \geqslant$ 90 mm. Testing is only required when the wall thickness of the pipe is greater than the wall thickness of the pipe used in the RCP test to qualify the compound (see Table 2). For severe working conditions (e.g. sub-zero temperatures) RCP testing is also recommended to establish the critical pressure at the minimum working temperature.

The full-scale/S4 correlation factor is equal to 3,6 and is defined by the formula:

$$p_{cFS} + p_{atm} = 3{,}6\ (p_{cS4} + p_{atm})$$

where p_{cFS} is the full-scale test critical pressure, p_{atm} is the atmospheric pressure, and p_{cS4} is the small-scale, steady-state (S4) test critical pressure.

NOTE Attention is drawn to the fact that the correlation factor could be modified in the future.

If the requirement is not met, then retest using the full-scale test ISO 13478. In this case, critical pressure $p_c = p_{c,FS}$.

[d] See ISO 13479 for test conditions.

Table 9 — Hydrostatic strength (80 °C) — Stress/minimum failure time correlation

PE 80		PE 100	
Stress MPa	**Minimum failure time** h	**Stress** MPa	**Minimum failure time** h
4,5	165	5,4	165
4,4	233	5,3	256
4,3	331	5,2	399
4,2	474	5,1	629
4,1	685	5,0	1000
4,0	1 000		

5.4 Physical characteristics

The pipe shall be tested in accordance with Table 10 and, following those tests, have the physical characteristics specified in the table.

Table 10 — Physical characteristics of the pipes

Characteristic	Unit	Requirement	Test parameter	Test method
Thermal stability	min	> 20	200 °C [b]	ISO 11357-6
Melt flow rate (MFR)	g/10 min	Change in MFR by processing < 20 % [a]	190 °C	ISO 1133
Heat reversion	%	$\leqslant 3$, no effect on surface	110 °C	ISO 2505

[a] Value as measured by the pipe manufacturer relative to the value measured on the compound.

[b] The test may be carried out at 210 °C, provided that there is a clear correlation with the results at 200 °C. In the case of a dispute, the reference temperature shall be 200 °C.

5.5 Fusion compatibility for butt-fusion joints

For the assessment of fitness for purpose, the pipes conforming to this International Standard shall be compatible with each other for the purpose of butt fusion. This shall be demonstrated by the pipe manufacturer for each pipe of his own product range by checking that the requirement for tensile strength given in Table 3 is fulfilled for butt-fusion joints prepared using the parameters specified in ISO 11414:1996, Annex A, at an ambient temperature of (23 ± 2) °C, and in accordance with the scheme given in Table 11.

Table 11 — Scheme for butt-fusion joints

Pipe	PE 80	PE 100
PE 80	X	X [a]
PE 100	X [a]	X

[a] Only when requested by the purchaser.

5.6 Minimum required marking

Marking details shall be printed or formed directly on the pipe in such a way that the marking does not initiate cracks or other types of failure. Under normal storage, weathering and processing conditions, and utilizing the permissible method of installation and use, legibility shall be maintained during the use of the pipe.

If printing is used, the colouring of the printed information shall differ from the basic colouring of the product.

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

All pipes shall be marked in accordance with Table 12.

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

The frequency of the printing shall be at intervals not greater than 1 m.

Table 12 — Minimum required marking

Aspects	Marking or symbol
Manufacturer or trademark	Name or symbol
Internal fluid	Gas
For pipes $e_n \leqslant 3,0$ mm: Nominal outside diameter × wall thickness	 $d_n \times e_n$
For pipes $e_n > 3,0$ mm: Nominal outside diameter Pipe series	 d_n SDR
Material and designation	PE 80 or PE 100
Production month, year and site (to provide traceability)	Production period, year and month, in figures or in code Name or code for production site, if manufacturer producing at different sites
Reference to this International Standard	ISO 4437

Annex A
(normative)

Resistance to gas constituents

The test shall be carried out on 32 mm SDR 11 pipe. The test may be carried out on other sizes, provided that there is a clear correlation to the results on the 32 mm SDR 11 pipe.

Prepare a synthetic condensate comprising a mixture of a 50 % mass fraction of *n*-decane (99 %) and a 50 % mass fraction of 1-3-5-trimethylbenzene.

Condition the pipe by filling it with condensate and allowing it to stand in air for 1 500 h at (23 ± 2) °C. Carry out the test in accordance with ISO 1167-1 and ISO 1167-2, but using the synthetic condensate inside the pipe at a temperature of 80 °C.

Annex B
(informative)

Design guidance

This International Standard specifies the physical properties of buried PE pipes for the supply of gaseous fuels. It lays down dimensional requirements and maximum operating pressures related to the overall service (design) coefficient and operating temperatures.

Guidance is given regarding the calculation of pipe design stress, σ_S, and pipe SDR and wall thickness. The MRS of the pipe material (determined at 20 °C and 50 years life parameters using ISO 9080) is divided by the overall service (design) coefficient, C:

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

For gas systems, a minimum value of C of 2,0 is allocated by this International Standard for the calculation.

B.1 Pipe design stress, σ_S

ISO 12162 describes the “overall service (design) coefficient” or “C factor”, detailing the contents of this coefficient and giving the minimum values to be used for it.

According to ISO 12162:1995, Clause 5, the minimum coefficient is to be established for static water pressure at 20 °C for 50 years, taking into account the following considerations:

a) additional stress and other unquantifiable effects which are considered to arise in the application;

b) influence of temperature, time and environment inside or outside of the pipe, if different from the 20 °C, 50 years life parameters specified in ISO 9080, this influence having either positive or negative effects;

c) standards relating to MRS for temperatures other than 20 °C.

Minimum values are given in ISO 12162:1995, Table 2.

The symbol for design stress given in ISO 12162 is σ_S, however the abbreviation HDS (hydrostatic design stress) has also widespread use internationally. In order to satisfy the requirements of the full international arena, and as a compromise, an alternative version is therefore suggested: σ_{HDS}.

B.2 The C factor

The current C factor is related to the pipe material and the anticipated installation and operating conditions. There is, however, no clear distinction between the relative effect on the coefficient of material performance and application conditions. This should be corrected, with individual factors introduced to separately cover material and application aspects. The proportion of the factor related to application conditions should not be considered in relation to this International Standard, where the focus should be solely on material.

In this way, the material related factor, C_M, will be less than the value of 2,0 currently allocated in this International Standard and will be within the experience of ISO/TC 138 SC 4 to determine. It reflects the properties of the components of a piping system other than those represented in the σ_{lpl} (e.g. extrusion, batch-to-batch variation). In this way, the minimum factor should be 1,25 (the same as for water).

The application-related component, C_A, should be left to the gas distribution engineer to incorporate via appropriate design codes (such as are given in ISO/TS 10839) and national regulations, and should be dependent on the location of the pipeline, the MOP, the type of gas being conveyed, etc. Care should be taken regarding the differences between (hydro)static and dynamic loading.

Internal fluids such as gases and aggressive condensates when absorbed may have the effect of reducing the material strength upon which the design stress is based, the influence of gas being much less severe than condensate. For natural gas, it is therefore proposed that the component of C_A related to the type of gas be 1,0 (the same as for water). For LPG gas, the gas-related component of C_A should be 1,1 — 10 % greater than that of natural gas, which difference is in line with values already in use by the gas industry in the ISO codes of practice. The factor for manufactured gas should take into consideration the analysis of the gas with special reference to liquid hydrocarbons and should be at least 1,2. However, this component needs to be the subject of further discussion.

Annex C
(normative)

Pipes with co-extruded layers

C.1 General

This annex specifies the additional geometrical, mechanical and physical properties of polyethylene (PE) pipes with co-extruded layer(s), intended to be used for the supply of gaseous fuels. Additional marking requirements are given. The outside diameter (d_n) is defined as the total outside diameter, including the co-extruded black or pigmented layer(s) at the outside of the pipe, and the wall thickness (e_n) is defined as the total wall thickness including all layers. The PE material used for the layer(s) shall be in accordance with Clause 4.

NOTE Other types of layered pipe are covered by standards such as ISO 17484-1 or ISO 18225.

C.2 Geometrical characteristics

The geometrical characteristics of the pipe, inclusive of the co-extruded layer(s), shall be in accordance with 5.2.

C.3 Mechanical characteristics

The mechanical characteristics of the pipe, inclusive of the co-extruded layer(s), shall be in accordance with 5.3.

C.4 Physical characteristics

The physical characteristics shall be in accordance with 5.4. The requirements for thermal stability and for melt flow rate shall apply to the individual layers respectively. Heat reversion shall be applicable to the pipe, inclusive of the co-extruded layer(s).

C.5 Marking

The marking of pipes with co-extruded layer(s) shall be in accordance with 5.6.

C.6 Delamination

No delamination shall occur during all tests of the co-extruded pipe.

Annex D
(normative)

Pipes with peelable layer

D.1 General

This annex specifies the geometrical, mechanical and physical properties of those polyethylene (PE) pipes (outside diameter d_n) having a peelable, contiguous, thermoplastics layer on the outside of the pipe (“coated pipe”), intended to be used for the supply of gaseous fuels. Marking requirements are also given.

The PE-material used for the production of the base pipe shall be in accordance with Clause 4.

The external coating shall be manufactured from a thermoplastic material. When attached, the coating shall not affect the ability of the PE pipe to meet the performance requirements of this International Standard.

NOTE Other types of layered pipe are covered by standards such as ISO 17484-1 or ISO 18225.

D.2 Geometrical characteristics

The geometrical characteristics of the pipe, with the coating removed, shall be in accordance with 5.2.

D.3 Mechanical characteristics

The coating shall not have a detrimental effect on the pipe or vice versa. The mechanical characteristics of the pipe, with the coating removed shall be in accordance with 5.3, and the attachment of the coating shall not affect the ability of the pipe to conform with those requirements. Conformity before and after weathering according to 4.5 shall be assessed.

When the pipe is tested with the coating attached conformity with 5.3 before and after weathering according to 4.5 shall be assessed. The conditions selected shall ensure that pipe is subjected to the specified test stresses.

D.4 Physical characteristics

The physical characteristics of the pipe, with the coating removed, shall be in accordance with 5.4. The coating shall not have a detrimental effect on the pipe or vice versa.

D.5 Marking

Marking shall be applied to the coating and shall be in accordance with 5.6.

In addition, the coating shall be provided with marking clearly distinguishing the pipe from non-coated pipe in service.

The coating shall also carry marking that warns that the coating must be removed prior to electrofusion and mechanical jointing.

D.6 Storage and installation

The coating shall be resistant to detachment during storage and installation. The coating shall be manually removable without damage to the pipe surface, using simple tools in preparation for mechanical or electrofusion jointing. Exposed surfaces created immediately after coating removal shall be suitable for electrofusion or mechanical jointing. Coating adhesion properties shall be assessed using peel tests in accordance with national regulations.

Annex E
(informative)

Squeeze-off technique

In certain countries the technique of squeeze-off is used to restrict the flow of gas in PE pipelines during maintenance and repair operations.

If the user desires to employ this technique, the pipe manufacturer may provide evidence to the user that after squeeze-off in accordance with the method recommended by the manufacturer, or the possible use of a reinforcement sleeve, the long-term strength of the pipe will still be in conformance with this International Standard. The evidence may be given by the procedure described in EN 12106 for the resistance to internal pressure after application of squeeze-off.

Bibliography

[1] ISO/TS 10839, *Polyethylene pipes and fittings for the supply of gaseous fuels — Code of practice for design, handling and installation*

[2] ISO 17484-1, *Plastics piping systems — Multilayer pipe systems for indoor gas installations with a maximum operating pressure up to and including 5 bar (500 kPa) — Part 1: Specifications for systems*

[3] ISO 18225[3)], *Plastic piping systems — Multilayer piping systems for outdoor gas installations — Specifications for systems*

[4] CEN/TS 1555-7, *Plastics piping systems for the supply of gaseous fuels — Polyethylene (PE) — Part 7: Guide for the assessment of conformity*

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

[6] PPI TR-3, *Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Hydrostatic Design Stress (HDS), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe*

3) To be published.

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