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Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) - Part 2: Pipes

Systèmes de canalisations en plastique pour la distribution de combustibles gazeux - Polyethylene PE - Partie 2: Tubes

Kunststoff-Rohrleitungssysteme für die Gasversorgung Polyethylen (PE) - Teil 2: Rohre

This European Standard was approved by CEN on 1 November 2002.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
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Contents

Foreword

This document EN 1555-2:2002 has been prepared by Technical Committee CEN /TC 155, "Plastics piping systems and ducting systems", the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2003, and conflicting national standards shall be withdrawn at the latest by December 2004.

It has been prepared in liaison with Technical Committee CEN/TC 234 "Gas supply".

This standard is a part of a System Standard for plastics piping systems of a particular material for a specified application. There are a number of such System Standards.

System Standards are based on the results of the work undertaken in ISO/TC 138 "Plastics pipes, fittings and valves for the transport of fluids", which is a Technical Committee of the International Organization for Standardization (ISO).

They are supported by separate standards on test methods to which references are made throughout the System Standard.

The System Standards are consistent with general standards on functional requirements and on recommended practice for installation.

EN 1555 consists of the following parts, under the general title *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE):*

— *Part 1: General*

— *Part 2: Pipes* (this standard)

— *Part 3: Fittings*

— *Part 4: Valves*

— *Part 5: Fitness for purpose of the system*

— *Part 7: Guidance for assessment of conformity* (to be published as CEN/TS).

NOTE The document dealing with recommended practice for installation which was initially submitted for CEN enquiry as prEN 1555-6 was withdrawn when EN 12007-2[1], prepared by CEN/TC 234 Gas supply, was published with the title "Gas supply systems - Pipelines for maximum operating pressure up to and including 16 bar - Part 2: Specific functional recommendations for polyethylene (MOP up to and including 10 bar)".

This document includes an informative annex A and a Bibliography.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard : Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Introduction

The System Standard, of which this is Part 2, specifies the requirements for a piping system and its components made from polyethylene (PE) and which is intended to be used for the supply of gaseous fuels.

Requirements and test methods for material and components, other than pipes, are specified in EN 1555-1, EN 1555-3 and EN 1555-4 (for the titles see Foreword). Characteristics for fitness for purpose are covered in EN 1555-5. PrCEN/TS 1555-7 gives guidance for assessment of conformity. Recommended practice for installation is given in EN 12007-2I[1]! prepared by CEN/TC 234.

This part of EN 1555 covers the characteristics of pipes.

1 Scope

This part of EN 1555 specifies the characteristics of pipes made from polyethylene (PE) for piping systems in the field of the supply of gaseous fuels.

It also specifies the test parameters for the test methods referred to in this standard.

In conjunction with the other parts of EN 1555 (see Foreword) it is applicable to PE pipes, their joints and to joints with components of PE and other materials intended to be used under the following conditions:

a) a maximum operating pressure, MOP, up to and including 10 bar[1]) ;

b) an operating temperature of 20 °C as reference temperature.

NOTE 1 For other operating temperatures, derating coefficients should be used, see EN 1555-5.

EN 1555 covers a range of maximum operating pressures and gives requirements concerning colours and additives.

NOTE 2 It is the responsibility of the purchaser or specifier to make the appropriate selections from these aspects, taking into account their particular requirements and any relevant national regulations and installation practices or codes.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN 728, *Plastics piping and ducting systems — Polyolefin pipes and fittings — Determination of oxidation induction time.*

EN 743, *Plastics piping and ducting systems - Thermoplastics pipes — Determination of the longitudinal reversion.*

EN 921, *Plastics piping systems — Thermoplastics pipes — Determination of resistance to internal pressure at constant temperature.*

EN 1056, *Plastics piping and ducting systems — Plastics pipes and fittings — Method for exposure to direct (natural) weathering.*

EN 1555-1:2002, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) — Part 1: General.*

EN 1555-5:2002, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) — Part 5: Fitness for purpose of the system.*

EN ISO 1133, *Plastics - Determination of the melt mass-flow rate (MFR) and the melt volume-flow rate (MVR) of thermoplastics (ISO 1133:1997).*

prEN ISO 3126, *Plastics piping systems - Plastics piping components - Measurement and determination of dimensions (ISO/DIS 3126:1999).*

EN ISO 6259-1, *Thermoplastics pipes - Determination of tensile properties - Part 1: General test method (ISO 6259-1:1997*

EN ISO 13478, *Thermoplastics pipes for the conveyance of fluids — Determination of resistance to rapid crack propagation (RCP) — Full scale test (FST) (ISO 13478:1997).)*

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[1]) 1 bar = 0.1 MPa

EN ISO 13479:1997, *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 13479:1997).*

ISO 6259-3, *Thermoplastics pipes - Determination of tensile properties - Part 3: Polyolefin pipes.*

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 13480, *Polyethylene pipes - Resistance to slow crack growth - Cone test method.*

3 Terms and definitions, symbols and abbreviations

For the purposes of this European Standard, the terms and definitions, symbols and abbreviations given in EN 1555-1:2002 apply.

4 Material

4.1 Compound

The pipes shall be made from virgin, material or own reprocessable material from identical PE base polymer or a mixture of both materials.

The compound from which the pipes are made shall conform to EN 1555-1.

4.2 Compound for identification stripes

For black pipes with identification stripes, the compound used for these stripes shall be yellow and shall be manufactured from the identical PE base polymer as used for the compound for pipe production with additives necessary to fulfill the performance of the pipe.

5 General characteristics

5.1 Appearance

When viewed without magnification, the internal and external surfaces of pipes shall be smooth and clean and shall have no scoring, cavities and other surface defects to an extent that would prevent conformity to this standard.

The ends of the pipe shall be cut cleanly and square to the axis of the pipe.

5.2 Colour

Pipes shall be black, yellow or black with yellow identification stripes.

6 Geometrical characteristics

6.1 Measurement of dimensions

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

6.2 Mean outside diameters, out-of-roundness (ovality) and tolerances

The mean outside diameters of the pipe, d_{em} shall conform to Table 1.

Pipes with tolerances of grade A given in ISO 11922-1:1997[2] shall be used but if close tolerances are required, the tolerance grade B given in Table 1 shall apply.

For straight pipes, the maximum out-of-roundness shall conform to Table 1. For coiled pipes, the maximum out-of-roundness shall be specified by agreement between the manufacturer and the end-user.

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

Dimensions in millimetres

Nominal size DN/OD	Nominal outside diameter d_n	Mean outside diameter $d_{em,min}$	Mean outside diameter $d_{em,max}$ Grade A[c]	Mean outside diameter $d_{em,max}$ Grade B[c]	Maximum out-of-roundness for straight pipes [a] [b]
16	16	16,0	- -	16,3	1,2
20	20	20,0	-	20,3	1,2
25	25	25,0	-	25,3	1,2
32	32	32,0	-	32,3	1,3
40	40	40,0	-	40,4	1,4
50	50	50,0		50,4	1,4
63	63	63,0	-	63,4	1,5
75	75	75,0	-	75,5	1,6
90	90	90,0	-	90,6	1,8
110	110	110,0	-	110,7	2,2
125	125	125,0	- _	125,8	2,5
140	140	140,0	-	140,9	2,8
160	160	160,0	-	161,0	3,2
180	180	180,0	-	181,1	3,6
200	200	200,0	-	201,2	4,0
225	225	225,0	_	226,4	4,5
250	250	250,0	-	251,5	5,0
280	280	280,0	282,6	281,7	9,8
315	315	315,0	317,9	316,9	11,1
355	355	355,0	358,2	357,2	12,5
400	400	400,0	403,6	402,4	14,0
450	450	450,0	454,1	452,7	15,6
500	500	500,0	504,5	503,0	17,5
560	560	560,0	565,0	563,4	19,6
630	630	630,0	635,7	633,8	22,1

a Measurement of out-of-roundness shall be made at the point of manufacturing.

b If other values for the out-of-roundness than those given in this table are necessary, they shall be agreed between the manufacturer and the end-user.

c According to ISO 11922-1:1997[2].

6.3 Wall thicknesses and related tolerances

6.3.1 Minimum **wall** thicknesses

The use of any SDR derived from the pipe series S given according to ISO 4065:1996[3] is permitted.

The minimum wall thickness, e_{min}, of pipes with SDR 17,6 and SDR 11 shall conform to Table 2.

For existing piping systems of nominal sizes DN/OD 25 and DN/OD 32, a minimum wall thickness of $2{,}0_{0}^{+0{,}3}$ mm may be used for mechanical joints with electrometric seals, for nominal pressures up to and including 0,1 bar.

Table 2 — Minimum wall thicknesses for pipes of SDR 17,6 and SDR 11

Dimensions in millimetres

Nominal size DN/OD	Minimum wall thickness e_{min} [a]	
	SDR 17,6	SDR 11
16	2,3"	3,0"
20	2,3"	3,0"
25	2,3"	3,0"
32	2,3"	3,0
40	2,3	3,7
50	2,9	4,6
63	3,6	5,8
75	4,3	6,8
90	5,2	8,2
110	6,3	10,0
125	7,1	11,4
140	8,0	12,7
160	9,1	14,6
180	10,3	16,4
200	11,4	18,2
225	12,8	20,5
250	14,2	22,7
280	15,9	25,4
315	17,9	28,6
355	20,2	32,3
400	22,8	36,4
450	25,6	40,9
500	28,4	45,5
560	31,9	50,9
630	35,8	57,3

a $e_{min}^{a}=e_n$

b The calculated values of e_{min} have been rounded up to 2,3 mm for SDR 17,6 and 3,0 mm for SDR 11, respectively.

6.3.2 Tolerance on the wall thicknesses

The tolerance on the wall thickness at any point shall conform to Table 3, which is derived from grade V of ISO 11922-1:199712].

Table 3 — Tolerance on wall thicknesses

Dimensions in millimetres

Nominal wall thickness e_n [a]		Plus tolerance	Nominal wall thickness e_n [a]		Plus tolerance
>	≤	t_y [b]	>	≤	t_y [b]
–	2,0	0,3	30,0	31,0	3,2
2,0	3,0	0,4	31,0	32,0	3,3
3,0	4,0	0,5	32,0	33,0	3,4
4,0	5,0	0,6	33,0	34,0	3,5
5,0	6,0	0,7	34,0	35,0	3,6
6,0	7,0	0,8	35,0	36,0	3,7
7,0	8,0	0,9	36,0	37,0	3,8
8,0	9,0	1,0	37,0	38,0	3,9
9,0	10,0	1,1	38,0	39,0	4,0
10,0	11,0	1,2	39,0	40,0	4,1
11,0	12,0	1,3	40,0	41,0	4,2
12,0	13,0	1,4	41,0	42,0	4,3
13,0	14,0	1,5	42,0	43,0	4,4
14,0	15,0	1,6	43,0	44,0	4,5
15,0	16,0	1,7	44,0	45,0	4,6
16,0	17,0	1,8	45,0	46,0	4,7
17,0	18,0	1,9	46,0	47,0	4,8
18,0	19,0	2,0	47,0	48,0	4,9
19,0	20,0	2,1	48,0	49,0	5,0
20,0	21,0	2,2	49,0	50,0	5,1
21,0	22,0	2,3	50,0	51,0	5,2
22,0	23,0	2,4	51,0	52,0	5,3
23,0	24,0	2,5	52,0	53,0	5,4
24,0	25,0	2,6	53,0	54,0	5,5
25,0	26,0	2,7	54,0	55,0	5,6
26,0	27,0	2,8	55,0	56,0	5,7
27,0	28,0	2,9	56,0	57,0	5,8
28,0	29,0	3,0	57,0	58,0	5,9
29,0	30,0	3,1			

a See Table 2.
b The tolerance is expressed in the form o^mm.

6.4 Circumferential reversion

The circumferential reversion of pipes with a d_n equal to or greater than 250 mm shall be determined after a conditioning in water at 80 °C. The conditioning shall be in accordance with EN 921. 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} measurements made at distance of $1,0d_n$ and 0,1 d_n respectively from the end of the test piece shall not be greater than the d_{em} tolerance range (grade B) specified in Table 1.

7 Mechanical characteristics

7.1 Conditioning

Unless otherwise specified by the applicable test method, the test pieces shall be conditioned at (23 ± 2) °C before testing in accordance with Table 4.

7.2 Requirements

When tested in accordance with the test methods as specified in Table 4 using the indicated parameters, the pipe shall have mechanical characteristics conforming to the requirements given in Table **4.**

Table 4 - **Mechanical** characteristics

Characteristic	Requirements	Test parameters		Test method
		Parameter	Value	
Hydrostatic strength [a] (20 °C, 100 h)	No failure during the test period of any test piece	End caps Orientation Conditioning time Number of test pieces [b] Type of test Circumferential (hoop) stress for: PE80 PE100 Test period Test temperature	Type a) Free Shall conform to EN 921 3 Water-in-water 10 MPa 12,4 MPa 100 h 20 "C	EN 921
Hydrostatic strength [a] (80 °C, 165h)	No failure during the test period of any test piece[c]	End caps Orientation Conditioning time Number of test pieces [b] Type of test Circumferential (hoop) stress for: _ PE80 PE100 Test period Test temperature	Type a) Free Shall conform to EN 921 3 Water-in-water 4,5 MPa 5,4 MPa 165 h 80 °C	EN 921
Hydrostatic strength [a] (80°C,1000h)	No failure during the test period of any test piece	End caps Orientation Conditioning time Number of test pieces [b] Type of test Circumferential (hoop) stress for: PE80 PE100 Test period Test temperature	Type a) Free Shall conform to EN 921 3 Water-in-water 4 MPa 5 MPa 1000 h 80 °C	EN 921
Elongation at break [d]	2 350 %	Speed of testing: e < 13 mm *e* ≥ 13 mm Test piece dimensions Number of test pieces [b]	100 mm/min 25 mm/min Shall conform to ISO 6259-3 [e] Shall conform to EN ISO 6259-1	EN ISO 6259-1 [f] and ISO 6259-3
Resistance to slow crack growth for e≤5mm (Cone test)	v ≤ 10 mm/day	Number of test pieces [b]	Shall conform to ISO 13480	ISO 13480
Resistance to slow crack growth for e>5mm (Notch test)	No failure during the test period	Test temperature Internal test pressure: PE 80, SDR 11 PE 100, SDR **11** Test period Type of test Number of test pieces [b]	80 °C 8 bar 9 9,2 bar 9 165 h Water-in-water Shall conform to EN ISO 13479	EN ISO 13479:

continued

Table 4 — *(concluded)*

Characteristic	Requirements	Test parameters		Test
		Parameter	Value	
Resistance to rapid crack propagation (Critical pressure, pc)[hl]	Pc > 1.5 MOP with Pc =3.6 Pc,s4+ 2.6 '	Test temperature Number of test pieces [b]	0 °C Shall conform to ISO 13477	ISO 13477

a This characteristic may be also considered when using the squeeze-off technique (see annex A).
b The numbers of test pieces given indicate the numbers required to establish a value for the characteristic described in the table.
The numbers of test pieces required for factory production control and process control should be listed in the manufacturer's quality plan. For guidance see prCEN/TS 1555-7M.
c Only brittle failures shall be taken into account. If a ductile failure occurs before 165 h, the test may be repeated at a lower stress. The stress and the associated test period shall be selected from Table 5 or from a line based on the stress/time points given in Table 5.
d Where the rupture takes place outside the gauge marks, the test is accepted if the value conforms to the requirements.
e The test can be terminated when the requirement is met, without necessarily carrying out the test up to the rupture of the test piece.
f Where practical, machine or die cut type 2 test pieces may be used for pipo wall thickness equal to or less than 25 mm.
g For other SDR classes values are given in annex A of EN ISO 13479:1997.
h Rapid crack propagation testing is only required when the wall thickness of the pipe is greater than the wall thickness of the pipe used in the rapid crack propagation PE compound test (see Table 2 of EN 1555-1:2002).
i Full scale/S4 correlation factor is equal to 3,6 and is defined as the full scale/S4 critical absolute pressures ratio: $(Pc,fullscale+1)=3,6(p_{c,S4}+1)$.

NOTE Attention is drawn to the fact that the correlation factor may be modified, when revising this standard, according to the result of work of ISO/TC 138/SC4 "Plastics pipes, fittings and valves for the supply of gaseous fuels".

If the requirement is not met or S4 test equipment not available, then (re)testing by using the full scale test shall be performed in accordance with EN ISO 13478. In this case : $P_c = P_{c,fullscale}$

Table 5 — Circumferential (hoop) stress at 80 C and associated test period

PE80		PE100	
Stress MPa	Test period h	Stress MPa	Test period 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	1000	—	—

8 Physical characteristics

8.1 Conditioning

Unless otherwise specified by the applicable test method, the test pieces shall be conditioned at (23 ±2) °C before testing in accordance with Table 6.

8.2 Requirements

When tested in accordance with the test methods as specified in Table 6 using the indicated parameters, the pipe shall have physical characteristics conforming to the requirements given in Table 6.

Table 6 — Physical characteristics

Characteristic	Requirements	Test parameters		Test method
		parameter	Value	
Oxidation induction time (Thermal stability)	> 20 min	Test temperature Number of test pieces [ac]	200 °C [b] 3	EN 728
Melt mass-flow rate (MFR)	After processing maximum deviation of ± 20 % of the value measured on the batch used to manufacture the pipe	Loading mass Test temperature Time Number of test pieces [a]	5 kg 190 °C 10 min Shall conform to , EN ISO 1133	EN ISO 1133
Longitudinal reversion	≤3% original appearance of the pipe shall remain	Test temperature Length of test piece Immersion time Test method Number of test pieces [a]	110 °C 200 mm 1 h Free Shall conform to EN 743	EN 743
Multiple test[d]				
Resistance to weathering	The weathered test pieces shall fulfil the requirements of the following characteristics:	Preconditioning (weathering): Cumulative solar radiation Number of test pieces [a]	≥ 3,5 GJ/m² see below	EN 1056
a) oxidation induction time [e]	Shall conform to this table			EN 728
b) hydrostatic strength (165 h at 80 °C)	Shall conform to Table 4			EN 921
c) elongation at break	Shall conform to Table 4.			EN ISO 6259-1 and ISO 6259-3

a The numbers of test pieces given indicate the numbers required to establish a value for the characteristic described in the table. The numbers of test pieces required for factory production control and process control should be listed in the manufacturer's : quality plan. For guidance see prCEN/TS 1555-7[4].

b Test may be carried out at 210 °C providing that there is a clear correlation with the results at 200 °C. In case of dispute the reference temperature shall be 200 °C.

c Samples shall be taken from the outer and inner pipe surfaces. Samples from weathered pipes at the outside weathered surface shall be taken from surfaces prepared as for jointing (EN 1555-5:2002).

d Only for yellow pipes. As soon as possible after the completion of the weathering the three tests shall be carried out on the pipe in the order stated.

e Before sampling for the oxidation induction time test, 0,2 mm from the surface should be taken off.

9 Performance requirements

When pipes conforming to this standard are assembled to each other or to components conforming to other parts of EN 1555, the joints shall conform to EN 1555-5.

10 Marking

10.1 General

10.1.1 The marking elements shall be printed or formed directly on the pipe in such a way that after storage, weathering, handling and installation legibility is maintained during the use of the pipe.

NOTE The manufacturer is not responsible for marking being illegible, due to actions caused during installation and use such as painting, scratching, covering of the components or by use of detergents etc. on the components unless agreed or specified by the manufacturer.

10.1.2 Marking shall not initiate cracks or other types of defects, which adversely influence the performance of the pipe.

10.1.3 If printing is used, the colour of the printed information shall differ from the basic colour of the pipe.

10.1.4 The size of the marking shall be such that it is legible without magnification.

10.1.5 In case of pipes made from own reprocessable material, the use of appropriate marking should be subject to agreement between the manufacturer and the end-user.

10.2 Minimum required marking

The minimum required marking shall conform to Table 7.

Table 7 — Minimum required marking

Aspects	Mark or symbol
Number of the System Standard	EN 1555
Manufacturer's name and/or trademark	Name or symbol
For pipes d_n < 32 mm:	
Nominal outside diameter x nominal wall thickness (d_n x e_n)	e.g. 32 x 3,0
For pipes d_n > 32 mm:	
- Nominal outside diameter, d_n	e.g. 200
- SDR	e.g. SDR 17,6
Tolerance grade [a]	e.g. grade B
Material and designation	e.g. PE 80
Manufacturer's information	b
Internal fluid	Gas
a Only relevant for pipes DN/OD £ 280 mm.	
b For providing traceability the following details shall be given: the production period, year and month, in figures or in code; name or code for the production site, if the manufacturer is producing in different sites.	

The frequency of the marking shall not be less than once per metre.

The length of coiled pipes is permitted to be indicated on the coil; the remaining length of pipe on drums is permitted to be indicated on the pipe.

10.3 Additional marking

Pipes conforming to this standard, which are third party certified by a certification body, may be marked accordingly.

NOTE Attention is drawn to the possible need to include CE marking when required for legislative purposes.

11 Delivery conditions

The length of straight and coiled pipes shall be agreed between the manufacturer and the end-user.

The diameter of coils shall be such that out-of-roundness of pipe after uncoiling shall conform to 6.2.

For the storage of pipes see EN 12007-2:2000t[1]l.

Annex A
(informative)

Squeeze-off technique

A.1 General Squeeze-off technique

In certain countries the technique of squeeze-off is used to restrict the flow of gas in PE piping systems whilst effecting maintenance and repair operations.

If the end-user desires to employ the technique, the pipe manufacturer should provide evidence to the end-user that after squeeze-off in accordance with the method recommended by the manufacturer or a method using a reinforcement sleeve, all the requirements for hydrostatic strength of the pipe according to Table 4 are still fulfilled.

A.2 Definitions

A.2.1.
squeeze-off
gas flow stopped by squeezing the pipe when compressed between two clamps in such a way that the distance between both clamps is less than twice the nominal wall thickness

A.2.2 compression
factor
ratio comprising the distance between clamps divided by twice the nominal wall thickness, necessary to ensure squeeze-off

A.3 Test method

The evidence can be obtained using the test method specified in EN 12106[5].

Bibliography

[1] EN 12007-2:2000, *Gas supply systems — Pipelines for maximum operating pressure up to and including 16 bar— Part 2: Specific functional recommendations for polyethylene (MOP up to and including 10 bar).*

[2] ISO 11922-1:1997, *Thermoplastic pipes for the conveyance of fluids — Dimensions and tolerances — Part 1: Metric series.*

[3] ISO 4065:1996, *Thermoplastics pipes — Universal wall thickness table.*

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

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