



BSI Standards Publication

# Plastics piping systems for the supply of gaseous fuels — Polyethylene (PE)

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Part 1: General

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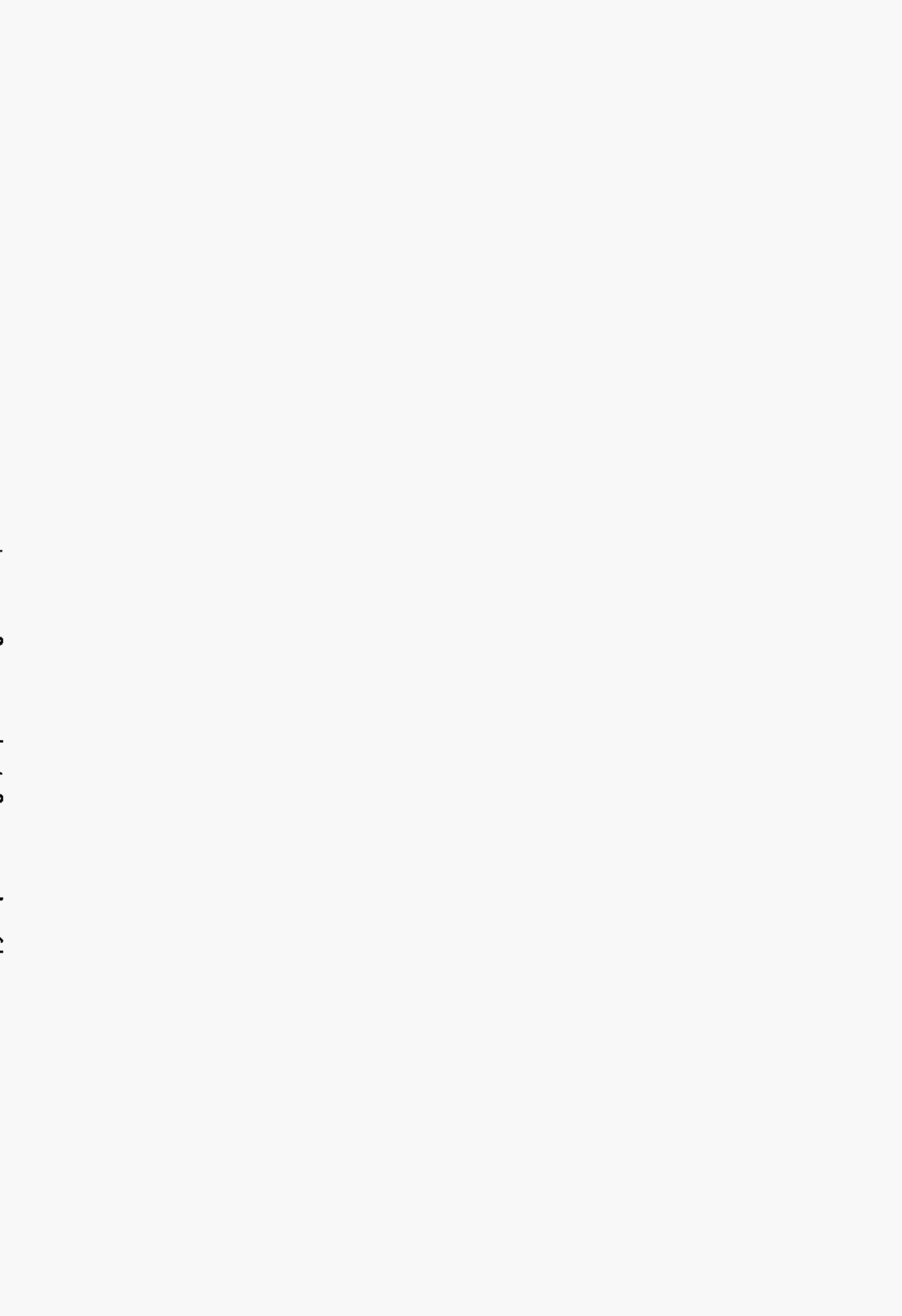
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## Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) - Part 1: General

Systèmes de canalisations en plastique pour la  
distribution de combustibles gazeux - Polyéthylène  
(PE) - Partie 1 : Généralités

Kunststoff-Rohrleitungssysteme für die Gasversorgung  
- Polyethylen (PE) - Teil 1: Allgemeines

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## European foreword

This document (EN 1555-1:2021) has been prepared by Technical Committee CEN/TC 155 “Plastics piping 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of an identical text or by endorsement, at the latest by January 2022, and conflicting national standards shall be withdrawn at the latest by January 2022.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1555-1:2010.

In comparison with the previous version, the following technical modifications have been introduced:

- PE 100-RC type materials with enhanced resistance to slow crack growth have been added.
- Annex A now discusses the performance of this type of material and gives additional information for non-conventional installation techniques.
- The size range has been increased to 800 mm diameter.
- Test methods have been updated.
- New test methods have been added for PE 100-RC materials.

This document has been prepared in liaison with Technical Committee CEN/TC 234 “Gas infrastructure”.

System Standards are based on the results of the work being 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:

- EN 1555-1, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) — Part 1: General* (this document);
- EN 1555-2, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) — Part 2: Pipes*;
- EN 1555-3, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) — Part 3: Fittings*;
- EN 1555-4, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) — Part 4: Valves*;
- EN 1555-5, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) — Part 5: Fitness for purpose of the system*;
- CEN/TS 1555-7, *Plastics piping systems for the supply of gaseous fuels — Polyethylene (PE) — Part 7: Guidance for assessment of conformity*.

NOTE EN 12007-2 [1] prepared by CEN/TC 234 "Gas infrastructure" deals with the recommended practice for installation of plastics pipes system in accordance with EN 1555 (all parts).

Any feedback and questions on this document should be directed to the users' national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

## Introduction

This document 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 components of the piping system are specified in EN 1555-2:2021, EN 1555-3:2021 and EN 1555-4:2021.

Characteristics for fitness for purpose are covered in EN 1555-5:2021 [3]. CEN/TS 1555-7 [2] gives guidance for assessment of conformity. Recommended practices for installation are given in EN 12007-2 [1], prepared by CEN/TC 234.

This part of EN 1555 covers the general aspects of the plastics piping system.

## 1 Scope

This document specifies the general aspects of polyethylene (PE) 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 document.

In conjunction with Parts 2 to 5 of EN 1555, this document is applicable to PE pipes, fittings, and valves, their joints and to joints with components of other materials intended to be used under the following conditions:

- a) a maximum operating pressure, MOP, up to and including 10 bar<sup>1</sup> at a reference temperature of 20 °C for design purposes;
- b) an operating temperature between -20 °C and 40 °C.

NOTE 1 For operating temperatures between 20 °C and 40 °C, derating coefficients are defined, see EN 1555-5 [3].

EN 1555 (all parts) covers a range of maximum operating pressures and gives requirements concerning colours.

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

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.

EN 1555-2:2021, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) - Part 2: Pipes*

EN 1555-3:2021, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) - Part 3: Fittings*

EN 1555-4:2021, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) - Part 4: Valves*

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

EN ISO 472, *Plastics - Vocabulary (ISO 472)*

EN ISO 1043-1, *Plastics - Symbols and abbreviated terms - Part 1: Basic polymers and their special characteristics (ISO 1043-1)*

EN ISO 1133-1, *Plastics - Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics - Part 1: Standard method (ISO 1133-1)*

EN ISO 1167-1:2006, *Thermoplastics pipes, fittings and assemblies for the conveyance of fluids - Determination of the resistance to internal pressure - Part 1: General method (ISO 1167-1:2006)*

EN 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 1167-2)*

EN ISO 1183-1, *Plastics - Methods for determining the density of non-cellular plastics - Part 1: Immersion method, liquid pycnometer method and titration method (ISO 1183-1)*

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<sup>1</sup>1 bar = 0,1 MPa = 10<sup>5</sup> Pa; 1 MPa = 1 N/mm<sup>2</sup>.

EN ISO 1183-2, *Plastics - Methods for determining the density of non-cellular plastics - Part 2: Density gradient column method (ISO 1183-2)*

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

EN ISO 6259-3, *Thermoplastics pipes - Determination of tensile properties - Part 3: Polyolefin pipes (ISO 6259-3)*

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

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

EN ISO 12162, *Thermoplastics materials for pipes and fittings for pressure applications - Classification, designation and design coefficient (ISO 12162)*

EN 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 13477)*

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

EN ISO 15512, *Plastics - Determination of water content (ISO 15512)*

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

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

ISO 6964, *Polyolefin pipes and fittings - Determination of carbon black content by calcination and pyrolysis - Test method*

ISO 11413:2019, *Plastics pipes and fittings - Preparation of test piece assemblies between a polyethylene (PE) pipe and an electrofusion fitting*

ISO 11414:2009, *Plastics pipes and fittings - Preparation of polyethylene (PE) pipe/pipe or pipe/fitting test piece assemblies by butt fusion*

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 13479:—<sup>2</sup>, *Polyolefin pipes for the conveyance of fluids - Determination of resistance to crack propagation - Test method for slow crack growth on notched pipes*

ISO 16770, *Plastics - Determination of environmental stress cracking (ESC) of polyethylene - Full-notch creep test (FNCT)*

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<sup>2</sup> Under preparation. Stage at the time of publication: ISO/DIS 13479:2021.

ISO 18488, *Polyethylene (PE) materials for piping systems - Determination of Strain Hardening Modulus in relation to slow crack growth - Test method*

ISO 18489, *Polyethylene (PE) materials for piping systems - Determination of resistance to slow crack growth under cyclic loading - Cracked Round Bar test method*

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

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 472 and EN ISO 1043-1 and the following apply.

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

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

#### 3.1 Geometrical definitions

##### 3.1.1 nominal size DN/OD

numerical designation of the size of a component related to the outside diameter

Note 1 to entry: It is a convenient round number approximately equal to the manufacturing dimension in millimetres (mm). It is not applicable to components designated by thread size.

##### 3.1.2 nominal outside diameter

$d_n$   
specified outside diameter assigned to a nominal size DN/OD

Note 1 to entry: Nominal outside diameter is expressed in millimetres.

##### 3.1.3 outside diameter at any point

$d_e$   
value of the measurement of the outside diameter through its cross-section at any point of the pipe, rounded to the next greater 0,1 mm

##### 3.1.4 mean outside diameter

$d_{em}$   
value of the measurement of the outer circumference of the pipe or spigot end of a fitting in any cross-section divided by  $\pi$  ( $= 3,142$ ), rounded to the next greater 0,1 mm

##### 3.1.5 minimum mean outside diameter

$d_{em,min}$   
minimum value for the mean outside diameter as specified for a given nominal size

**3.1.6**  
**maximum mean outside diameter**

$d_{em,max}$

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

**3.1.7**  
**out-of-roundness**  
**ovality**

difference between the maximum and the minimum outside diameter in the same cross-section of a pipe or spigot

**3.1.8**  
**nominal wall thickness**

$e_n$

numerical designation of the wall thickness of a component, which is a convenient round number, approximately equal to the manufacturing dimension in millimetres (mm)

Note 1 to entry: For thermoplastics components conforming to the different parts of EN 1555, the value of the nominal wall thickness,  $e_n$ , is identical to the specified minimum wall thickness at any point,  $e_{min}$ .

**3.1.9**  
**wall thickness at any point**

$e$

wall thickness at any point around the circumference of a component rounded to the next greater 0,1 mm

Note 1 to entry: The symbol for the wall thickness of the fittings and valves body at any point is E.

**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**  
**maximum wall thickness at any point**

$e_{max}$

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

**3.1.12**  
**mean wall thickness**

$e_m$

arithmetical mean of a number of measurements of the wall thickness, regularly spaced around the circumference and in the same cross-section of a component, including the measured minimum and the measured maximum values of the wall thickness in that cross-section

**3.1.13**  
**tolerance**

permitted variation of the specified value of a quantity, expressed as the difference between the permitted maximum and the permitted minimum value

**3.1.14**  
**wall thickness tolerance**

$t_y$   
permitted difference between the wall thickness at any point,  $e$ , and the nominal wall thickness,  $e_n$

Note 1 to entry:  $e_n \leq e \leq e_n + t_y$

**3.1.15**  
**standard dimension ratio**  
**SDR**

numerical designation of a pipe series, which is a convenient round number, approximately equal to the dimension ratio of the nominal outside diameter,  $d_n$ , and the nominal wall thickness,  $e_n$

**3.1.16**  
**pipe series**  
**S**

number for pipe designation, conforming to ISO 4065 [6]

Note 1 to entry: The relationship between the pipe series S and the standard dimension ratio SDR is given by the following equation as specified in ISO 4065 [6].

$$S = \frac{\text{SDR} - 1}{2}$$

**3.2 Material definitions**

**3.2.1**  
**compound**

homogenous extruded mixture of base polymer (PE) and additives, i.e. anti-oxidants, pigments, carbon black, UV-stabilizers and others, at a dosage level necessary for the processing and use of components conforming to the requirements of this document

**3.2.2**  
**virgin material**

compound in a form such as granules that has not been subjected to use or processing other than that required for its manufacture, and to which no reworked or recyclable materials have been added

**3.2.3**  
**reworked material**

plastics materials from rejected unused products or trimmings that have been manufactured and retained within plants owned and operated by the same legal entity

Note 1 to entry: Restrictions for use of reworked material for pipes are defined in EN 1555-2, fittings in EN 1555-3 and for valves in EN 1555-4.

**3.2.4**  
**base polymer**

polymer produced by the material supplier for the manufacture of the compound according to this document

### 3.3 Definitions related to material characteristics

#### 3.3.1 lower confidence limit of the predicted hydrostatic strength

$\sigma_{LPL}$   
quantity, with the dimensions of stress, which represents the 97,5 % lower confidence limit of the predicted hydrostatic strength at a temperature  $\theta$  and time  $t$

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

#### 3.3.2 minimum required strength

**MRS**  
value of  $\sigma_{LPL}$  at 20 °C and 50 years, rounded down to the next lower value of the R10 series when  $\sigma_{LPL}$  is less than 20 MPa, or down to the next lower value of the R20 series when  $\sigma_{LPL}$  is greater than or equal to 20 MPa

Note 1 to entry: Only compounds with a MRS of 8 or 10 are specified in this document.

Note 2 to entry: The R10 series conforms to ISO 3 and the R20 series conforms to ISO 497 [4].

Note 3 to entry: The minimum required strength is expressed in megapascals.

#### 3.3.3 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

#### 3.3.4 design stress

$\sigma_s$   
allowable stress for a given application at 20 °C, that is derived from the MRS by dividing it by the coefficient C, i.e.:

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

Note 1 to entry: It is expressed in Megapascals (MPa).

#### 3.3.5 Melt mass-flow rate

**MFR**  
value relating to the viscosity of the molten material at a specified temperature and load

Note 1 to entry: It is expressed in grams per 10 min (g/10 min).

### 3.4 Definitions related to service conditions

#### 3.4.1 gaseous fuel

fuel which is in gaseous state at a temperature of 15 °C, at atmospheric pressure

Note 1 to entry: There are proposals to inject gases from renewable sources in the natural gas network, e.g. hydrogen (H<sub>2</sub>). This is the subject of ongoing research.

### 3.4.2 maximum operating pressure MOP

maximum effective pressure of the fluid in the piping system, expressed in bar, which is allowed in continuous use

Note 1 to entry: It is expressed in bar and takes into account the physical and the mechanical characteristics of the components of a piping system and it is calculated using the following equation:

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

Note 2 to entry: Research on long-term performance prediction of PE water and gas distribution systems shows a possible service life of at least 100 years, see Bibliography [11], [12] and [13].

### 3.4.3 reference temperature

temperature for which the piping system is designed

Note 1 to entry: It is used as the base for further calculation when designing a piping system or parts of a piping system for operating temperatures different from the reference temperature.

## 3.5 Definitions related to joints

### 3.5.1 butt fusion joint using heated tool

joint made by heating the planed ends of pipes or spigot end fittings, the surfaces of which mate by holding them against a flat heating plate until the PE material reaches fusion temperature, removing the heating plate quickly and pushing the two softened ends against one another

### 3.5.2 fusion compatibility

ability of two similar or dissimilar polyethylene compounds to be fused together to form a joint which conforms to the performance requirements of this document

### 3.5.3 electrofusion joint

joint between a PE socket or saddle electrofusion fitting and pipe or fitting with spigot ends, made by heating the electrofusion fittings by the Joule effect of the heating element incorporated at their jointing surfaces, causing the material adjacent to them to melt and the pipe and fitting surfaces to fuse

### 3.5.4 mechanical joint

joint made by assembling a PE pipe to another PE pipe, or any other element using a fitting that generally includes a compression part, to provide for pressure integrity, leaktightness and resistance to end loads

## 4 Symbols and abbreviations

### 4.1 Symbols

For the purposes of this document, the following symbols apply.

$C$	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) of a pipe
$E$	wall thickness (at any point) of a fitting and valve body
$e_m$	mean wall thickness
$e_{max}$	maximum wall thickness (at any point)
$e_{min}$	minimum wall thickness (at any point)
$e_n$	nominal wall thickness
$\langle Gp \rangle$	strain hardening modulus
$t_y$	wall thickness tolerance
$\sigma_s$	design stress
$\sigma_{LPL}$	lower confidence limit of the predicted hydrostatic strength
NOTE	Symbols $d_e$ , $e$ , $e_{min}$ and $e_{max}$ in this document are equivalent to $d_{ey}$ , $e_y$ , $e_{y,min}$ and $e_{y,max}$ , respectively, used in ISO 11922-1 [7].

## 4.2 Abbreviations

AFNCT	accelerated full notch creep test
ANPT	accelerated notched pipe test
CRB	cracked round bar
DN/OD	nominal size, outside diameter related
FNCT	full notch creep test
LPL	lower predicted limit
MFR	melt mass-flow rate
MOP	maximum operating pressure
MRS	minimum required strength
NPT	notched pipe test
OIT	oxidation induction time
PE	polyethylene
R	renard series of preferred numbers
RC	raised crack resistance
RCP	rapid crack propagation
S	number for pipe designation
SDR	standard dimension ratio
SHT	strain hardening test

## **5 Material**

### **5.1 Material of the components**

The pipes, fittings and valves shall be made of polyethylene compound conforming to this document.

This document includes materials classified PE 80 and PE 100.

In addition another type of PE 100 designated PE 100-RC with enhanced resistance to slow crack growth is included in this document, see Annex A for additional information.

The material described in this document is a compound which shall be supplied in the form of granules, suitable for the production of pipes complying with EN 1555-2, fittings complying with EN 1555-3, or valves complying with EN 1555-4.

### **5.2 Compound**

#### **5.2.1 Additives and pigments**

The compound shall be made by the material producer by adding to the polyethylene base polymer only those additives, pigments (e.g. carbon black) necessary for the manufacture of pipes, fittings and valves conforming to EN 1555-2:2021, EN 1555-3:2021 or EN 1555-4:2021, as applicable, and for their fusibility, storage and use.

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

All additives and pigments shall be uniformly dispersed.

#### **5.2.2 Colour**

The colour of the compound shall be yellow (PE 80), orange (PE 100 and PE 100-RC), or black (PE 80, PE 100 and PE 100-RC).

#### **5.2.3 Characteristics**

##### **5.2.3.1 Characteristics of the compound in the form of granules**

The compound in the form of granules used for the manufacture of pipes, fittings and valves shall have characteristics conforming to the requirements given in Table 1.

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

Characteristic	Requirements <sup>a</sup>	Test parameters		Test method
		Parameter	Value	
Compound density	≥ 930 kg/m <sup>3</sup>	Test temperature Number of test pieces <sup>b</sup>	23 °C Shall conform to EN ISO 1183-1 or EN ISO 1183-2	EN ISO 1183-1 or EN ISO 1183-2
Oxidation induction time (OIT) (Thermal stability)	≥ 20 min	Test temperature Sample weight Test atmosphere Number of test pieces <sup>b</sup>	210 °C <sup>c</sup> (15 ± 2) mg Oxygen 3	EN ISO 11357-6
Melt mass-flow rate (MFR)	(0,20 ≤ MFR ≤ 1,40) g/10 min Maximum deviation of ± 20 % of the nominated value <sup>d j</sup>	Loading mass Test temperature Time Number of test pieces <sup>b</sup>	5 kg 190 °C 10 min 3	EN ISO 1133-1
Water content <sup>e</sup>	≤300 mg/kg (Equivalent to ≤ 0,03 % by mass)	Number of test pieces <sup>b</sup>	1	EN ISO 15512
Volatile content	≤350 mg/kg	Number of test pieces	1	EN 12099
Carbon black content <sup>f</sup>	(2,0 to 2,5) % (by mass)	Number of test pieces	Shall conform to ISO 6964 <sup>g</sup>	ISO 6964
Carbon black dispersion <sup>f</sup>	Grade ≤3 Rating of appearance A1, A2, A3 or B	Preparation of test pieces Number of test pieces <sup>b</sup>	Free <sup>h</sup> Shall conform to ISO 18553	ISO 18553
Pigment dispersion <sup>i</sup>	Grade ≤3 Rating of appearance A1, A2, A3 or B	Preparation of test pieces Number of test pieces <sup>b</sup>	Free <sup>h</sup> Shall conform to ISO 18553	ISO 18553
Resistance to slow crack growth for PE 100-RC Strain – Hardening test <sup>m</sup> (SHT)	< G <sub>p</sub> > ≥ 53,0 MPa	Test temperature Thickness Test speed and number of test pieces	80 °C 300 μm Shall conform to ISO 18488	ISO 18488
Resistance to slow crack growth for PE 100-RC Cracked Round Bar test <sup>m</sup> (CRB)	≥ 1,5 × 10 <sup>6</sup> cycles at an interpolated stress range (Δσ <sub>0</sub> ) of 12,5 MPa	Test temperature Type of test Diameter of test piece Waveform/frequency Number of test pieces	23 °C In air 14 mm Sinusoid 10 Hz Shall conform to ISO 18489	ISO 18489

Characteristic	Requirements <sup>a</sup>	Test parameters		Test method
		Parameter	Value	
Resistance to slow crack growth for PE 100-RC Accelerated full notch creep test <sup>l m</sup> (AFNCT)	≥ 550 h at an interpolated reference tensile stress of 4 MPa or ≥ 300 h at an interpolated reference tensile stress of 5 MPa	Test temperature Environment Concentration <sup>j</sup> Test piece dimension Failure mode Number of test pieces	90 °C Lauramine oxide <sup>k</sup> 2 % 10 mm square Brittle 4	ISO 16770

- <sup>a</sup> Conformity to these requirements shall be proven by the compound producer.
- <sup>b</sup> 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 CEN/TS 1555-7 [2].
- <sup>c</sup> Test may be carried out at 220 °C provided that a clear correlation has been established. In case of dispute the reference temperature shall be 210 °C. The test may be carried out on melt flow extrudate or pellet. In case of dispute the test shall be carried out on pellet. The sample thickness is free and not in accordance with EN ISO 11357-6.
- <sup>d</sup> Nominated value given by the compound manufacturer.
- <sup>e</sup> Volatile or water content shall be measured. In case of dispute the requirement for water content shall be used. As an alternative method, ISO 760 [5] may apply. The requirement applies to the compound producer at the stage of manufacturing and to the compound user at the stage of processing (if the water content exceeds the limit, drying is required prior to use).
- <sup>f</sup> Only for black compounds.
- <sup>g</sup> In case of dispute, method A 'electric tube furnace' shall be used.
- <sup>h</sup> In case of dispute, the test pieces shall be prepared by the microtome method.
- <sup>i</sup> Only for non-black materials.
- <sup>j</sup> Materials  $0,15 \leq \text{MFR} < 0,20$  g/10 min may be introduced, in such case attention is drawn to the fusion compatibility subclause 5.3. The lowest MFR value resulting from the maximum lower deviation of the nominated value to be not less than 0,15 g/10 min.
- <sup>k</sup> Lauramine oxide (CAS number 85408-49-7) is commercially available as Dehyton<sup>®</sup> PL<sup>3</sup>. The dilution of the lauramine oxide in the product shall be taken into account when calculating the concentration of 2 wt%. For example, when Dehyton<sup>®</sup> PL<sup>3</sup> is used, it is already diluted to 30 wt%. Therefore, 6,67 wt% of Dehyton<sup>®</sup> PL<sup>3</sup> is needed to obtain 2 wt% lauramine oxide.
- <sup>l</sup> This requirement correlates to a test in accordance with ISO 16770, with a stress of 4 MPa at 80 °C in nonylphenol ethoxylate with no failure for a period of 8 760 h [16], and can be used as an alternative. Nonylphenol ethoxylate (CAS number 9016-45-9) with a trade name of Arkopal<sup>®4</sup> N100 is used for this test with a concentration for testing of 2 %. In case of dispute the AFNCT applies.
- <sup>m</sup> These tests are only performed on PE 100-RC material.

<sup>3</sup> Dehyton<sup>®</sup> PL is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by CEN.

<sup>4</sup> Arkopal<sup>®</sup> is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by CEN.

### 5.2.3.2 Characteristics of the compound in the form of pipe

Unless otherwise specified by the applicable test method, the test pieces shall be conditioned at  $(23 \pm 2) ^\circ\text{C}$  before testing in accordance with Table 2.

**Table 2 — Characteristics of compound in the form of pipe**

Characteristic	Requirements <sup>a</sup>	Test parameters		Test method
		Parameter	Value	
Resistance to gas condensate	No failure during the test period of all test pieces	End caps Test temperature Orientation Number of test pieces <sup>b</sup> Circumferential (hoop) stress Pipe dimensions: $d e_n$ Type of test  Test period Conditioning period (pipe filled with condensate)	Type A 80 °C Free 3 2,0 MPa 32 mm, 3 mm Synthetic condensate in water <sup>c</sup> 20 h 1500 h in air at 23 °C	EN ISO 1167-1:2006 and EN ISO 1167-2
Resistance to weathering <sup>d e</sup>	The weathered test pieces shall fulfil the requirements of the following characteristics:	Preconditioning (weathering): Cumulative radiant exposure Number of test pieces <sup>b</sup>	$\geq 3,5 \text{ GJ/m}^2$  See below	EN ISO 16871
a) de-cohesion of an electrofusion joint b) hydrostatic strength (1000 h at 80 °C) c) elongation at break	Pipe dimension ( $d_n$ : 110 mm SDR 11) a) Sample prepared in accordance with ISO 11413:2019 Jointing condition 1: 23 °C: $\leq 33 \%$ brittle failure b) Shall conform to Table 4 of EN 1555-2:2021 c) Shall conform to Table 4 of EN 1555-2:2021			a) ISO 13954 b) EN ISO 1167-1:2006 and EN ISO 1167-2 c) EN ISO 6259-1 and EN ISO 6259-3
Resistance to rapid crack propagation (RCP) (Critical pressure, $p_c$ )	$p_c \geq 1,5 \text{ MOP}$ with $p_c = 3,6 p_{c,s4} + 2,6$ <sup>f g</sup>	Dimension Test temperature Number of test pieces <sup>b</sup>	$d_n$ : 250 mm SDR 11 0 °C Shall conform to EN ISO 13477	EN ISO 13477
Resistance to slow crack growth for PE 80 and PE 100 Notched Pipe test (NPT) <sup>j</sup>	No failure during the test period	Pipe dimension Test temperature Internal test pressure: for PE 80 for PE 100 Test period Type of test Number of test pieces <sup>b</sup>	$d_n$ : 110 mm SDR 11 80 °C 8,0 bar 9,2 bar $\geq 500 \text{ h}$ Water-in-water Shall conform to ISO 13479:— <sup>2</sup>	ISO 13479:— <sup>2</sup>

Characteristic	Requirements <sup>a</sup>	Test parameters		Test method
		Parameter	Value	
Resistance to slow crack growth for PE 100-RC Accelerated Notched Pipe test (ANPT) <sup>k</sup>	No failure during the test period	Pipe dimension Test temperature Internal test pressure: for PE 100-RC Test period Type of test  Concentration Number of test pieces <sup>b</sup>	$d_n$ : 110 mm SDR 11 80 °C 9,2 bar $\geq 300$ h <sup>h</sup> Water-in-nonylphenol aqueous solution <sup>i</sup> 2 % Shall conform to ISO 13479:— <sup>2</sup>	ISO 13479:— <sup>2</sup>
Determination of the failure mode in a tensile test on butt fusion weld	Test to failure: Ductile - pass Brittle - fail	Pipe dimension Test temperature Number of test pieces <sup>b</sup>	$d_n$ : 110 mm SDR 11 23 °C Shall conform to ISO 13953	ISO 13953
<p><sup>a</sup> Conformity to these requirements shall be proved by the compound producer.</p> <p><sup>b</sup> 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 CEN/TS 1555-7 [2].</p> <p><sup>c</sup> 50 % (by mass) n-decane and 50 % (by mass) 1-3-5 trimethylbenzene.</p> <p><sup>d</sup> Only for non-black compounds.</p> <p><sup>e</sup> For outdoor storage for 1 year to be applicable in some parts of the world, a cumulative radiant exposure of up to 7 GJ/m<sup>2</sup> is valid based on current measurements. For details of 1 year cumulative radiant exposure levels in Europe, see EN 12007-2:2012, Figure 2.</p> <p><sup>f</sup> Full scale/S4 correlation factor is equal to 3,6 and is defined as the full scale/S4 critical absolute pressure ratio: <math>(p_{c,full\ scale} + 1) = 3,6 (p_{c,S4} + 1)</math>. 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: <math>p_c = p_{c,full\ scale}</math>.</p> <p><sup>g</sup> For PE 80 materials smaller pipe diameters may be used for the RCP test. RCP performance is dependent on wall thickness. Pipe of thickness <math>\geq 15</math> mm shall be tested for RCP performance.</p> <p><sup>h</sup> This requirement correlates to a test on 110 mm diameter SDR 11 PE 100-RC pipe in accordance with ISO 13479:—<sup>2</sup>, at a pressure level of 9,2 bar, at 80 °C, water-in-water, with no failure in a test period of 8 760 h, which can be used as an alternative test to meet this requirement [15], [19], [20]. In case of dispute the ANPT applies, Annex D ISO 13479:—<sup>2</sup>.</p> <p><sup>i</sup> Nonylphenol ethoxylate (CAS number 9016-45-9) with a trade name of Arkopal<sup>®4</sup> N100 is used for this test with a concentration for testing of 2% aqueous solution.</p> <p><sup>j</sup> This test is not performed on PE 100-RC materials.</p> <p><sup>k</sup> The ANPT test is specifically for testing PE 100-RC materials</p>				

NOTE In the past, a Point Load Test (PLT) as included in the withdrawn DIN PAS 1075 published by DIN [16], has been performed on 110 mm SDR11 PE 100-RC materials in Europe. An equivalent ISO test method is currently under development in ISO/TC 138/SC5/WG20 [17]. A correlation between the PLT and FNCT has been demonstrated, [18]. Instead of the PLT, the combination of the SHT, CRB, ANPT and AFNCT test methods for PE100-RC compounds is referenced in this document.

## 5.3 Fusion compatibility

**5.3.1** The compounds conforming to Table 1 shall be fusible. The compound manufacturer shall check that the requirement for the failure mode in a tensile test given in Table 2 is fulfilled for a butt fusion joint. The test sample shall be prepared by using the parameters specified in Annex A of ISO 11414:2009, at an ambient temperature of  $(23 \pm 2)$  °C from pipes both manufactured from that compound.

This shall be demonstrated by the compound manufacturer for each compound of his own product range.

For  $0,15 \leq \text{MFR} < 0,20$  compounds, fusion compatibility of pipes with diameter  $> 200$  mm and wall thickness  $> 20$  mm shall be investigated to confirm compatibility. If electrofusion is used, appropriate testing should be carried out to verify the fusion capability of such pipes.

**5.3.2** Compounds conforming to Table 1 are considered fusible to each other. If requested, the compound manufacturer shall demonstrate this by checking that the requirement for the failure mode in a tensile test given in Table 2 is fulfilled for a butt fusion joint prepared by using the parameters as specified in ISO 11414:2009, Annex A at an ambient temperature of  $(23 \pm 2)$  °C from two pipes manufactured from the compounds from his own range covered by this request.

## 5.4 Classification and designation

Compounds shall be designated by the type of PE material. The minimum required strength (MRS) shall conform to Table 3 when tested in the form of pipe.

**Table 3 — Classification and designation of compounds**

Classification by MRS MPa	Designation
8	PE 80
10	PE 100
	PE 100-RC

The compound shall be evaluated in accordance with EN ISO 9080 from pressure tests on pipe in accordance with EN ISO 1167-1:2006 and EN ISO 1167-2 performed on pipe at least at three temperatures, where the first temperature is 20 °C, and the second temperature is 80 °C, and a third temperature is free between 30 °C and 70 °C, to find the  $\sigma_{LPL}$ . The MRS-value shall be derived from the  $\sigma_{LPL}$  and the compound shall be classified by the compound producer in accordance with EN ISO 12162.

At 80 °C, there shall be no knee detected in the regression curve at a time of  $< 5\,000$  h.

The conformity of the designation of the compound to the classification given in Table 3 shall be demonstrated by the compound producer.

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

For the classification of a compound intended only for the manufacture of fittings, test pieces in the form of extruded pipe made from the compound shall be used.

## 5.5 Design coefficient and design stress

The design coefficient,  $C$ , for pipes, fittings and valves for the supply of gaseous fuels shall be greater or equal to 2. The maximum value for the design stress,  $\sigma_s$ , shall be 4,0 MPa for PE 80, and 5,0 MPa for PE 100 and PE 100-RC materials.

## Annex A (informative)

### Additional information related to the installation of PE100-RC systems for non-conventional installations

#### A.1 Pipe material

Polyethylene materials have been used for the manufacture of piping systems for gas supply since the 1960s, offering a corrosion resistant system. Since this time, the materials used for these systems have been developed and improved in terms of performance, potential pressure rating, and above all durability and resistance to Rapid Crack Propagation.

Whilst initial improvements increased the material's pressure resistance (PE 63, PE 80 and PE 100), considerable progress has been made in recent years in increasing the resistance to slow crack growth [15].

The main technical advantage of PE 100-RC is that it is even more resistant to slow crack growth (RC: **R**aised **C**rack resistance). PE100-RC materials for piping systems require a separate number of tests to assess SCG performance. Piping systems made of such a material can be used for alternative trenchless installation methods when more surface damage might be encountered or for installations where excavated soil is used as the embedding material, respecting local regulations. As a result, the durability of the system is increased by using these materials.

The material and product requirements of PE 100-RC compared to well-known and established PE 100 are identical in each part of EN 1555, with the exception of the requirements defined for the Slow Crack Growth (SCG) behaviour for the material and the pipe, fitting and valve components given in EN 1555, Part 1 to Part 5, as appropriate. Table A.1 gives a comparison between performance of PE 100 and PE 100-RC materials related to resistance to slow crack test methods.

**Table A.1 — Resistance to slow crack growth for PE 100 and PE 100-RC**

<b>PE 100 Typical performance</b>	<b>PE 100-RC Expected performance</b>	<b>Accelerated test method for PE 100-RC to reduce test time</b>
NPT ≥ 500 h	NPT ≥ 8760 h	ANPT 80°C, ≥ 300 h 2% Arkopal® <sup>4</sup> N100
FNCT ≥ 300 h at 4 MPa stress 80 °C, 2% solution Arkopal® <sup>4</sup> N100	FNCT ≥ 8760 h at 4 MPa stress 80 °C, 2% solution Arkopal® <sup>4</sup> N100	AFNCT ≥ 550 h at 4 MPa stress or ≥ 300 h at 5 MPa stress (Brittle fracture surface required) 90°C, 2 % solution <sup>a</sup> Lauramine oxide
SHT <Gp> ≥ 40 MPa <sup>a</sup>	SHT <Gp> ≥ 53 MPa <sup>a</sup>	Not applicable
CRB ≥ 0,9 × 10 <sup>6</sup> cycles <sup>a</sup>	CRB ≥ 1,5 × 10 <sup>6</sup> cycles <sup>a</sup>	Not applicable
<sup>a</sup> Derived from DVGW study (Determining limits and minimum requirements for materials and pipes for the rough-beddable pipes made from PE100-RC. 2018, [14]).		

The Notch Pipe test according to ISO 13479:—<sup>2</sup> simulates scratches on the outside of the pipe, which under pressure and stress would slowly drive the crack through the pipe wall. In this test, the PE 100-RC offers a significantly higher resistance to slow crack propagation resistance so that failure time of > 500 h for PE 100 increases to > 8 760 h for PE 100-RC. Such a long test time is not practical. A correlated accelerated method, the accelerated Notch Pipe test (ANPT) has been developed with the stress cracking media on the outside of the pipe reducing failure time to > 300 h, Annex D I ISO 13479:—<sup>2</sup>. That has been proven in broader technical studies and is referred to in the bibliography, [15],[19].[20].

Similar performance for PE 100-RC materials is found in tests involving point loads applied in excess of 8 760 h to simulate the effect of stone indentation, see note below Table 1. Work is ongoing to develop an accelerated point load test [17] in ISO/TC 138/SC5/WG20, see Note below Table 2.

## A.2 Installation Conditions

The usual conventional installation method for PE 80 and PE 100 piping systems is often open trench installation with sand bedding around the pipe.

Other non-conventional installation techniques using specialized machinery and trenchless 'No-Dig' techniques can increase the risk of scratches and damage to the pipe in more undefined conditions. Using the PE100-RC material with the lower notch sensitivity and reduced rates of crack growth increases the safety, reliability and lifetime of the pipe system, and therefore is used especially for:

- a) Installation without sand embedding and a re-use of the excavated soil in open trenches;
- b) Installation using trenchless installation techniques:
  - Replacement of pipeline systems, replacement off line;
  - Horizontal Directional Drilling (HDD);
  - Impact moling;
  - Mole ploughing;
  - Pipe jacking;
  - Auger boring;
  - Micro-tunnelling.
- c) Installation using trenchless installation techniques:
  - Rehabilitation of pipeline systems, replacement on line;
  - Pipe bursting;
  - Pipe splitting;
  - Pipe removal;
  - Pipe eating;
  - Pipe extraction.

d) Rehabilitation of pipeline systems using renovation methods:

- Lining with continuous pipe;
- Lining with close-fit pipes;
- Lining with inserted hoses.

NOTE Terminology from EN ISO 11295 [8], EN ISO 21225-1 [9] and EN ISO 21225-2 [10].

A selection between PE100 or PE100-RC for the pipe system material according to the installation method, soil condition and safety factor should be determined by agreement with the network owner, the installation company and the producer.

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- [3] EN 1555-5, *Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE) Part 5: Fitness for purpose of the system*
- [4] ISO 497, *Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers*
- [5] ISO 760, *Determination of water - Karl Fischer method (General method)*
- [6] ISO 4065, *Thermoplastics pipes - Universal wall thickness table*
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- [20] Interlaboratory comparison Accelerated Notch Pipe test (ANPT) ISO 13479, KIWA The Netherlands, 22<sup>nd</sup> October 2020 (LC 18841-2a), see [www.pe100plus.com](http://www.pe100plus.com).

## National Annex NA (informative)

### Additional information on the selection and installation of piping systems and components in the UK

The UK committee gives the following advice concerning the selection and installation of piping systems and components conforming to this British Standard.

- a) CE marking against the Construction Products Directive and the Pressure Equipment Directive does not apply to pipes and fittings within the scope of BS EN 1555-1, BS EN 1555-2 and BS EN 1555-3. However, CE marking might apply to valves within the scope of BS EN 1555-4. For England, Scotland and Wales, the UKCA (UK Conformity Assessed) mark covers most goods that previously required the CE mark. For Northern Ireland, either the CE mark or the UKNI mark applies. For information on using the UKCA mark, see [www.gov.uk/guidance/using-the-ukca-marking](http://www.gov.uk/guidance/using-the-ukca-marking).
- b) Where there are options, care should be taken to ensure that agreement is established between suppliers and purchasers, for example in terms of colour, size, physical characteristics and quality assurance.
- c) For colour, it is the practice of UK gas companies to use yellow and orange polyethylene (PE) pipes to facilitate identification of buried gas pipelines, in accordance with the recommendations of the National Joint Utilities Group (NJUG) concerning the colour coding of pipelines and other services. For UK public gas supply applications, the pipes and fittings should also be marked in accordance with the relevant standards of the national network distributors<sup>1)</sup> (i.e. Cadent Gas Industry Standard GIS/PL2-4, *Polyethylene pipes and fittings for natural gas and suitable manufactured gas — Part 4: Fusion fittings with integral heating element(s)*, and Cadent Gas Industry Standard GIS/PL2-8, *Polyethylene pipes and fittings for natural gas and suitable manufactured gas — Part 8: Pipes for use at pressures up to 7 bar*).
- d) To comply with health and safety requirements for safe handling of PE pipes supplied as coils or on drums, guidance should be sought from the national network distributors.
- e) This standard requires the critical pressure for rapid crack propagation (RCP) as measured in accordance with BS EN ISO 13477 to be equal to or greater than 1,50 maximum operation pressure (MOP) in [Table 2](#) of this standard. It is the current practice of UK gas companies to use a value of 2.0 instead of 1.5 times MOP.
- f) Requirements for slow crack growth (SCG) are specified in BS EN 1555-2:2021, Table 4. The PE 80 and PE 100 pipe compounds should be tested in pipe form in accordance with BS EN ISO 13479, with a test period of 500 h. It is established practice in the UK to use a test period of 1,000 h. For PE 100-RC materials, the requirements of each part of BS EN 1555 apply.
- g) [Subclause 5.5](#) specifies a minimum overall service (design) coefficient, *C*. Information regarding the value of *C* used in the design of UK gas distribution systems should be sought from the national network distributors.

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1) The national network distributors are a group of companies that operate the pipelines in the UK. There are four companies that make up this group: Cadent, Wales & West Utilities, Northern Gas Networks and SGN.

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