INTERNATIONAL STANDARD

ISO 10146

Second edition
2019-03

Crosslinked polyethylene (PE-X) and crosslinked medium density polyethylene (PE-MDX) — Effect of time and temperature on expected strength

Tubes en polyéthylène réticulé (PE-X et PE-MDX) — Influence du temps et de la température sur la résistance espérée

Reference number
ISO 10146:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

This document was prepared by ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, SC 5, *General properties of pipes, fittings and valves of plastic materials and their accessories — Test methods and basic specifications*.

This second edition cancels and replaces the first edition (ISO 10146:1997), which has been technically revised. The main changes compared to the previous edition are as follows:

— a second type of material termed crosslinked medium density polyethylene (PE-MDX) has been added in accordance with DIN 16894:2011 [1];

— the minimum degree of crosslinking applicable for pipe conforming to this document is specified.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Crosslinked polyethylene (PE-X) and crosslinked medium density polyethylene (PE-MDX) — Effect of time and temperature on expected strength

1 Scope

This document specifies the minimum values for expected strength as a function of time and temperature in the form of reference lines, for use in calculations on crosslinked polyethylene (PE-X) pipes and crosslinked medium density polyethylene (PE-MDX) pipes.

NOTE 1 This document is applicable for pipes with the minimum level of crosslinking after production in accordance with Clause 4.

NOTE 2 The density range for medium density polyethylene is 926 kg/m^3 to 940 kg/m^3 in accordance with ISO 17855-1:2014[2].

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 10147, *Pipes and fittings made of crosslinked polyethylene (PE-X) — Estimation of the degree of crosslinking by determination of the gel content*

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*

3 Terms and definitions

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

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

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
reference lines
generic description of the minimum long-term hydrostatic strength to be expected from a particular polymer

Note 1 to entry: Reference lines are not to be considered as characteristic of a specific grade or of material from a specific supplier.

Note 2 to entry: The lines are described by a mathematical equation which permits interpolation and extrapolation in an unambiguous way at various temperatures.

Note 3 to entry: The reference lines for crosslinked polyethylene (PE-X) and crosslinked medium density polyethylene (PE-MDX) have been agreed upon by a group of experts after considering experimental data, and have been accepted by the relevant technical committees in ISO.

4 Characteristics

Prior to testing to demonstrate conformance to the reference curves given in this document, the pipes shall meet the following minimum degree of crosslinking given in Table 1, and measured in accordance with ISO 10147.

Table 1 — Requirements for degree of crosslinking

Crosslinking process	Requirement	Characteristics	Test method
Peroxide PE-Xa, PE-MDXa	≧70 %	According to ISO 10147	ISO 10147
Silane PE-Xb, PE-MDXb	≧65 %		
Electron beam PE-Xc, PE-MDXc	≧60 %		
UV light initiated PE-Xe, PE-MDXe	≧70 %		

NOTE PE-Xd is the designation for the Azo process of crosslinking, which is no longer used.

5 Basic formulae

The reference lines for temperatures between 20 °C and 95 °C are described by Formula (1):

$$\lg t = A + (B/T)\lg\sigma + C/T + D\lg\sigma \quad (1)$$

NOTE lg is log to the base 10.

where

t is the time, in hours;

T is the temperature, in Kelvins;

σ is the hoop stress, in Megapascals.

For PE-X:

A = –105,861 8

B = –18 506,15

C = 57 895,49

D = –24,799 7

Ig t = –105,861 8 – (18 506,15/T) Ig (σ) + 57 895,49/T – 24,799 7 Ig (σ)

For PE-MDX:

A = –129,108 9

B = –26 934,09

C = 58 914,15

D = 20,630 6

Ig t = –129,108 9 – (26 934,09/T) Ig (σ) + 58 914,15/T + 20,630 6 Ig (σ)

The 110 °C values have been determined separately using water inside and air outside the test specimen. The reference line is described by Formula (2):

$$\mathrm{Ig}\, t = \mathrm{A} + \mathrm{B}\, \mathrm{Ig}(\sigma) \tag{2}$$

where

t is the time, in hours;

σ is the hoop stress, in Megapascals.

For PE-X:

A = 37,495 8

B = –84,033 6

lg t = 37,495 8 – 84,033 6 lg (σ)

For PE-MDX:

A = 22,528

B = – 80,662

lg t = 22,528 – 80,662 lg (σ)

6 Expected strength

6.1 Extrapolation limits

The extrapolation limits (the end points of the reference lines) are based on an experimentally determined life at 110 °C and Arrhenius equation for the temperature dependence with an activation energy of 110 kJ/mole(= 26 kcal/mole). This yields the values given in Table 2 for the extrapolation factor k_e (i.e. the expected lifetime at a given temperature divided by the lifetime at 110 °C).

Table 2 — Extrapolation factors

T °C	k_e
≤100	2,5
≤95	4
≤90	6
≤85	10
≤80	18
≤75	30
≤70	50
≤50	100

With a testing time of one year at 110 °C, these values are therefore the number of years the pipes would be expected to last at each of the temperatures given.

With a testing time of longer than one year at 110 °C, the extrapolation can be extended using the extrapolation factors given in ISO 9080.

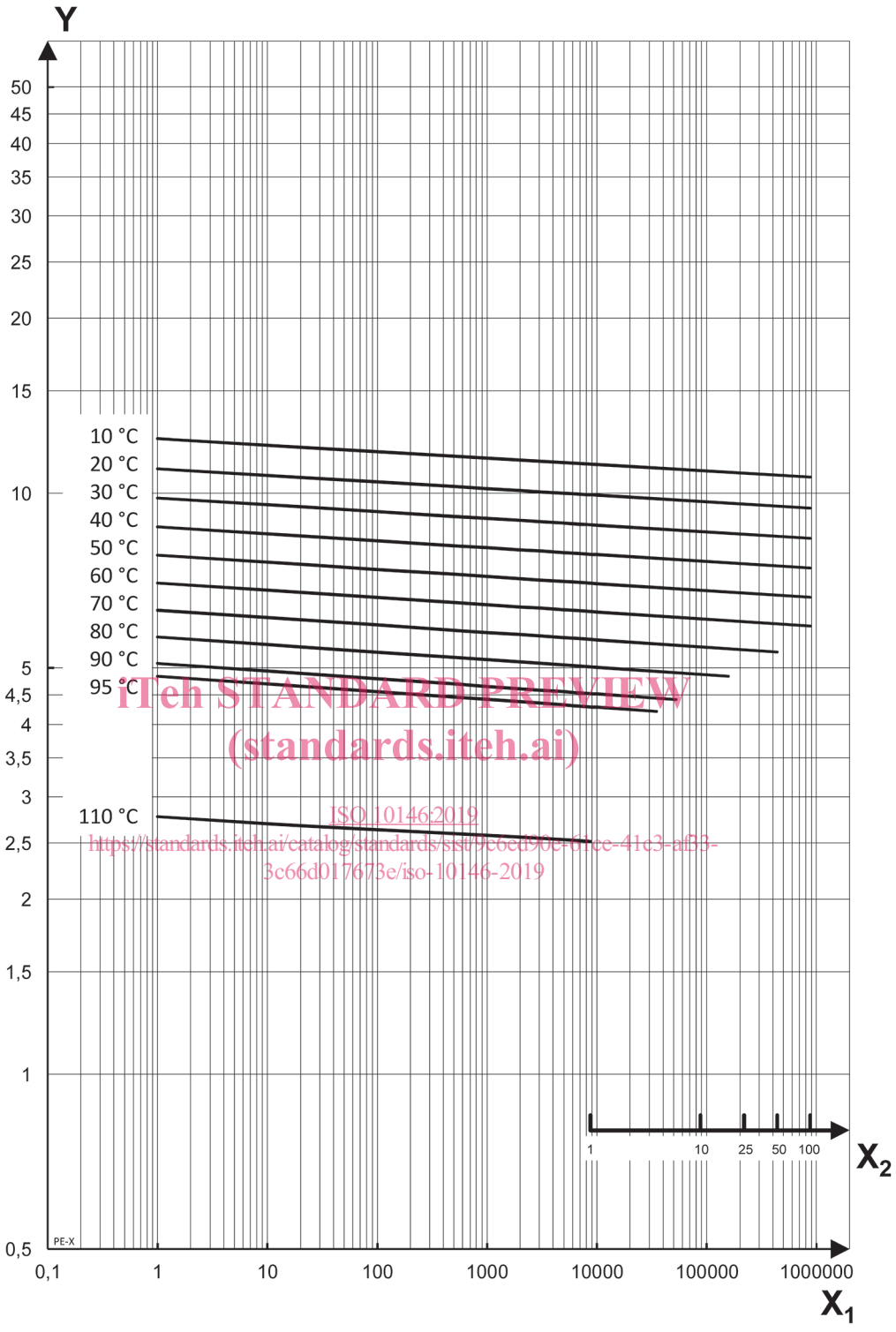
6.2 Graphical representation

Figures 1 and 2 for PE-X and PE-MDX respectively contain the reference lines corresponding to the values of the parameters given in Clause 5, to be used for demonstrating conformance to this document, as described in Annex A.

6.3 Tabulated values

The calculated hoop strength values to be used for various temperatures and times given in Tables 3 and 4 include no safety factors or design factors.

The times at 80 °C, 90 °C and 95 °C in the 'time' column in Tables 3 and 4 are based on a test time of one year at 110 °C. Testing for longer than one year at 110 °C allows a corresponding extension of the times at lower temperatures by the application of the extrapolation factors given in Table 2.



Key

Y stress (MPa)

X_1 time (h)

X_2 time (yr)

Figure 1 — Expected strength of crosslinked polyethylene (PE-X) pipes