INTERNATIONAL STANDARD

ISO 3213

Third edition
2009-09-15

Polypropylene (PP) pipes — Effect of time and temperature on the expected strength

Tubes en polypropylène (PP) — Influence du temps et de la température sur la résistance espérée

Reference number
ISO 3213:2009(E)

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.

ISO 3213 was prepared by Technical Committee ISO/TC 138, *Plastics pipes, fittings and valves for the transport of fluids*, Subcommittee SC 5, *General properties of pipes, fittings and valves of plastic materials and their accessories — Test methods and basic specifications*.

This third edition cancels and replaces the second edition (ISO 3213:1996), which has been revised technically to accommodate technical developments of the polypropylene material. A new type of PP-R is introduced, with a modified crystallinity, designated PP-RCT in accordance with ISO 1043-1[1].

ISO (the International Organization for Standardization) draws attention to the fact that it is claimed that compliance with this document can involve the use of a patent concerning the material class PP-RCT given in Clause 1, Clause 4, Table 5 and Figure 4.

ISO takes no position concerning the evidence, validity and scope of this patent right.

The holder of this patent right has assured ISO that it is willing to negotiate licenses under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right (EP1448631) is registered with ISO. Information may be obtained from:

Borealis Technology Oy
Managing Director
P.O. Box 330
FI-06101 Porvoo
Tel: +3589394900

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

Polypropylene (PP) pipes — Effect of time and temperature on the expected strength

1 Scope

This International Standard 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 pipes made of:

— polypropylene homopolymer (PP-H);

— polypropylene block copolymer[1] (PP-B);

— polypropylene random copolymer (PP-R);

— polypropylene random copolymer[2] with a modified crystallinity (PP-RCT).

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 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.

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

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

NOTE 2 The lines are described by a mathematical equation, which permits interpolation and extrapolation in an unambiguous way at various temperatures.

NOTE 3 The reference lines for PP-H, PP-B, PP-R and PP-RCT have been agreed upon by a group of experts after consideration of experimental data, and are accepted by the relevant technical committees in ISO.

1) This is also called heterophasic copolymer.

2) This material can be distinguished by DSC testing or other appropriate method to indicate a second melting peak.

4 Basic equations

The reference lines for temperatures between 20 °C and 95 °C are described using Equations (1) and (2):

$$\lg\ t = A_1 + \frac{B_1}{T}\lg\ \sigma + \frac{C_1}{T} + D_1 \lg\ \sigma \quad (1)$$

$$\lg\ t = A_2 + \frac{C_2}{T} + D_2 \lg\ \sigma \quad (2)$$

where

t is the time, in hours;

T is the temperature, in kelvin;

σ is the hoop stress, in megapascal.

For PP-H

$A_1 = -46{,}364$ $A_2 = -18{,}387$

$B_1 = -9\ 601{,}1$

$C_1 = 20\ 381{,}5$ $C_2 = 8\ 918{,}5$

$D_1 = 15{,}24$ $D_2 = -4{,}1$

For PP-B

$A_1 = -56{,}086$ $A_2 = -13{,}699$

$B_1 = -10\ 157{,}8$

$C_1 = 23\ 971{,}7$ $C_2 = 6\ 970{,}3$

$D_1 = 13{,}32$ $D_2 = -3{,}82$

For PP-R

$A_1 = -55{,}725$ $A_2 = -19{,}98$

$B_1 = -9\ 484{,}1$

$C_1 = 25\ 502{,}2$ $C_2 = 9\ 507$

$D_1 = 6{,}39$ $D_2 = -4{,}11$

For PP-RCT

$A_1 = -119{,}546$

$B_1 = -23\ 738{,}797$

$C_1 = 52\ 176{,}696$

$D_1 = 31{,}279$

The 110 °C values are determined separately using water inside and air outside the test specimen and are not derived from Equations (1) and (2).

NOTE The 110 °C line is added to Figures 1, 2, 3 and 4 for information purposes.

5 Expected strength

5.1 Extrapolation limits

The extrapolation limits (the end points of the reference lines) are based on an experimentally determined life at 110 °C and an Arrhenius equation for the temperature dependence with an activation energy of 110 kJ/mole (≈ 26 kcal/mole). This yields the values given in Table 1 for the extrapolation factor, K_x (i.e. the expected lifetime at a given temperature divided by the lifetime at 110 °C).

Table 1 — Extrapolation limits

T °C	K_x
$100 \geqslant T > 95$	2,5
$95 \geqslant T > 90$	4
$90 \geqslant T > 85$	6
$85 \geqslant T > 80$	12
$80 \geqslant T > 75$	18
$75 \geqslant T > 70$	30
$T \leqslant 70$	50

With a life 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.

For temperatures up to and including 50 °C, an extrapolation factor, K_x, of 100 is acceptable.

5.2 Graphical representation

Figures 1, 2, 3 and 4 give the reference lines corresponding to the values of the parameters given in Clause 4, to be used for demonstrating conformance to this specification, as described in Annex A.

The broken lines represent the extrapolation of the reference lines, applicable when longer failure times are obtained at 110 °C, extrapolation being permitted up to the limits given by the extrapolation factors in Table 1.

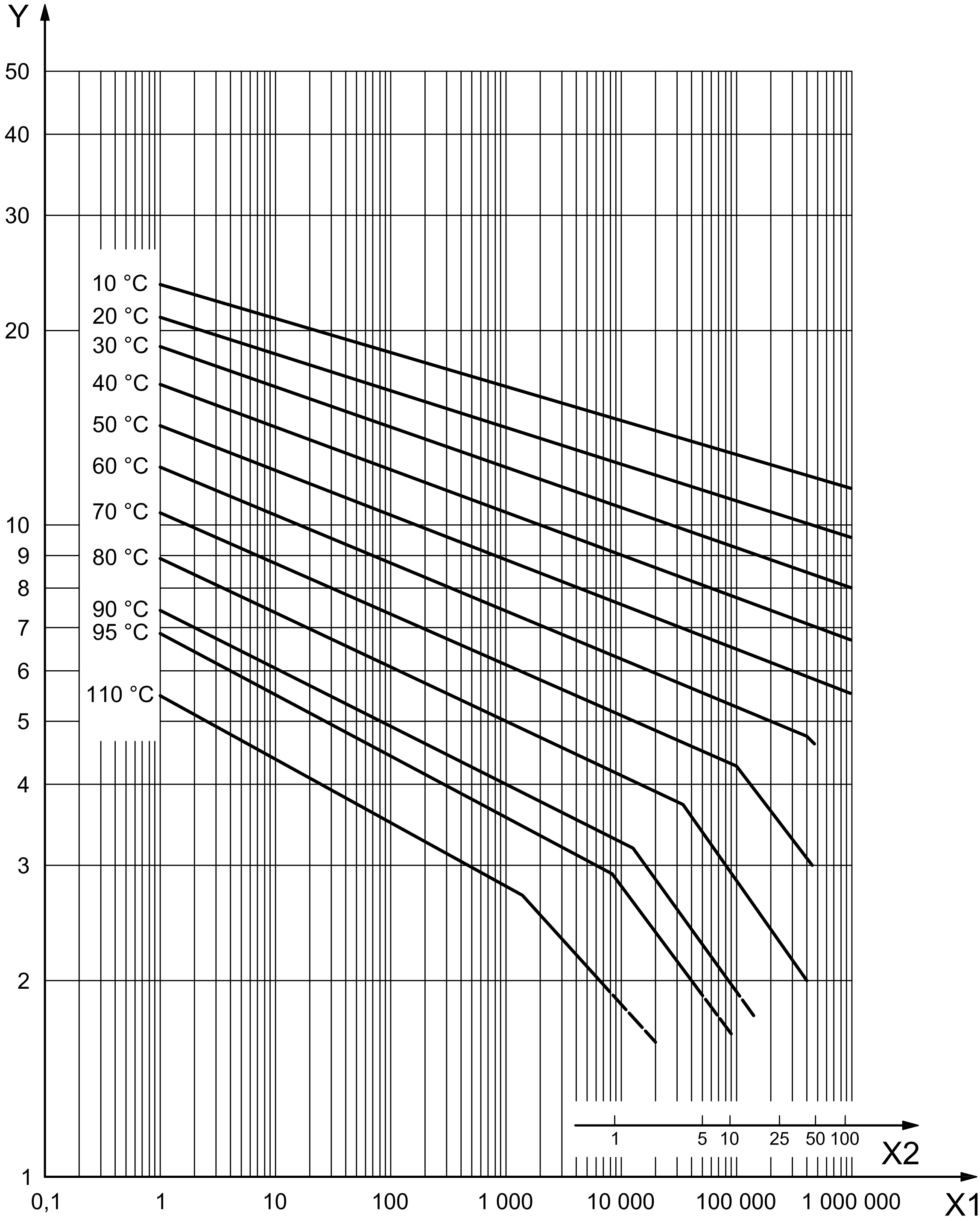
5.3 Tabulated values

The calculated hoop strength values used for various temperatures and times are given in Tables 2, 3, 4 and 5 and include no design factors.

NOTE The times at 80 °C, 90 °C and 95 °C not in parentheses in the “time” column in Tables 2, 3, 4 and 5 are based on a lifetime of one year at 110 °C. Proof of a longer lifetime at 110 °C allows a corresponding extension of the times at lower temperatures. Such values are given in parentheses in Tables 2, 3, 4 and 5.

Table 2 — Expected hoop strength values for various values of time and temperature for PP homopolymer (PP-H)

Temperature °C	Time years	Expected strength MPa
20	1 5 10 25 50 100	12,5 11,4 11,0 10,4 10,0 9,6
30	1 5 10 25 50 100	10,7 9,7 9,3 8,8 8,4 8,1
40	1 5 10 25 50 100	9,1 8,2 7,8 7,4 7,0 6,7
50	1 5 10 25 50 100	7,6 6,8 6,5 6,1 5,8 5,5
60	1 5 10 25 50	6,3 5,6 5,3 5,0 4,7
70	1 5 10 25 50	5,1 4,5 4,3 3,5 3,0
80	1 5 10 18 (25)	4,1 3,5 2,9 2,5 (2,3)
90	1 4 6 (10) (15)	3,3 2,5 2,2 (2,0) (1,8)
95	1 4 (6) (10)	2,9 2,1 (1,8) (1,6)



Key

X1 time, t_1, to fracture, in hours

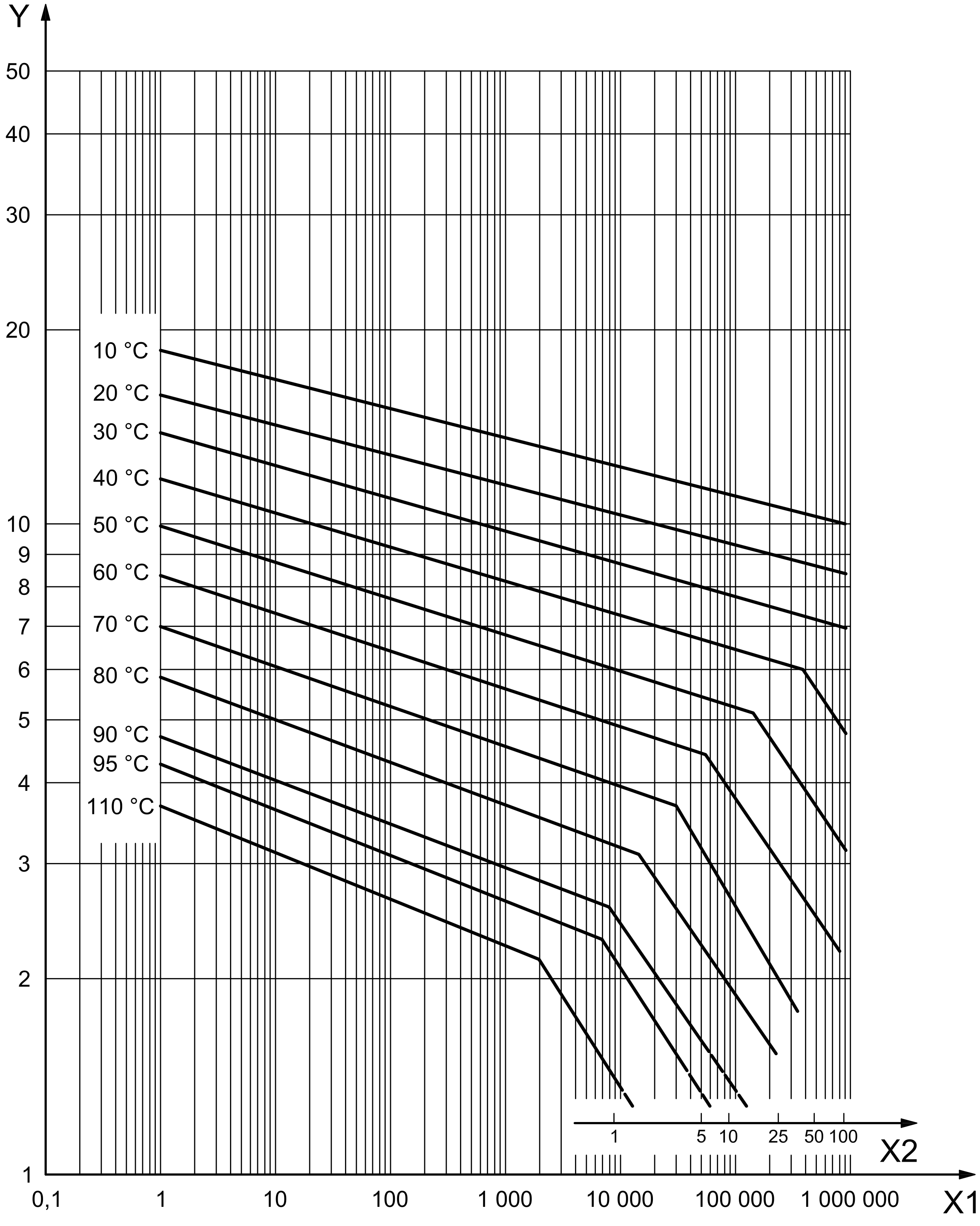
X2 time, t_2, to fracture, in years

Y hoop stress, σ, in megapascal

Figure 1 — Expected strength of PP-H pipes

Table 3 — Expected hoop strength values for various values of time and temperature for PP block copolymer (PP-B)

Temperature °C	Time years	Expected strength MPa
20	1 5 10 25 50 100	10,4 9,7 9,4 9,0 8,7 8,4
30	1 5 10 25 50 100	8,8 8,1 7,8 7,5 7,2 7,0
40	1 5 10 25 50 100	7,3 6,7 6,5 6,2 5,8 4,8
50	1 5 10 25 50 100	6,0 5,5 5,3 4,6 3,8 3,2
60	1 5 10 25 50	4,9 4,5 3,9 3,1 2,6
70	1 5 10 25 50	4,0 3,3 2,7 2,1 1,8
80	1 5 10 18 (25)	3,2 2,3 1,9 1,6 (1,5)
90	1 4 6 (10) (15)	2,5 1,7 1,6 (1,4) (1,2)
95	1 4 (6) (10)	2,1 1,5 (1,3) (1,2)



Key

X1 time, t_1, to fracture, in hours

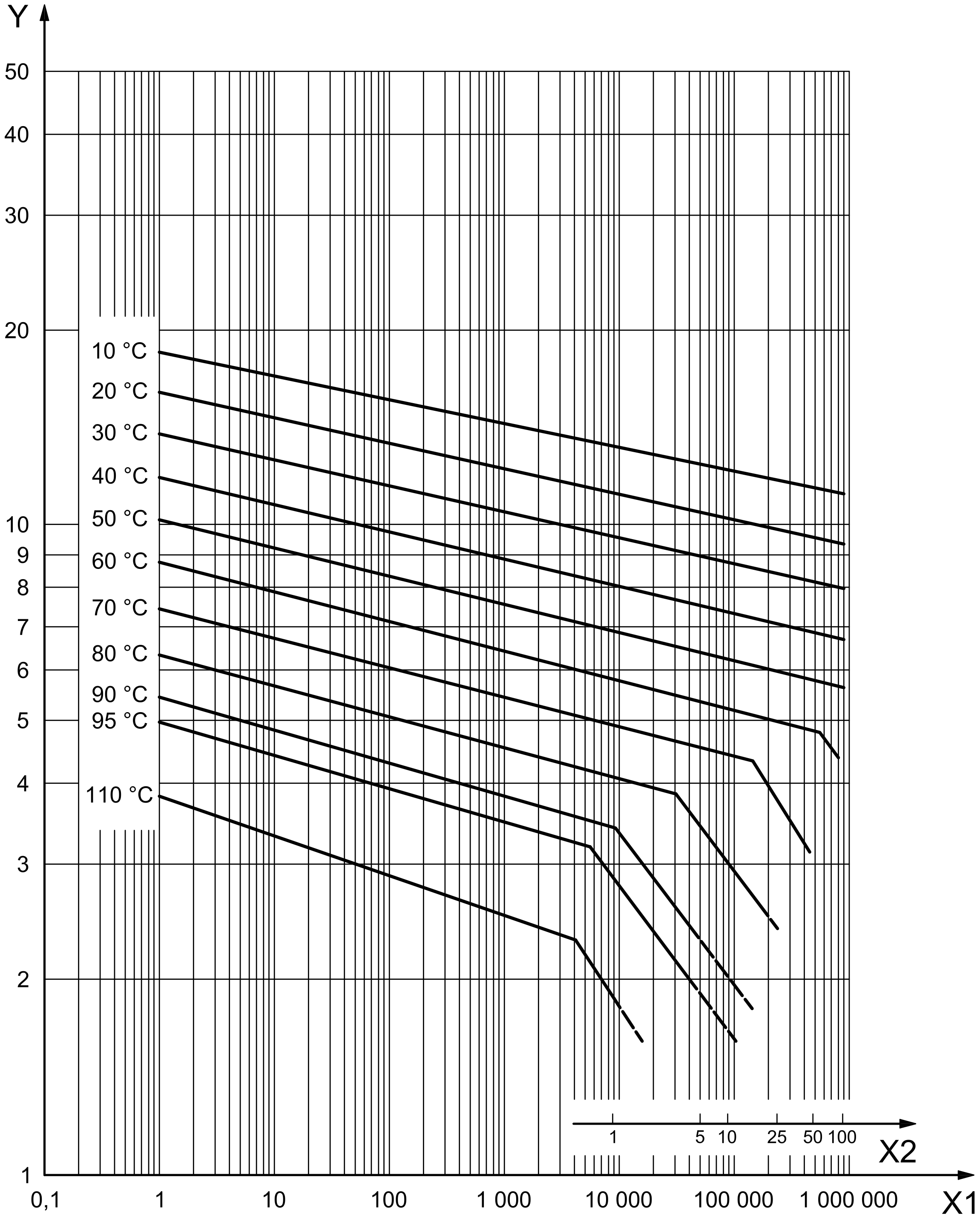
X2 time, t_2, to fracture, in years

Y hoop stress, σ, in megapascal

Figure 2 — Expected strength of PP-B pipes

Table 4 — Expected hoop strength values for various values of time and temperature for PP random copolymer (PP-R)

Temperature °C	**Time** years	**Expected strength** MPa
20	1	11,3
	5	10,6
	10	10,3
	25	10,0
	50	9,7
	100	9,4
30	1	9,6
	5	9,0
	10	8,7
	25	8,4
	50	8,2
	100	8,0
40	1	8,1
	5	7,6
	10	7,4
	25	7,1
	50	6,9
	100	6,7
50	1	6,9
	5	6,4
	10	6,2
	25	6,0
	50	5,8
	100	5,6
60	1	5,8
	5	5,4
	10	5,2
	25	5,0
	50	4,8
70	1	4,9
	5	4,5
	10	4,4
	25	3,8
	50	3,2
80	1	4,1
	5	3,6
	10	3,0
	18	2,6
	(25)	(2,4)
90	1	3,4
	4	2,5
	6	2,3
	(10)	(2,0)
	(15)	(1,8)
95	1	2,9
	4	2,1
	(6)	(1,9)
	(10)	(1,6)



Key

X1 time, t_1, to fracture, in hours

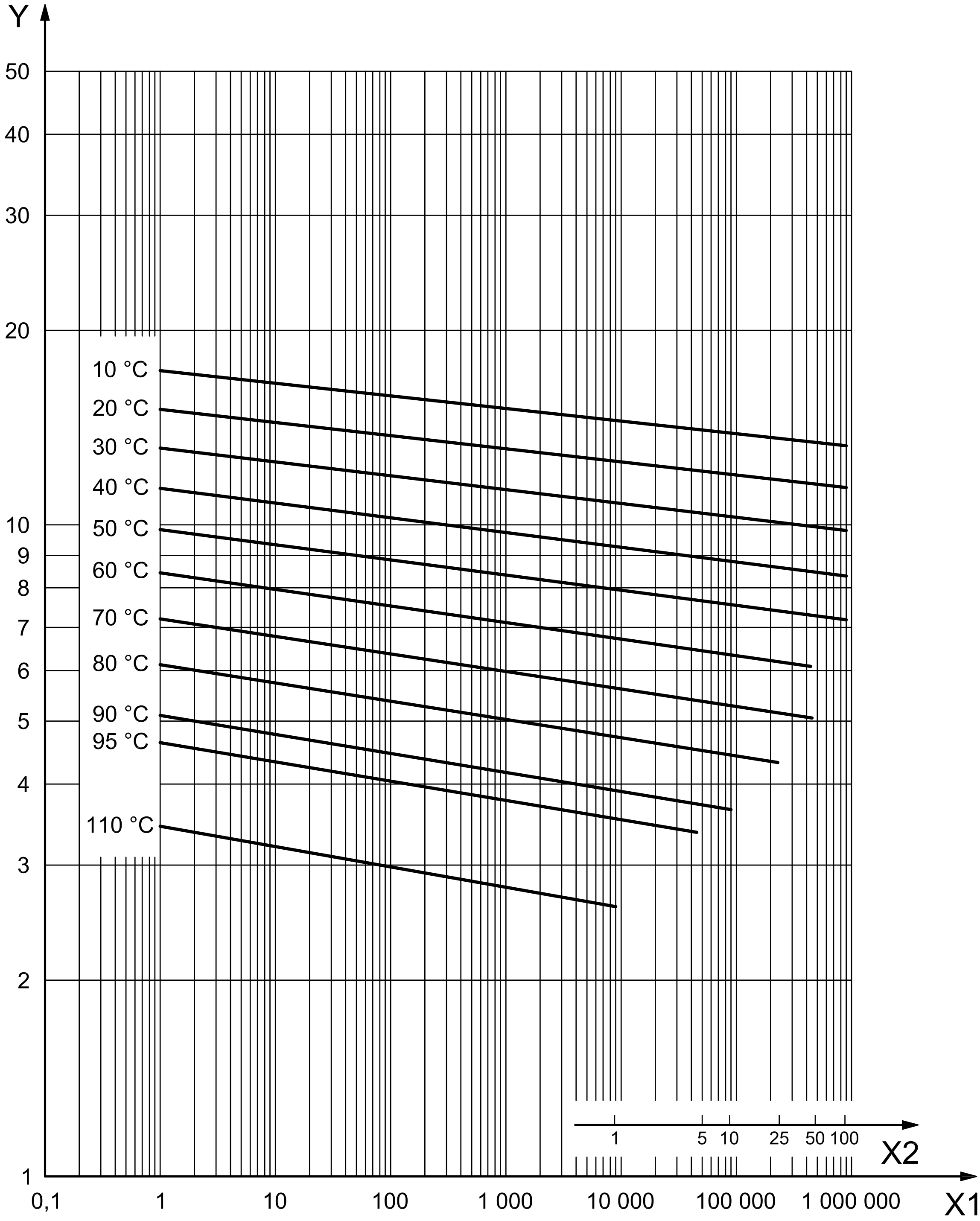
X2 time, t_2, to fracture, in years

Y hoop stress, σ, in megapascal

Figure 3 — Expected strength of PP-R pipes

Table 5 — Expected hoop strength values for various values of time and temperature for PP random copolymer with modified crystallinity (PP-RCT)

Temperature °C	Time years	Expected strength MPa
20	1 5 10 25 50 100	12,4 12,0 11,9 11,7 11,5 11,3
30	1 5 10 25 50 100	10,8 10,4 10,2 10,0 9,9 9,8
40	1 5 10 25 50 100	9,3 8,9 8,8 8,6 8,5 8,3
50	1 5 10 25 50 100	7,9 7,6 7,5 7,3 7,2 7,1
60	1 5 10 25 50	6,7 6,4 6,3 6,2 6,1
70	1 5 10 25 50	5,6 5,4 5,3 5,2 5,1
80	1 5 10 18 (25)	4,7 4,5 4,4 4,3 (4,3)
90	1 4 6 (10) (15)	3,1 3,7 3,7 (3,6) (3,6)
95	1 4 (6) (10)	3,5 3,4 (3,3) (3,3)



Key

X1 time, t_1, to fracture, in hours

X2 time, t_2, to fracture, in years

Y hoop stress, σ, in megapascal

Figure 4 — Expected strength of PP-RCT pipes

Annex A
(normative)

Demonstrating conformance of pipes to the reference lines

At each of the following temperatures, test pieces shall be tested at various hoop stresses such that, at each of the temperatures given, at least three failure times fall into each of the following time intervals:

Temperatures: 20 °C; 60 °C to 82 °C; 95 °C.

Time intervals:

— 10 h to 100 h;

— 100 h to 1 000 h;

— 1 000 h to 8 760 h;

— $>$ 8 760 h

In the case of tests lasting longer than 8 760 h, any test time after this value may be considered as the failure time.

Testing shall be carried out in accordance with ISO 1167-1 and ISO 1167-2.

Conformance to the reference lines shall be demonstrated by plotting the individual experimental results on the graph. At least 97,5 % of them shall lie on or above the reference lines given in either Figure 1, 2, 3 or 4, as appropriate.

NOTE 82 °C is equivalent to 180 °F, commonly used as a test temperature in ASTM standards.

Bibliography

[1] ISO 1043-1, *Plastics — Symbols and abbreviated terms — Part 1: Basic polymers and their special characteristics*

ICS 23.040.20

Price based on 13 pages