

# Polyethylene of raised temperature resistance (PE-RT) pipes — Effect of time and temperature on the expected strength

ICS 23.040.20

## National foreword

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The UK participation in its preparation was entrusted to Technical Committee PRI/88/4, Test methods.

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 28 February 2009

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ISBN 978 0 580 57516 7

### Amendments/corrigenda issued since publication

Date	Comments

# INTERNATIONAL STANDARD

**ISO**  
**24033**

Second edition  
2009-01-15

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## **Polyethylene of raised temperature resistance (PE-RT) pipes — Effect of time and temperature on the expected strength**

*Tubes en polyéthylène de meilleure résistance à la température  
(PE-RT) — Influence du temps et de la température sur la résistance  
espérée*



Reference number  
ISO 24033:2009(E)

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Published in Switzerland

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ISO 24033 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 second edition cancels and replaces the first edition (ISO 24033:2006), which is extended to cover PE-RT materials, type II, which have a higher hoop stress performance at higher temperatures than type I. The first edition dealt only with PE-RT materials, currently designated type I.

## **Introduction**

An increasing number of types of polyethylene (PE) polymers, made in a variety of processes, is on the market for different applications in plastic piping and ducting systems. Many applications have their own system standard that defines the properties and requirements for the pipes and fittings used.

The types of PE suitable for use in hot and cold water systems are basically different from those for applications at ambient temperatures such as in water supply, sewage and drainage, and gaseous fuels.

Therefore, it makes sense to differentiate those PE having raised temperature-resistance by terming them "PE-RT" (for polyethylene of raised temperature)<sup>1)</sup>.

See the foreword for details of PE-RT materials, types I and II.

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1) Abbreviated term based on the provisions of, and guidance for preparing new abbreviated terms for, basic polymers, mixtures of polymers, and related terms given in ISO 1043-1<sup>[1]</sup>.

# Polyethylene of raised temperature resistance (PE-RT) pipes — Effect of time and temperature on the expected strength

## 1 Scope

This International Standard specifies 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:

- a) polyethylene of raised temperature resistance (PE-RT) type I;
- b) PE-RT type II.

## 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 line

(PE-RT pipes) generic description of the minimum long-term hydrostatic strength to be expected from a particular polymer

NOTE 1 A reference line is not to be considered as characteristic of a specific grade or of material from a specific supplier.

NOTE 2 A line is described by a mathematical equation, which permits interpolation and extrapolation in an unambiguous way at various temperatures.

NOTE 3 The reference lines for PE-RT have been agreed by a group of experts after considering experimental data, and have been accepted by the relevant ISO technical committees.

## 4 Basic equations

The reference lines for PE-RT type I temperatures between 20 °C and 95 °C are described by Equations (1) and (2):

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

$$\lg t = A_2 + (B_2/T) \lg \sigma + C_2/T + D_2 \lg \sigma \quad (2)$$

where

$t$  is the time, in hours;

$T$  is the temperature, in kelvin;

$\sigma$  is the hoop stress, in megapascals;

$$A_1 = -190,481 \quad A_2 = -23,795 4$$

$$B_1 = -58 219,035 \quad B_2 = -1 723,318$$

$$C_1 = 78 763,07 \quad C_2 = 11 150,56$$

$$D_1 = 119,877 \quad D_2 = 0$$

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

The reference lines for PE-RT type II for temperatures between 20 °C and 110 °C are described by Equation (3):

$$\lg t = A + (B/T) \lg \sigma + C/T + D \lg \sigma \quad (3)$$

where

$$A = -219$$

$$B = -62 600,752$$

$$C = 90 635,353$$

$$D = 126,387$$

NOTE ISO 9080<sup>[2]</sup> quotes equations in a different sequence where  $C_1 = A$ ,  $C_2 = C$ ,  $C_3 = D$  and  $C_4 = B$ .

## 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/mol ( $\approx 26$  kcal/mol). 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 factors,  $K_x$**

Temperature $T$ °C	Extrapolation factor $K_x$
$100 \geq T > 95$	2,5
$95 \geq T > 90$	4
$90 \geq T > 85$	6
$85 \geq T > 80$	12
$80 \geq T > 75$	18
$75 \geq T > 70$	30
$T \leq 70$	50

With a life of 1 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

Figure 1 and Figure 2 contain the reference lines corresponding to the values of the parameters given in Clause 4, to be used for demonstrating conformity to this specification, as specified 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.

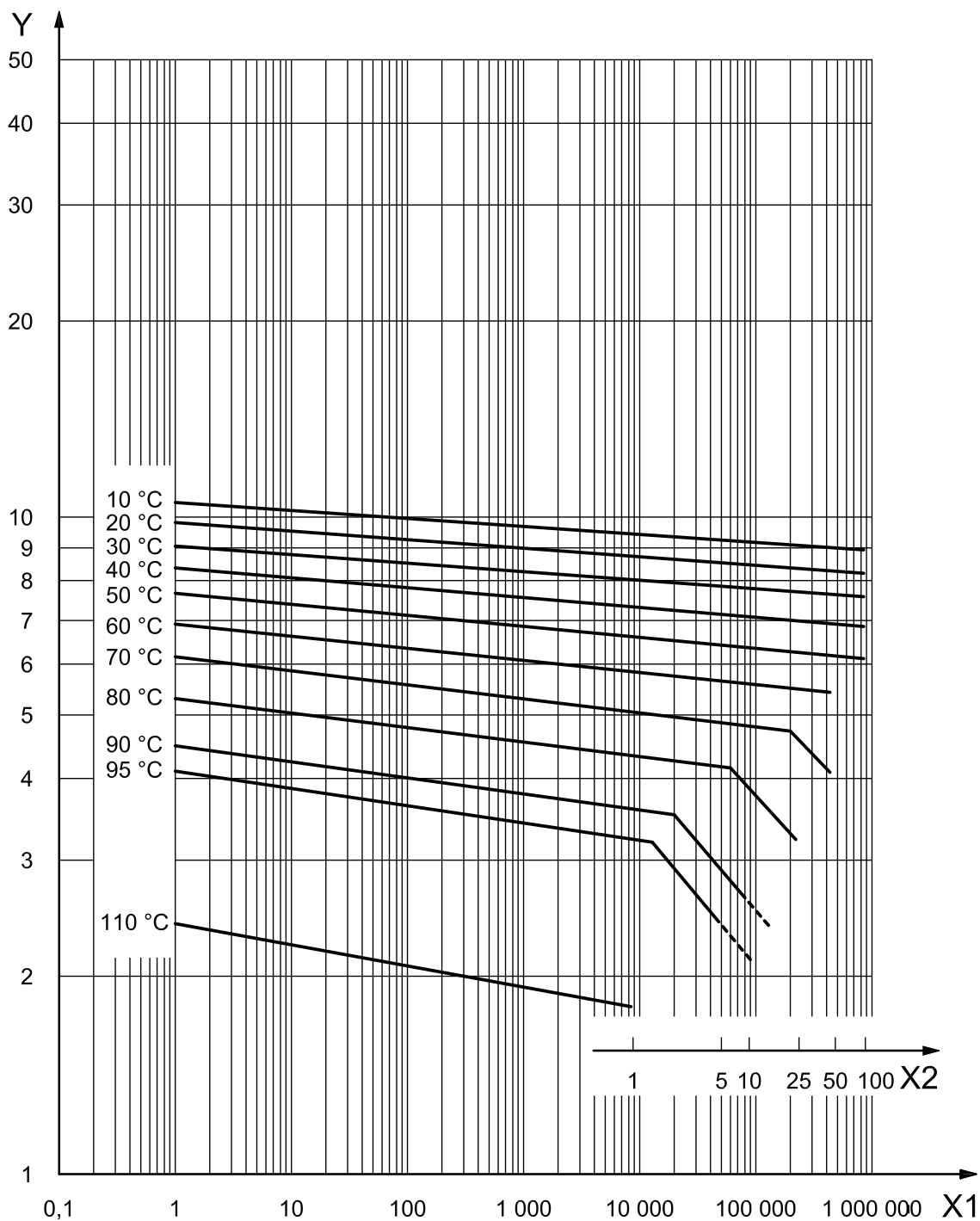
## 5.3 Tabulated values

The calculated hoop strength values to be used for various temperatures and times are given in Table 2 and include no safety factors or design factors.

The times at 80 °C, 90 °C and 95 °C not in brackets in the “Time” column in Table 2 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 brackets in Table 2.

**Table 2 — Expected hoop strength values for various values of time and temperature for PE-RT**

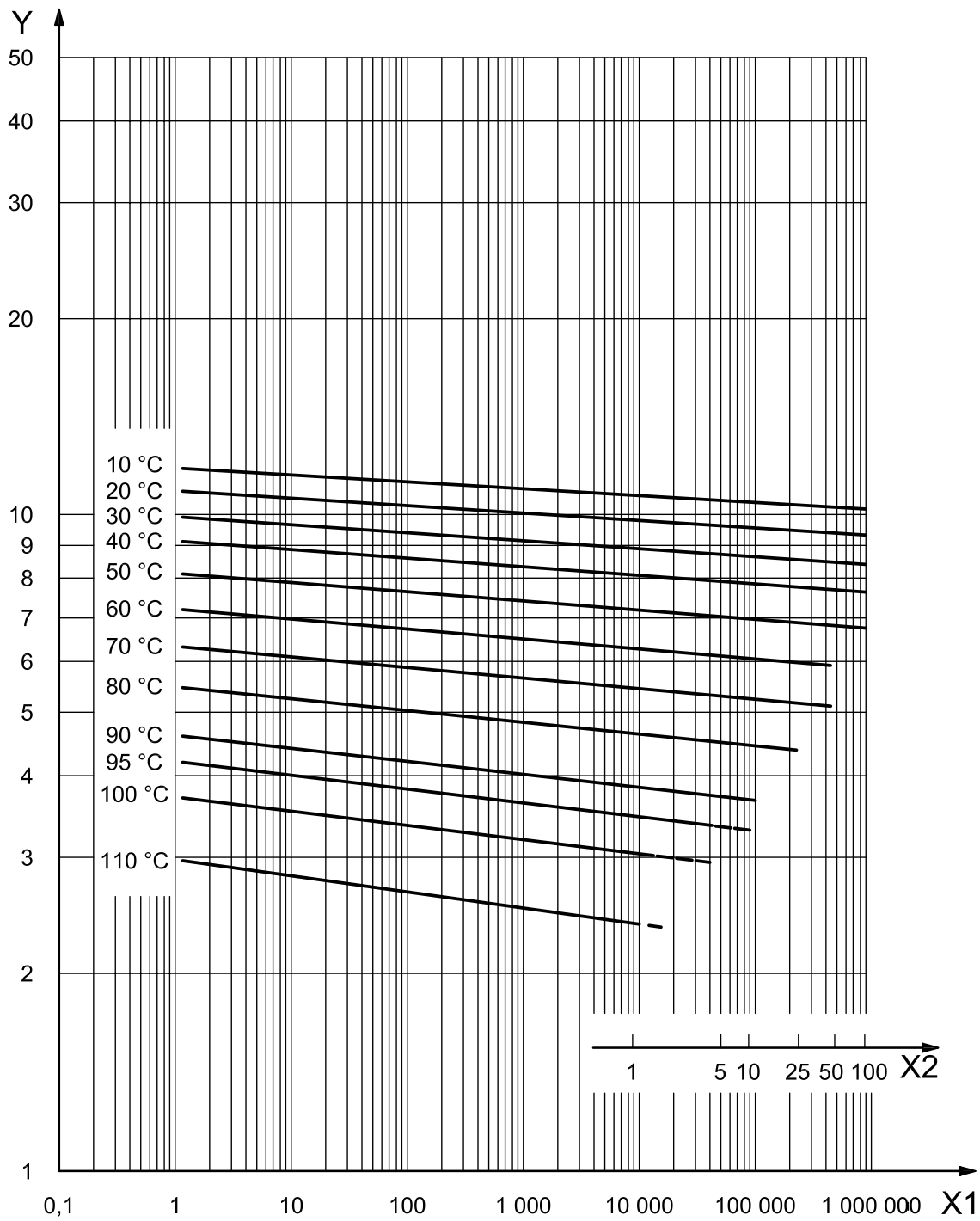
Temperature °C	Time a	Expected strength MPa		Temperature °C	Time a	Expected strength MPa		
		Type I	Type II			Type I	Type II	
20	1	8,8	9,8	70	1	5,1	5,4	
	5	8,6	9,6		5	4,8	5,3	
	10	8,5	9,5		10	4,8	5,2	
	25	8,4	9,4		25	4,7	5,1	
	50	8,3	9,3		50	4,1	5,1	
	100	8,3	9,3					
30	1	8,1	8,9	80	1	4,3	4,6	
	5	7,9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



**Key**

- $X_1$   $t_1$  time to fracture, h
- $X_2$   $t_2$  time to fracture, a
- $Y$   $\sigma$  hoop stress, MPa

**Figure 1 — Expected strength of PE-RT type I pipes**



**Key**

- $X_1$   $t_1$  time to fracture, h
- $X_2$   $t_2$  time to fracture, a
- $Y$   $\sigma$  hoop stress, MPa

**Figure 2 — Expected strength of PE-RT type II pipes**

## **Annex A** (normative)

### **Demonstrating conformity of pipes to reference lines**

At each of the following temperatures, specimens shall be tested at each of the temperatures given; at least three failure times shall fall in each of the following time intervals:

Temperatures: 20 °C, 60 °C to 82 °C, 95 °C and, for type II, 110 °C

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

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.

Conformity to 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 or Figure 2.

For PE-RT type II materials, these experimental results shall not give any brittle failures indicating the presence of a knee at any temperature up to 110 °C within 8 760 h.

## Bibliography

- [1] ISO 1043-1, *Plastics — Symbols and abbreviated terms — Part 1: Basic polymers and their special characteristics*
- [2] ISO 9080, *Plastics piping and ducting systems — Determination of the long-term hydrostatic strength of thermoplastics materials in pipe form by extrapolation*









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