SLOVENSKI STANDARD
SIST EN 1778:2000

01-december-2000

Značilne vrednosti zvarjenih konstrukcij iz plastomerov - Določanje dovoljenih obremenitev in modulov za načrtovanje opreme iz plastomerov

Characteristic values for welded thermoplastics constructions - Determination of allowable stresses and moduli for design of thermoplastics equipment

Charakteristische Kennwerte für geschweißte Thermoplast-Konstruktionen - Bestimmung der zulässigen Spannungen und Moduli für die Berechnung von Thermoplast-Bauteilen

Valeurs caractéristiques des constructions thermoplastiques soudées - Détermination des contraintes admissibles et des modules pour la conception du matériel thermoplastique

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Characteristic values for welded thermoplastics constructions - Determination of allowable stresses and moduli for design of thermoplastics equipment

Valeurs caractéristiques des constructions thermoplastiques soudées - Détermination des contraintes admissibles et des modules pour la conception du matériel thermoplastique

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This European Standard has been prepared by Technical Committee CEN/TC 249 "Plastics", the secretariat of which is held by IBN.

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of an identical text or by endorsement, at the latest by April 2000, and conflicting national standards shall be withdrawn at the latest by April 2000.

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, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.
This European Standard has been prepared by Technical Committee CEN/TC 249 "Plastics", the secretariat of which is held by IBN.

Annex A (normative) contains the neccessary creep strength diagrams, the creep modulus diagrams as well as the reduction factors. In Annex B (informative) explanations and calculation examples are included.

Introduction

Because most components are subjected to multiaxial loading, the creep strength diagrams for pipes are taken as a basis for the allowable design stresses. The diagrams have been confirmed by results from many years of measurements and by experience (see [1]).

Extrapolation of creep strength curves to higher temperatures is not permitted. The use of the creep strength curves for dumbbell tensile test pieces is not correct practice because of the reasons mentioned above.

A large number of reduction factors A_2 for the action of the medium taking into account material, stress and temperature have been included. The reduction factors A_2 for the action of the medium and the weld factors f_l were determined independently of each other.

Investigations established the validity of the multiplicative connection between the weld factor f_l and reduction factor A_{2K} (reciprocal value of factor for resistance to chemicals $f_{cR\sigma}$ (see [2] and [3]).

1 Scope

This standard specifies a methodology for determination of the characteristic values necessary for the design of welded constructions for example vessels and tanks, ventilation ducting, containers and apparatus.

It is assumed that due regard is paid to the standards and Codes of Practice listed in clause 2 as far as the choice of materials and their processing are concerned. The data is applicable for static loading.

The relevant EN-Standards or ISO-Standards are applicable to the design calculations, dimensions, construction and testing of the various structures.

This standard applies to a wide range of thermoplastic materials, for example: Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC) and Polyvinylidene Fluoride (PVDF).

Annex A gives minimum properties for specific grades of these materials. The use of other thermoplastics is permitted, provided that their creep properties exceed the minimum values given in annex A for the known materials.

Properties should be determined in accordance with the relevant ISO and EN standards.

This allows the introduction of thermoplastics with improved properties as appropriate data becomes available.

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 standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

prEN 12202
Plastics piping systems for hot and cold water – Polypropylene (PP)

ISO 899-2
Plastics – Determination of creep behaviour – Part 2: Flexural creep by three-point-loading

ISO 1167

Thermoplastics pipes for the conveyance of fluids – Resistance to internal pressure – Test method

ISO 8584-1
Thermoplastics pipes for industrial applications under pressure – Determination of the chemical resistance factor and of the basic stress – Part 1: Polyolefin pipes

ISO/TR 8584-2
Thermoplastics pipes for industrial applications under pressure – Determination of the chemical resistance factor and of the basic stress – Part 2: Pipes made of halogenated polymers

ISO/TR 9080
Thermoplastics pipes for the transport of fluids – Methods of extrapolation of hydrostatic stress rupture data to determine the long-term hydrostatic strength of thermoplastics pipe materials

3 Definitions, symbols and abbreviations

K	Creep strength at the design temperature and lifetime in newtons per square millimetres
S	Factor of safety
A_1	Reduction factor to take account of the effect of specific strength
A_{2K}	Reduction factor taking into account the effect of surrounding medium (reciprocal value of resistance factor $f_{cR\sigma}$)
$f_{cR\sigma}$	Stress dependent chemical resistance factor
A_{2E}	Reduction factor taking into account the effect of surrounding medium on the modulus of elasticity
E_c	Creep modulus at the design condition (temperature, stress, time) in newtons per square millimetres
$E_{c(al.),St}$	Allowable creep modulus at the design condition for stability (temperature, stress, time, medium, safety factor) in newtons per square millimetres
$E_{c(al.),D}$	Allowable creep modulus at the design condition for deformation (temperature, stress, time, medium) in newtons per square millimetres
T	Design temperature in degrees Centigrade
f_s	Short-term weld factor
f_l	Long-term weld factor
$\sigma_{ef.}$	Effective stress in newtons per square millimetres
$\sigma_{al.}$	Allowable stress at the design condition in newtons per square millimetres
n	Number of fractional loadings
$a_1, a_2 .. a_n$	Proportion of total loading time at each design condition expressed as per cent
$t_1, t_2 .. t_n$	Service life at the individual working conditions (constant pressure and temperature) taking into account reduction, joint and safety factors
t_x	Design life with or without intermittent loading
σ	Principal stress in newtons per square millimetres

4 Determination of allowable stresses and moduli

4.1 General

Design calculations for components are based on long-term values. Depending on the nature of the loading, there are generally three criteria:

1) Stress;

2) Deformation (e. g. deflection);

3) Stability (e. g. short or long-term buckling).

Stress design calculations shall be made with reference to creep strength, as multiaxial states of stresses are present in most cases. The maximum principal stress shall not exceed the allowable creep strength.

The allowable values are derived by using reduction factors (see clause 5), a joint factor (see clause 6) and factors of safety (see clause 7) from the characteristic values of the material.

In terms of deformation and stability, the critical design parameter is creep modulus. This can be obtained from creep modulus diagrams depending on time, temperature and stress. In the event of stability problems, allowance shall be made for an appropriate factor of safety (see clause 7).

4.1.1 Design calculation according to strength

The allowable stress is obtained from the creep strength, reduction factors, joint factor and the factor of safety.

$$\sigma_{al.} = \frac{K \cdot f_1}{A_1 \cdot A_{2K} \cdot S} \qquad (1)$$

The creep strength K to be used as a basis for design calculations can be obtained for a stated working time and working temperature from the diagrams in A.1.1 or determined in accordance with ISO/TR 9080.

4.1.1.1 Creep strength curves

The creep strength curves show strength as a function of time and temperature. They were determined from long-term internal pressure tests on pipe specimens filled with water and represent minimum values in accordance with ISO 1167.

The minimum creep strength values for other semi-finished products shall be equal to or higher than those determined for pipes.

Other materials than those specified in figures A.1 to A.12 can be taken into consideration if appropriately demonstrable tests are available in accordance with ISO/TR 9080.

4.1.1.2 Intermittent loading

For applications where regularly alternating (intermittent) loading occurs, as an approximation, the theory of linear accumulation of damage can be taken as a basis (Miner's rule) (see [4]). With this rule, the design life is determined in relation to the time spent at each design condition, taking into account the appropriate reduction, joint and safety factors.

See the example in B.2.2.

According to this rule:

$$\sum_{i=1}^{n} \frac{a_1 \cdot t_x}{100 \cdot t_i} = 1 \qquad (2)$$

For two fractional loadings:

$$\frac{a_1 \cdot t_x}{100 \cdot t_1} + \frac{a_2 \cdot t_x}{100 \cdot t_2} = 1 \qquad (3)$$

or

$$t_x = \frac{100 \cdot t_1 \cdot t_2}{a_1 \cdot t_2 + a_2 \cdot t_1} \qquad (4)$$

4.1.2 Design calculation according to stability and bending

The creep modulus (E_c) is used in the case of thermoplastics instead of the modulus of elasticity used in theoretical mechanics. The creep modulus is dependent on time, stress and temperature. It can also depend on the medium (particularly in the case of substances which have a swelling effect; characteristic values for this are still to be determined). For the materials used, the creep modulus can be obtained as a function of the stated parameters from the creep modulus curves (figures A.13 to A.27) or in accordance with ISO 899-2.

The creep modulus is used:

– in stability calculations:

$$E_{c(al.)St} = \frac{E_c}{A_{2E} \cdot S} \qquad (5)$$

– to determine deformations:

$$E_{c(al.)D} = \frac{E_c}{A_{2E}} \qquad (6)$$

5 Reduction factors

5.1 Reduction factor A_2 (see [5] and [6])

5.1.1 Reduction factor A_{2K}

The reduction factor A_{2K} quantifies the effect of the working medium on the creep strength of thermoplastic materials.

The reduction factor A_{2K} is the reciprocal of the stress dependent resistance factor $f_{cR\sigma}$ ($f_{cR\sigma}$ is determined according to ISO 8584-1 or ISO/TR 8584-2).

A.1.3 contains the reduction factors for a wide range of chemicals.

Other media than those specified in A.1.3 can be taken into consideration, if appropriately demonstrable experience with the same or similar liquids, or the same material of construction and/or tests are available in accordance with ISO 8584-1 or ISO/TR 8584-2.

5.1.2 Reduction factor A_{2E}

The reduction factor A_{2E} except for mediums causing swelling is A_{2E} = 1.

For mediums which cause swelling (see footnote 9 of A.1.3), A_{2E} shall be determined by appropriate tests.

5.2 Reduction factor A_1

(As a function of temperature and impact strength for separate materials)

This factor takes into account the strength of the materials as a function of temperature and is therefore derived from impact strength values. Table 1 contains values for A_1. The values for other materials shall be established in accordance with annex B.

Table 1: Reduction factors A_1

Material		Working temperature			
		-10 °C	20 °C	40 °C	60 °C
PE-HD	high density	1,2	1	1	1
PP-H	homopolymer	1,8	1,3	1	1
PP-B	block - copolymer	1,2	1,0	1	1
PP-R	random - copolymer	1,2	1	1	1
PVC-NI	normal impact strength (PVC-U)	1,8	1,6	1,4	1,1
PVC-RI	raised impact strength (PVC-U)	1,6	1,3	1	1
PVC-C	chlorinated	1,9	1,8	1,6	1,2
PVDF-H	homopolymer	1,6	1,4	1,2	1

Further explanation can be found in B.1.

6 Joint factor (weld factor) (see [7] and [8] of annex C)

The values for this factor are stated only for welded joints. Weld factors (f_s and f_l) are indicated in Table 2 for several materials.

The values stated assume complete mastery of the relevant welding processes and that the work is carried out by qualified, tested personnel.

The short-term factors are applicable to loading times up to one hour. Only the long-term factors should therefore be used for component design calculations. The values for other materials and/or joining processes are to be established individually.

Table 2: Short-term (f_s) and long-term (f_l) weld factors

Process		Material				
		PE-HD	PP*)	PVC-U**)	PVC-C	PVDF
Heated-tool butt welding HS	f_s	0,9	0,9	0,9	0,8	0,9
	f_l	0,8	0,8	0,6	0,6	0,6
Hot gas extrusion welding WE	f_s	0,8	0,8	-	-	-
	f_l	0,6	0,6	-	-	-
Hot gas welding W	f_s	0,8	0,8	0,8	0,7	0,8
	f_l	0,4	0,4	0,4	0,4	0,4

*) PP-H, PP-B, PP-R

**) PVC-NI, PVC-RI

NOTE: The weld factors in the table will be re-examined by CEN/TC 249/SC 5/WG 2 and will be corrected later if necessary.

7 Factor of safety

The factor of safety S denotes that, when the component is used in accordance with the specifications, at any time during its design life, this margin of safety is ensured with respect to the creep strength of the material.

The factor of safety therefore also takes into account simplifications made in load assumptions and during design assessment or experimental verification of strength.

In the case where no other CEN standards apply and state the safety coefficient to be used, then the values listed in table 3 are to be taken into account.

The factors of safety in table 3 are stated for two loading cases depending on the potential hazard posed by the containers and apparatus. In each individual case, the design engineer shall decide which classification is appropriate for the component to be designed.

If applicable, intermediate values can be appropriate.

Table 3: Factors of safety

Type of loading	S
Loading case 1 Static load at room temperature and constant conditions. No possible danger to persons, objects and environment in the event of failure	1,3
Loading case 2 Loading under alternating conditions (e. g. temperature, filling level). Possible danger to persons, objects and environment in the event of failure.	2,0

For stability calculations as in 4.1.2, use a minimum factor of safety of 2 (see [9]).

Allowance shall be made separately for the effects of eccentricity and out-of-roundness (see [10]).

Annex A (normative) Creep strength diagrams, creep modulus diagrams and reduction factors

A.1.1 Creep strength diagrams (Figures A.1 to A.12)

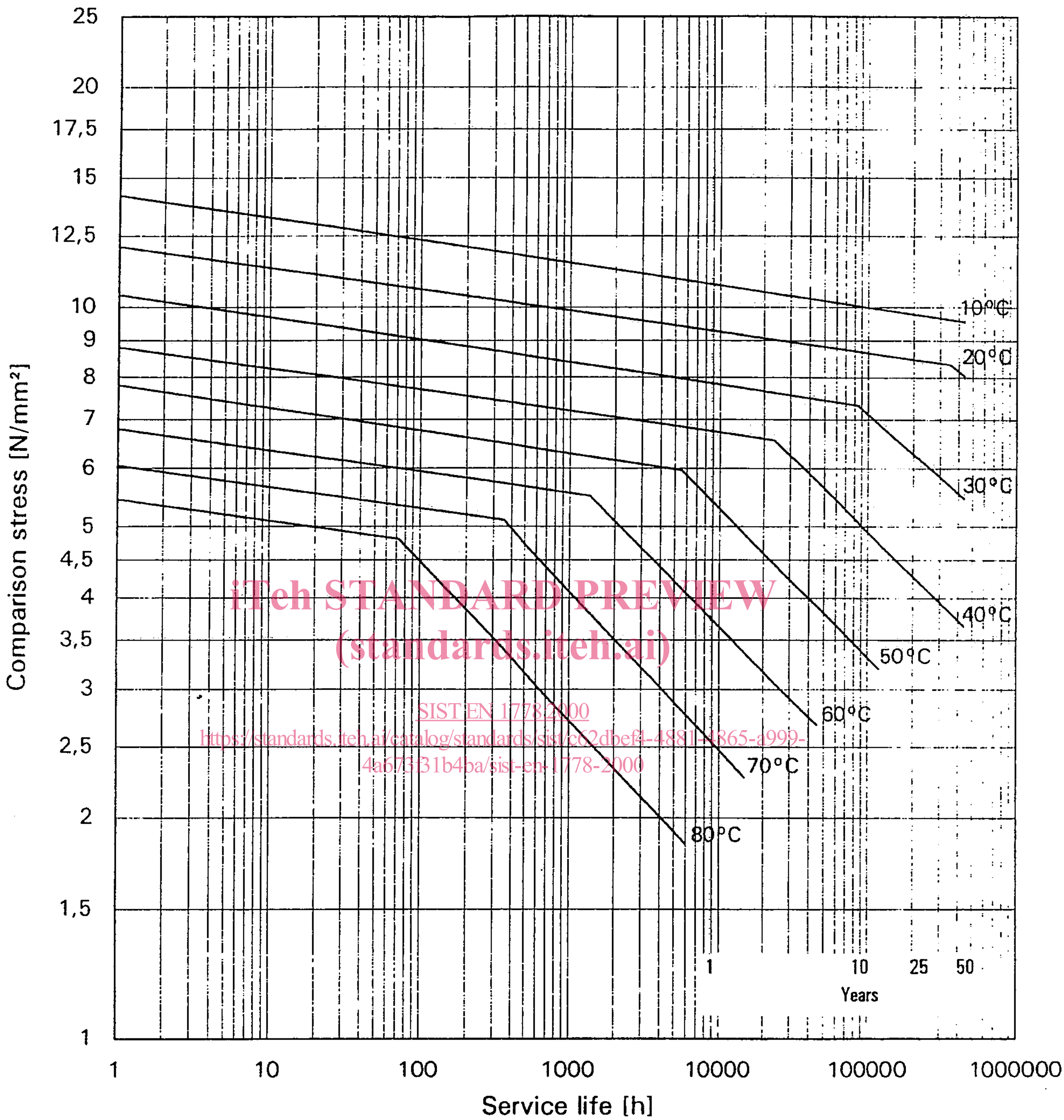

Figure A.1: Creep strength of pipes made from high density polyethylene (PE-HD according to ISO 8584-1)

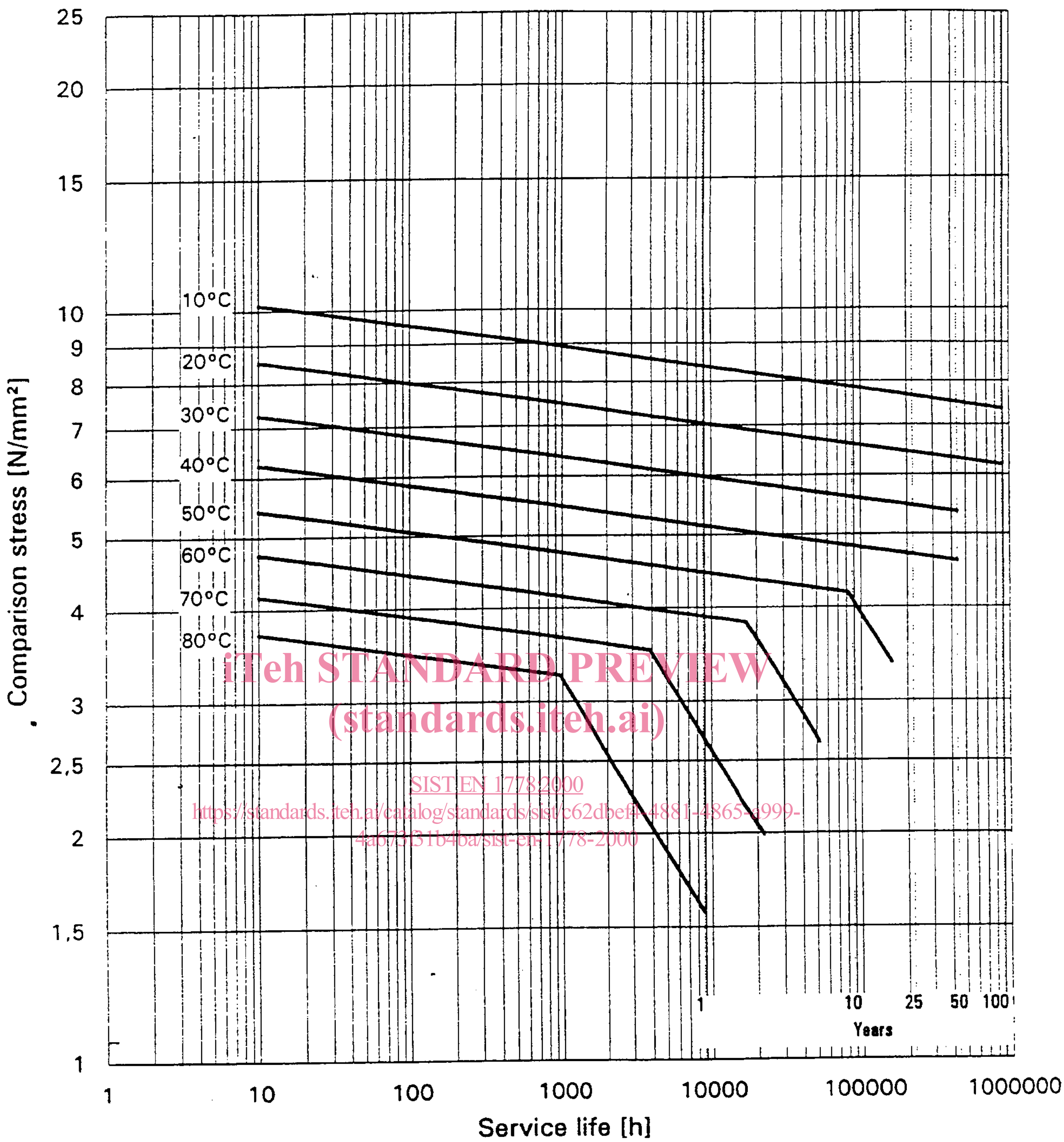

Figure A.2: Creep strength of pipes made from polyethylene (PE 63)

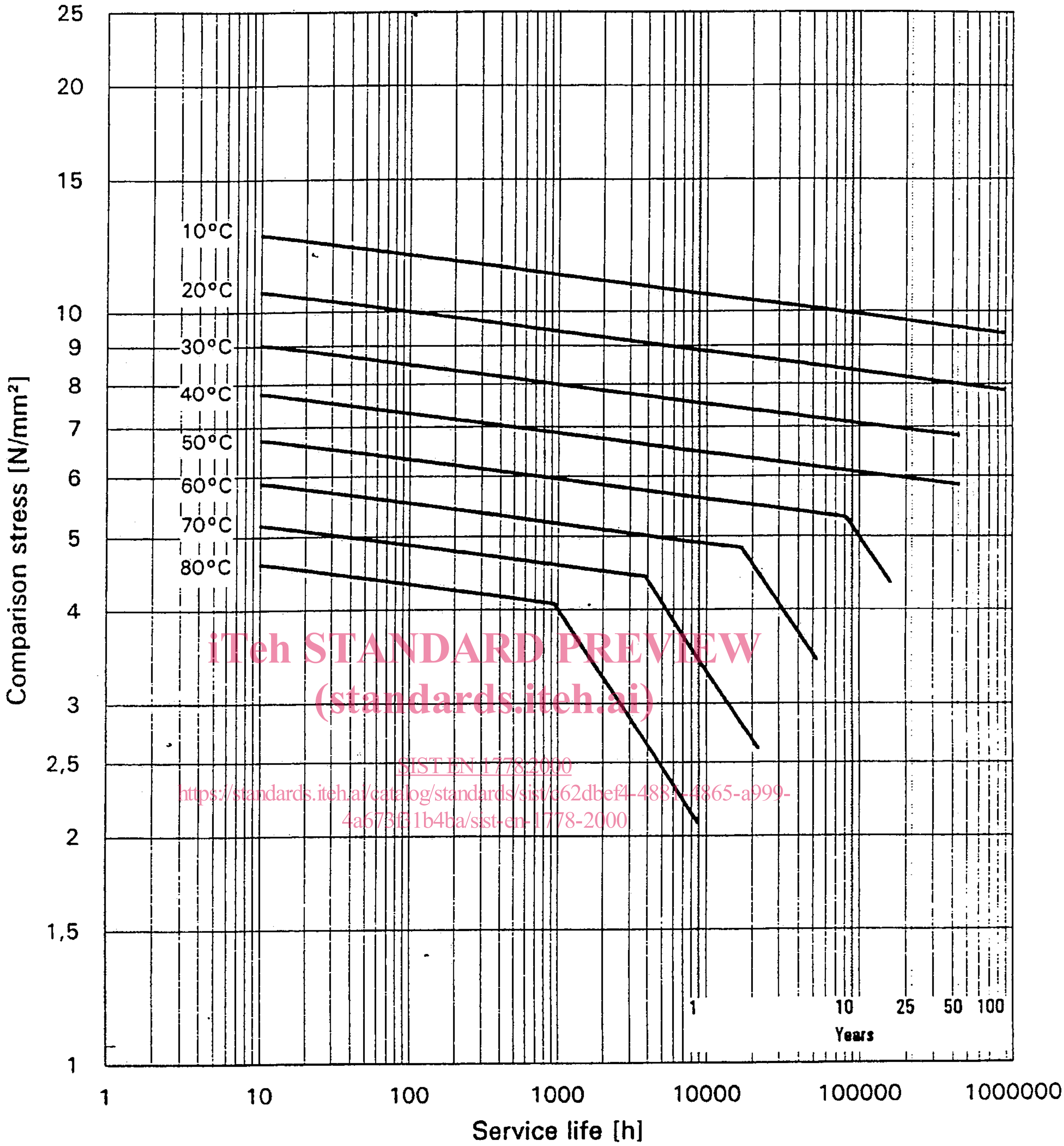

Figure A.3: Creep strength of pipes made from polyethylene (PE 80)

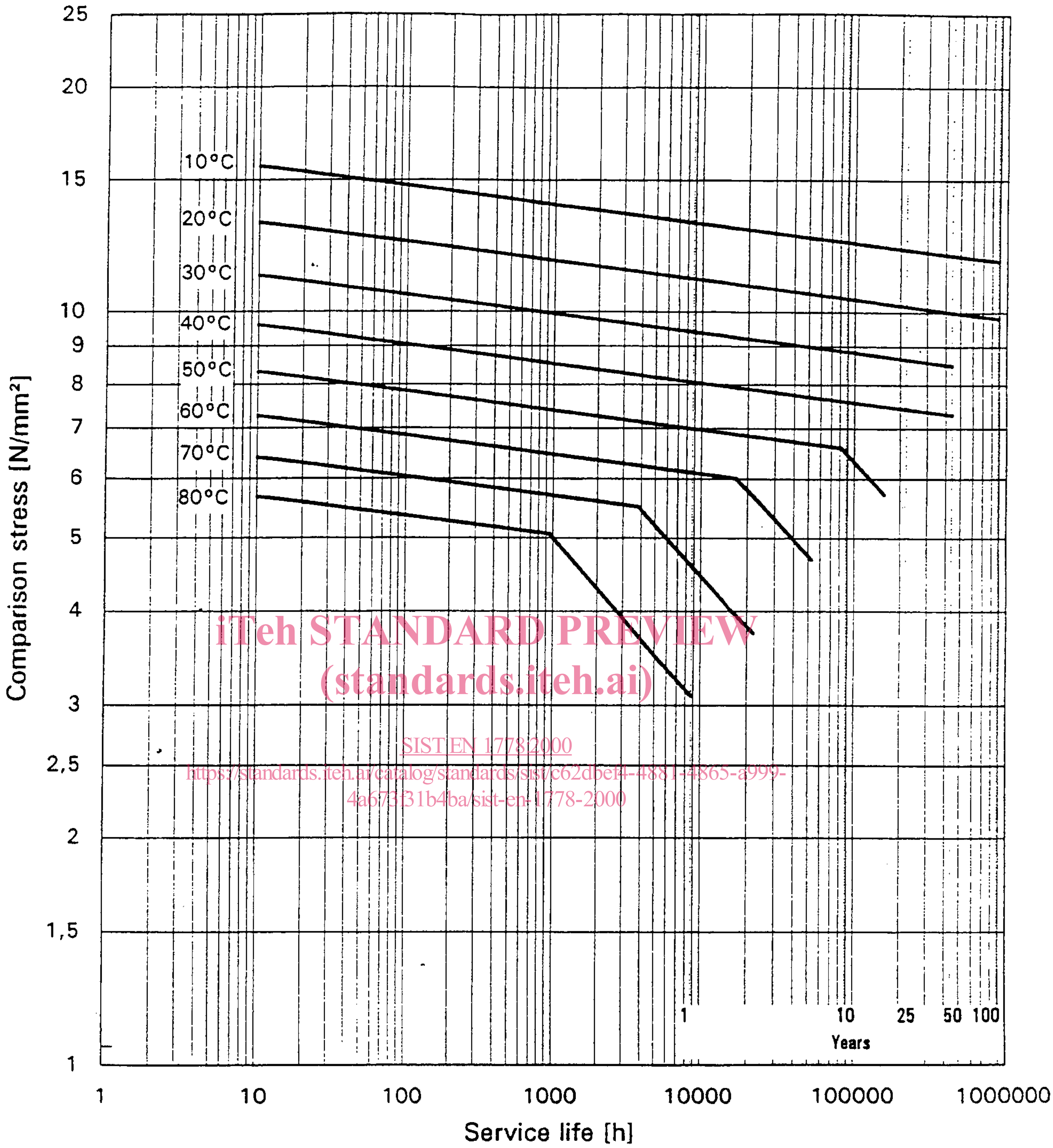

Figure A.4: Creep strength of pipes made from polyethylene (PE 100)

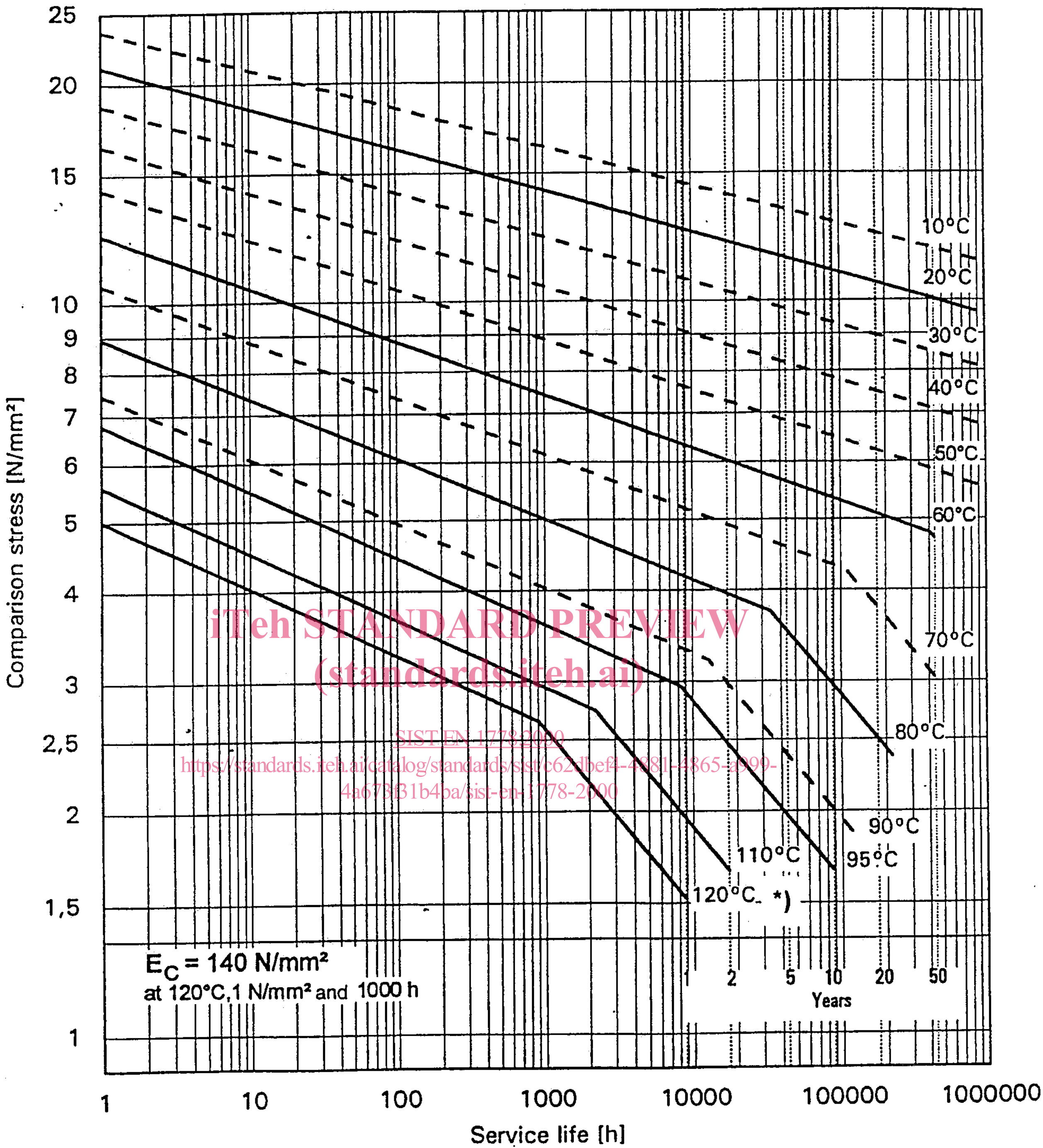

Figure A.5: Creep strength of pipes made from polypropylene (PP-H)

*) In contrast to prEN 12202 this temperature-parameter has been included.

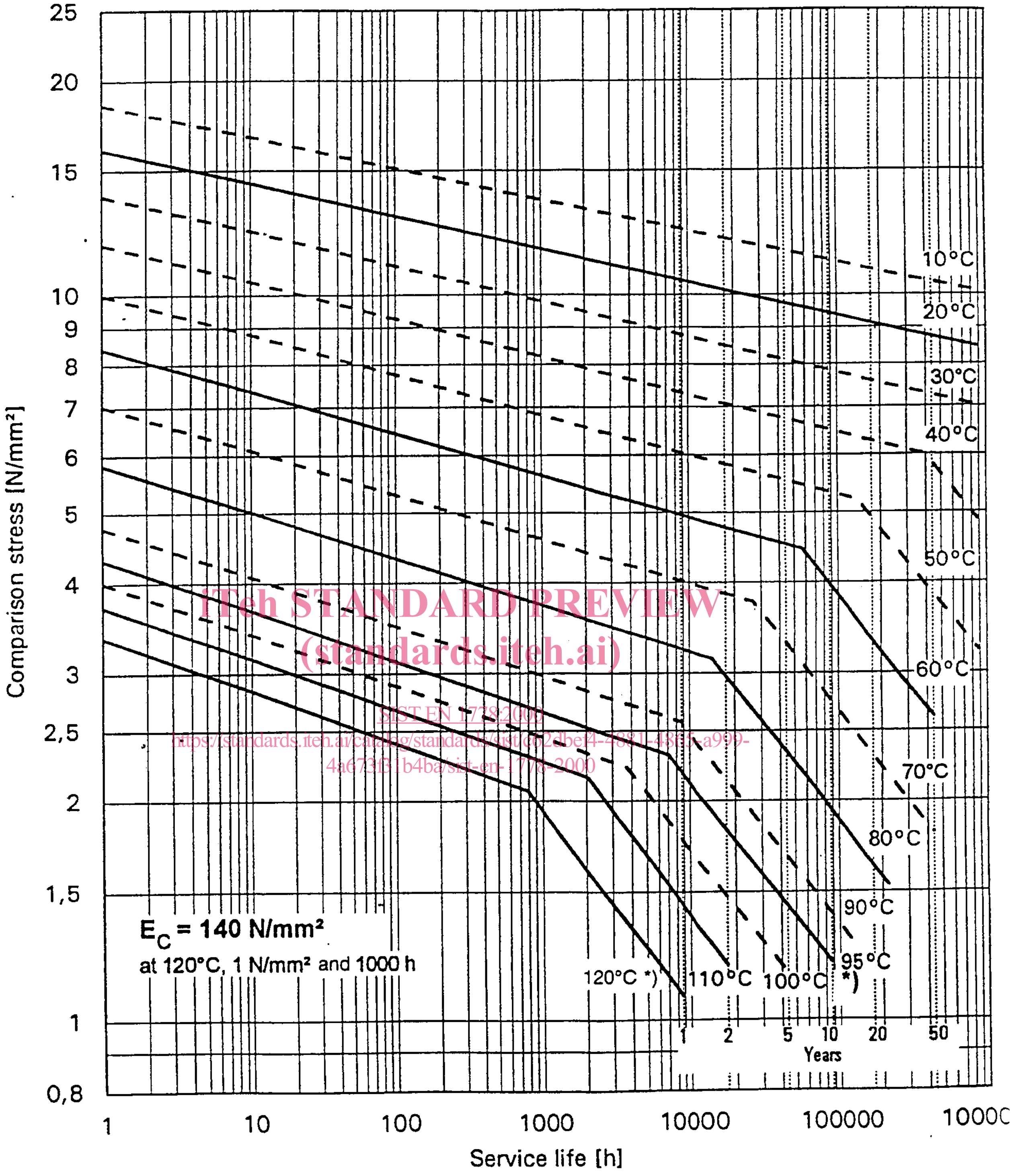

Figure A.6: Creep strength of pipes made from polypropylene (PP-B)

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*) In contrast to prEN 12202 this temperature-parameter has been included.