BRITISH STANDARD

BS EN 1778:2000

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

The European Standard EN 1778:1999 has the status of a British Standard

ICS 83.080.20; 83.140.01

National foreword

This British Standard is the official English language version of EN 1778:1999.

The UK participation in its preparation was entrusted to Technical Committee PRI/80, Welding thermoplastics, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 52, an inside back cover and a back cover.

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EUROPEAN STANDARD

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EN 1778

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English version

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

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

This European Standard was approved by CEN on 2 September 1999.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 1778:1999 E

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.

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 thermoplastics 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.

$$\sigma_{al.} = \frac{K \times f_l}{A_1 \times A_{2K} \times S} \tag{1}$$

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:

$$\sum_{i=1}^{n} \frac{a_1 \times t_x}{100 \times t_i} = 1 \tag{2}$$

For two fractional loadings:

$$\frac{a_1 \times t_x}{100 \times t_1} + \frac{a_2 \times t_x}{100 \times t_2} = 1 \tag{3}$$

or

$$t_x = \frac{100 \times t_1 \times t_2}{a_1 \times t_2 + a_2 \times t_1} \tag{4}$$

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:

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

– to determine deformations:

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

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 thermoplastics 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)

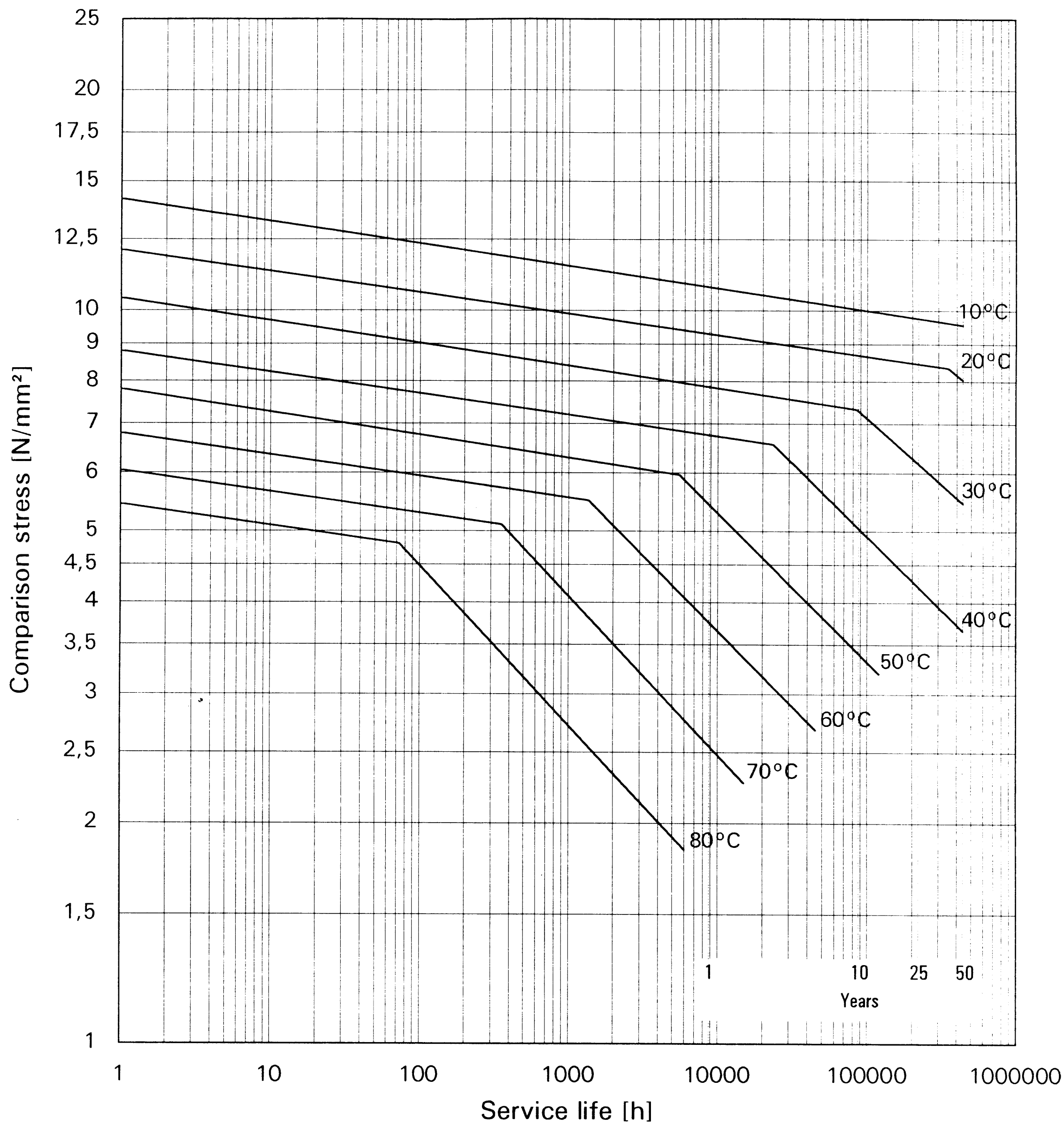


Figure A.1: Creep strength of pipes made from high density polyethylene (PE-HD according to ISO 8584-1)

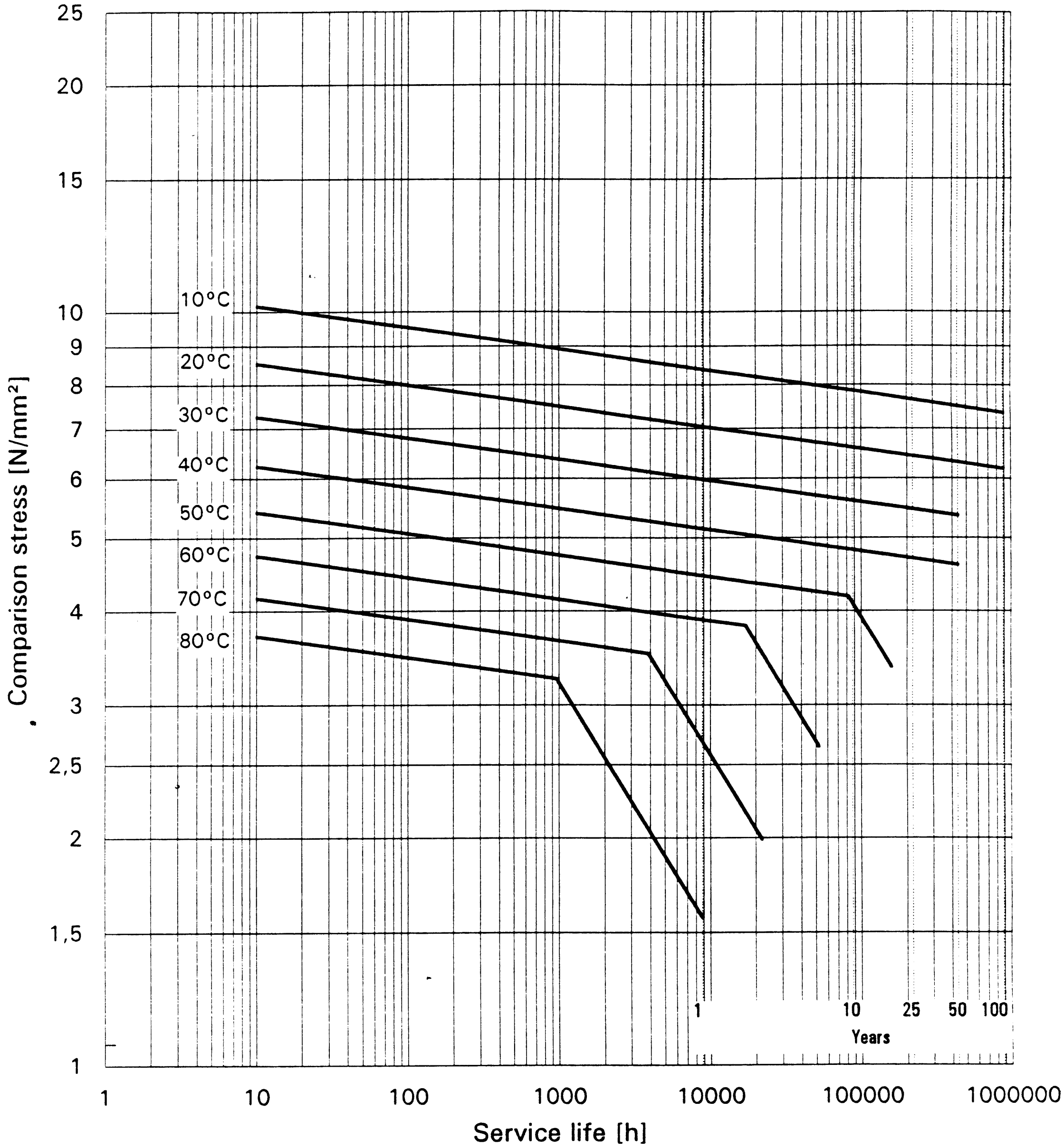


Figure A.2: Creep strength of pipes made from polyethylene (PE 63)

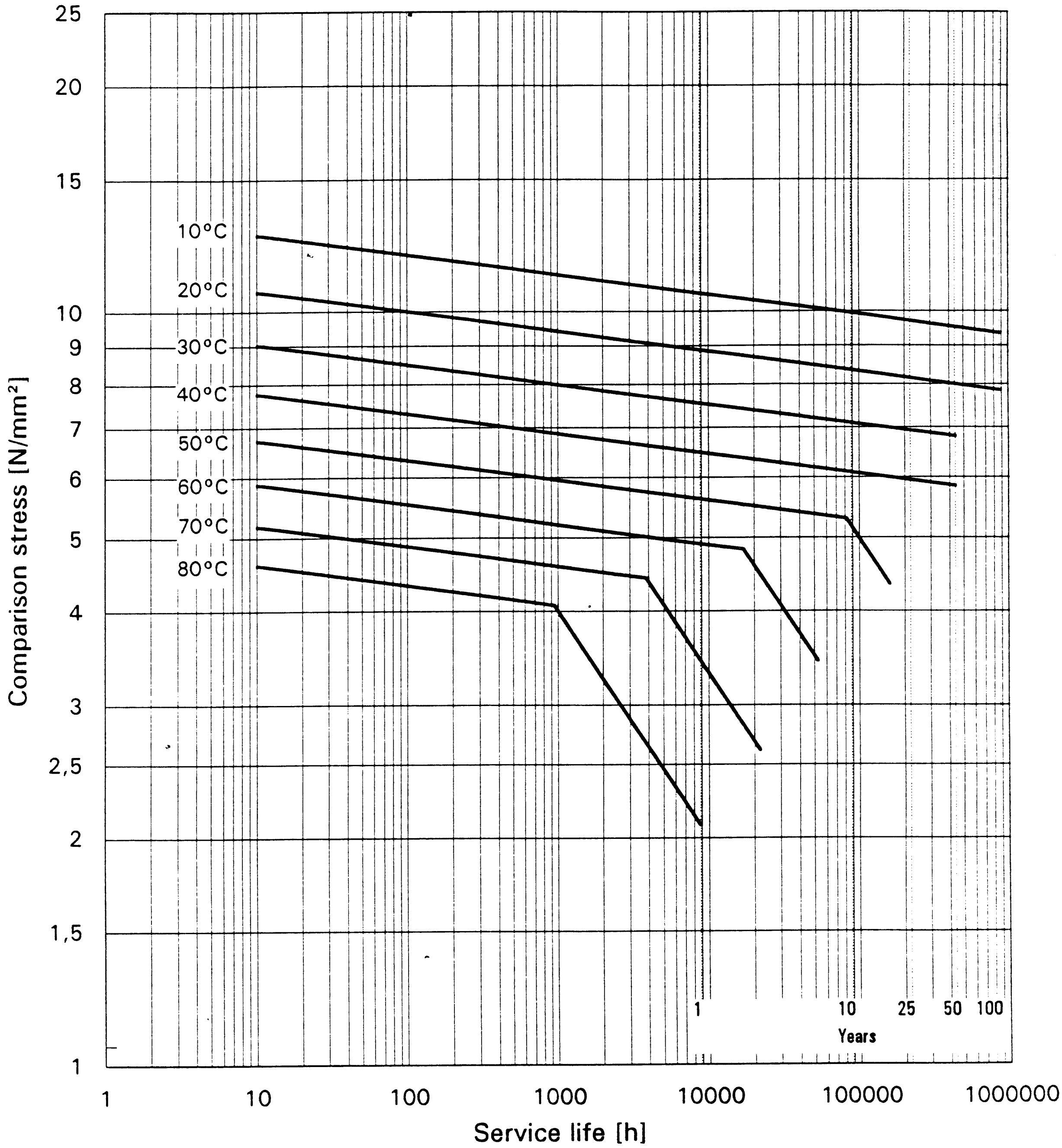


Figure A.3: Creep strength of pipes made from polyethylene (PE 80)

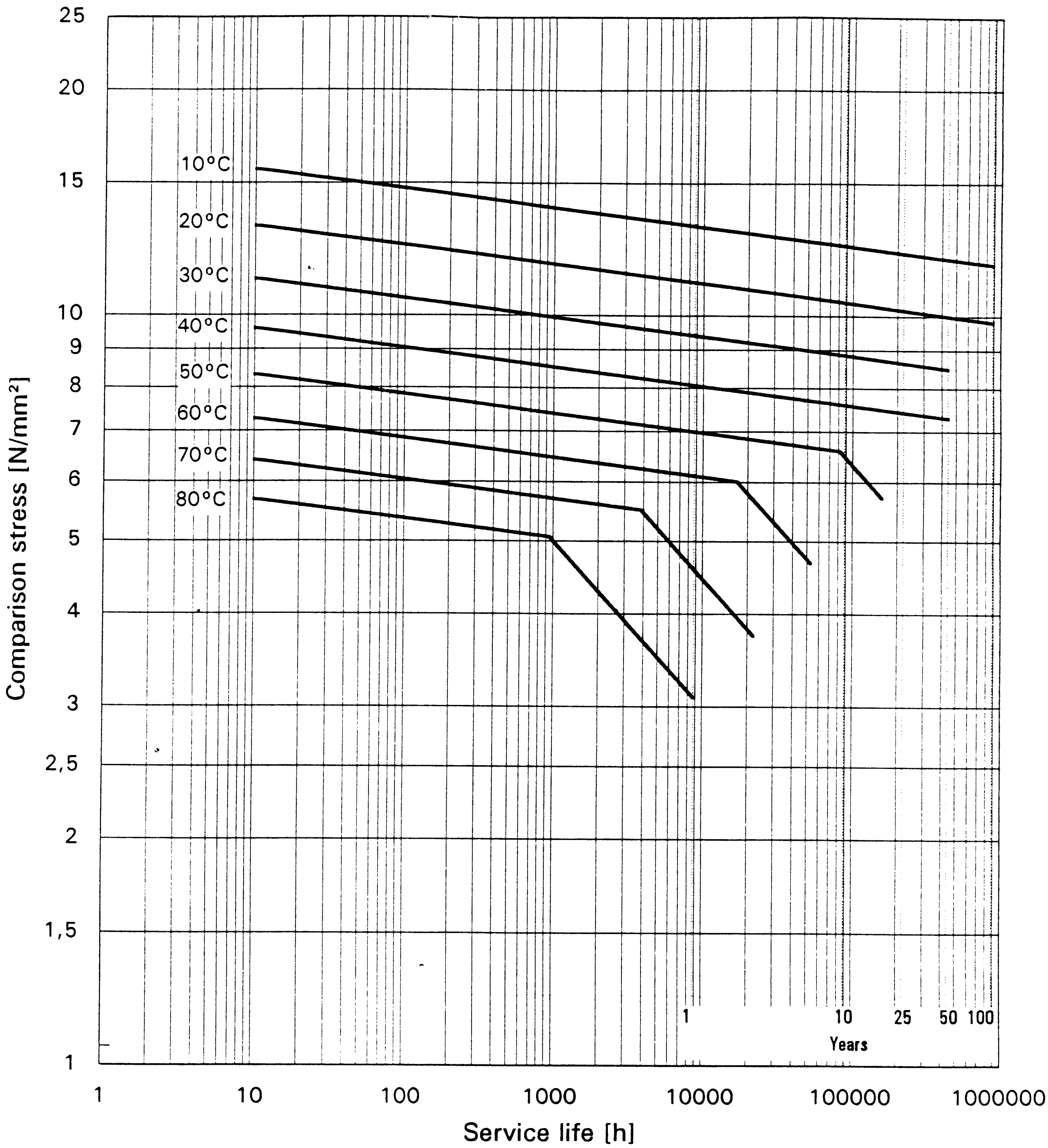


Figure A.4: Creep strength of pipes made from polyethylene (PE 100)

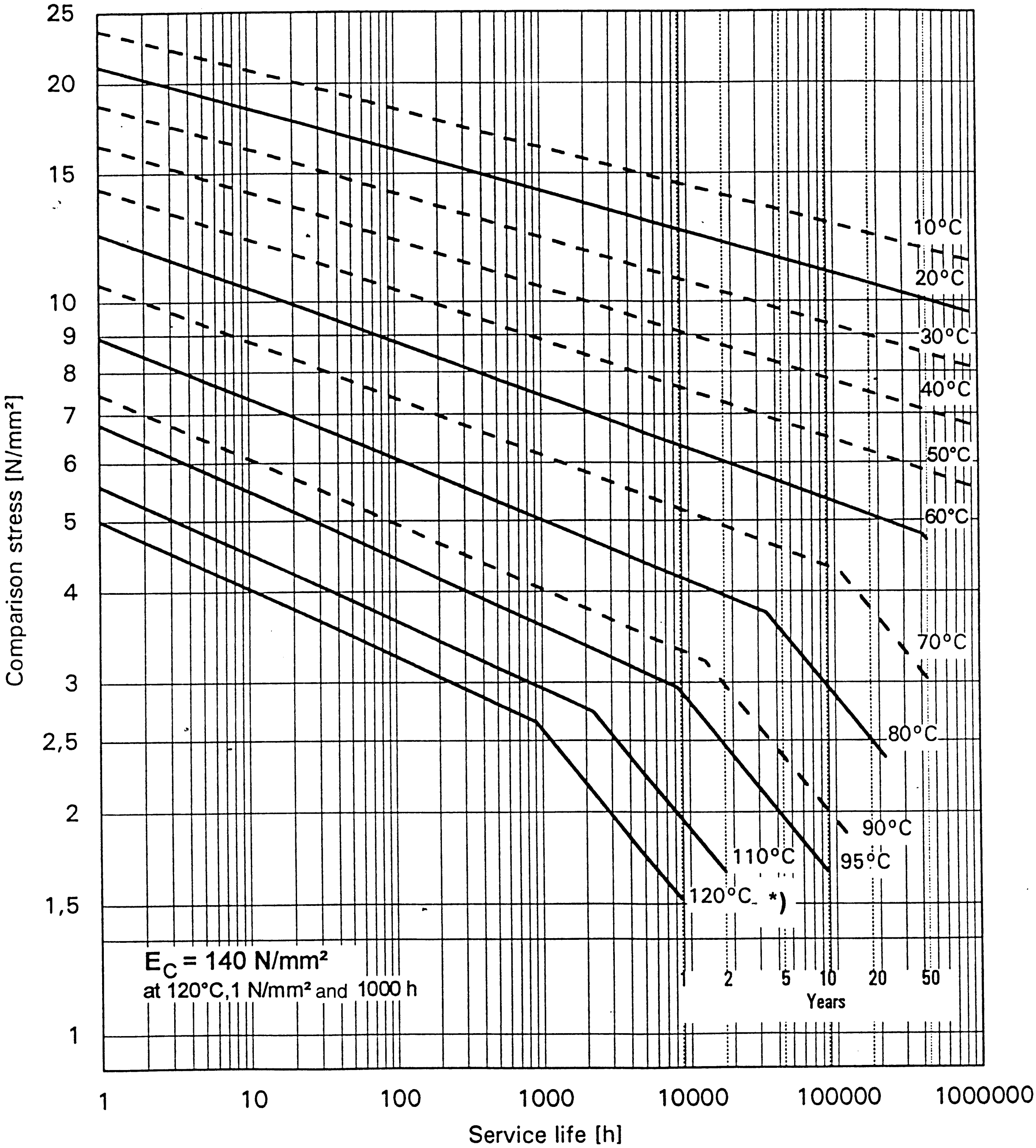


Figure A.5: Creep strength of pipes made from polypropylene (PP-H)

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

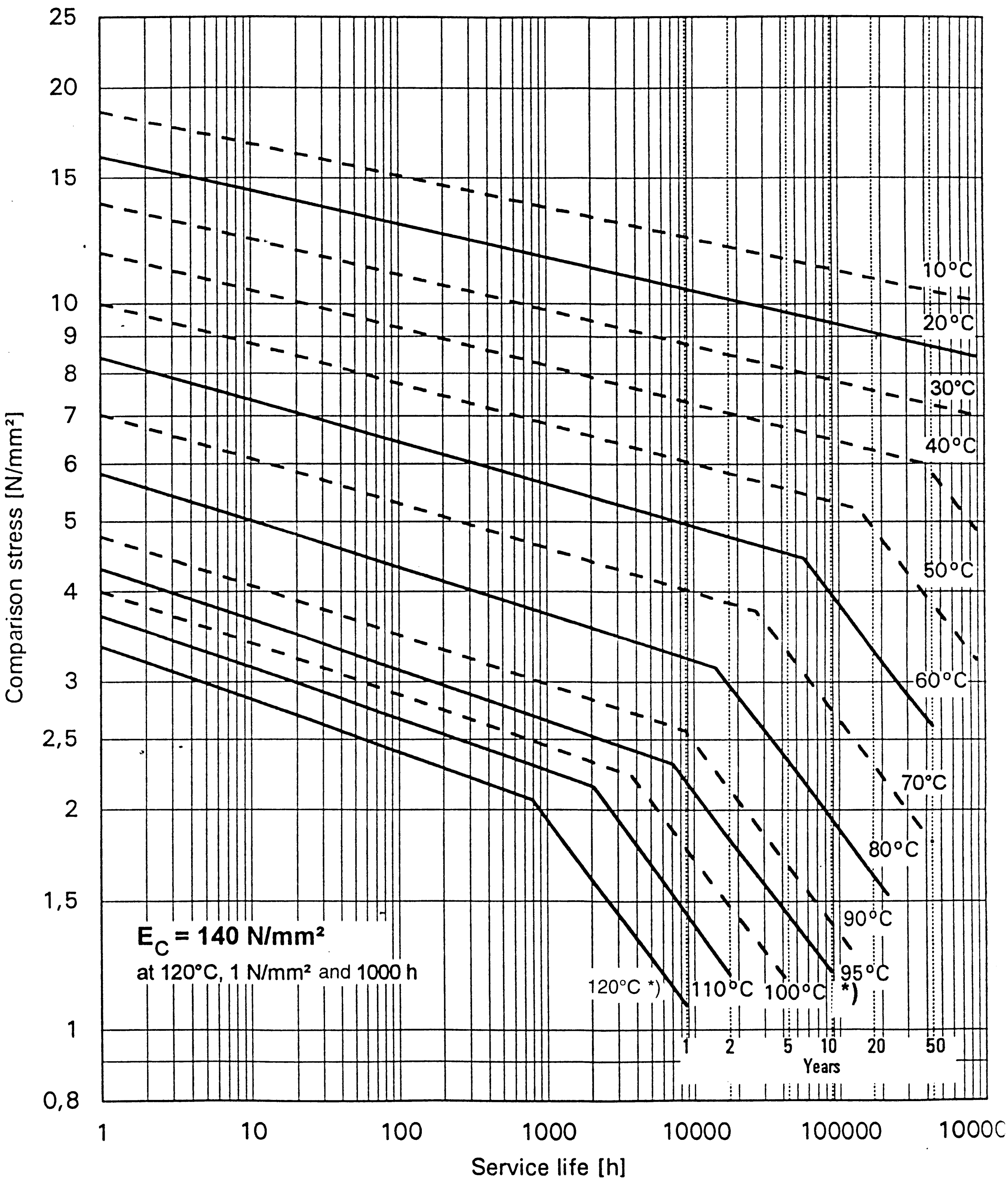


Figure A.6: Creep strength of pipes made from polypropylene (PP-B)

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

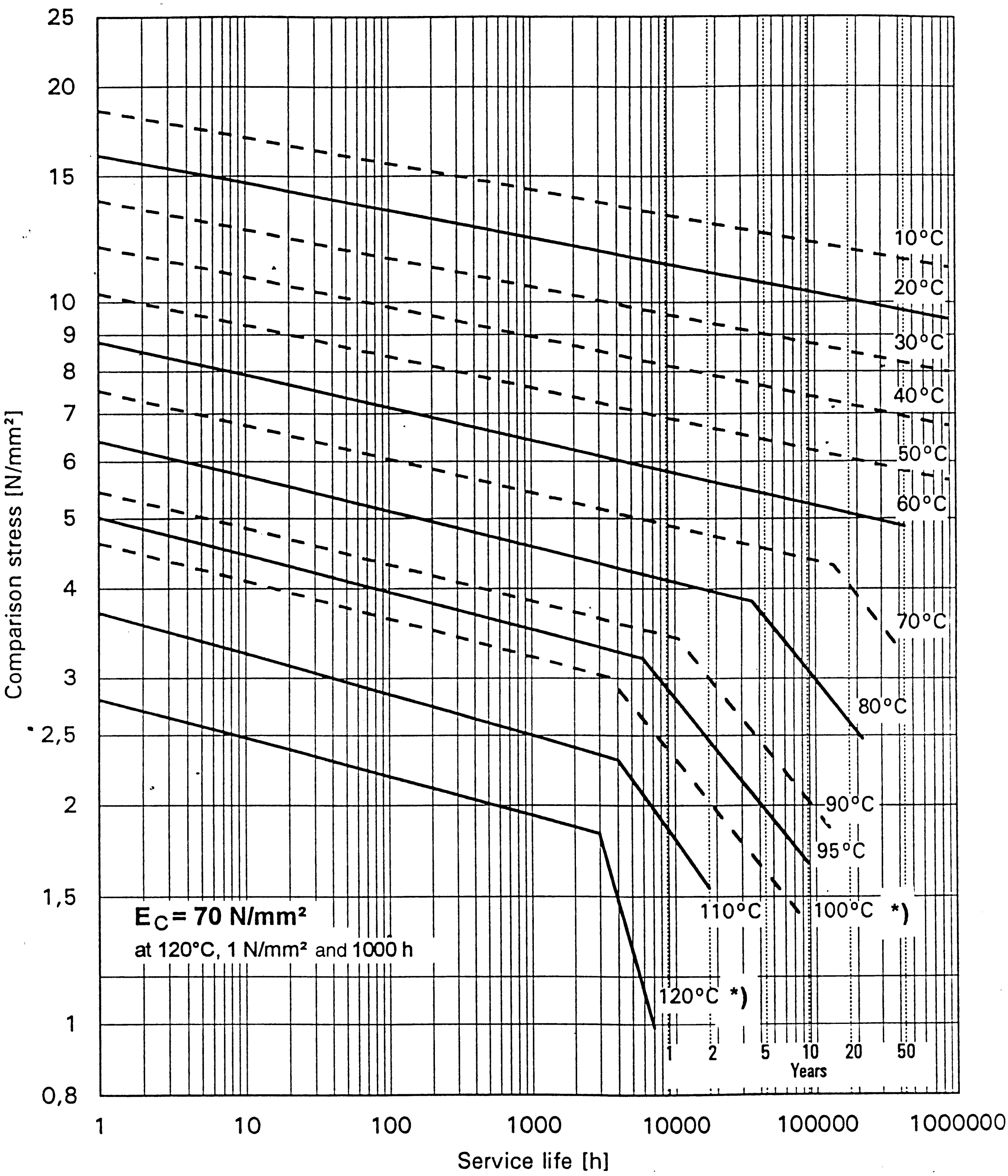


Figure A.7: Creep strength of pipes made from polypropylene (PP-R)

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

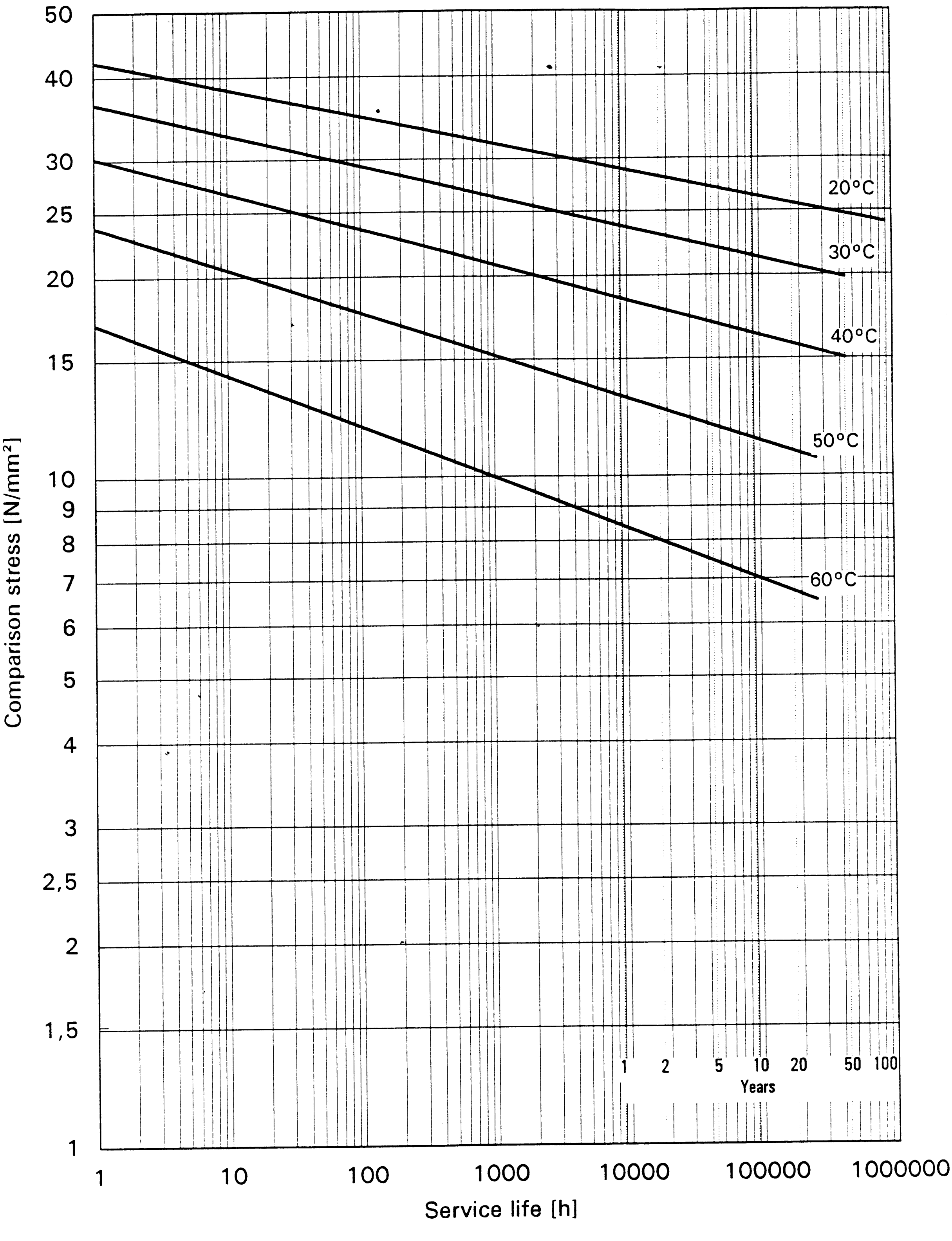


Figure A.8: Creep strength of pipes made from unplasticized normal impact polyvinylchloride (PVC-NI according to PVC-U)

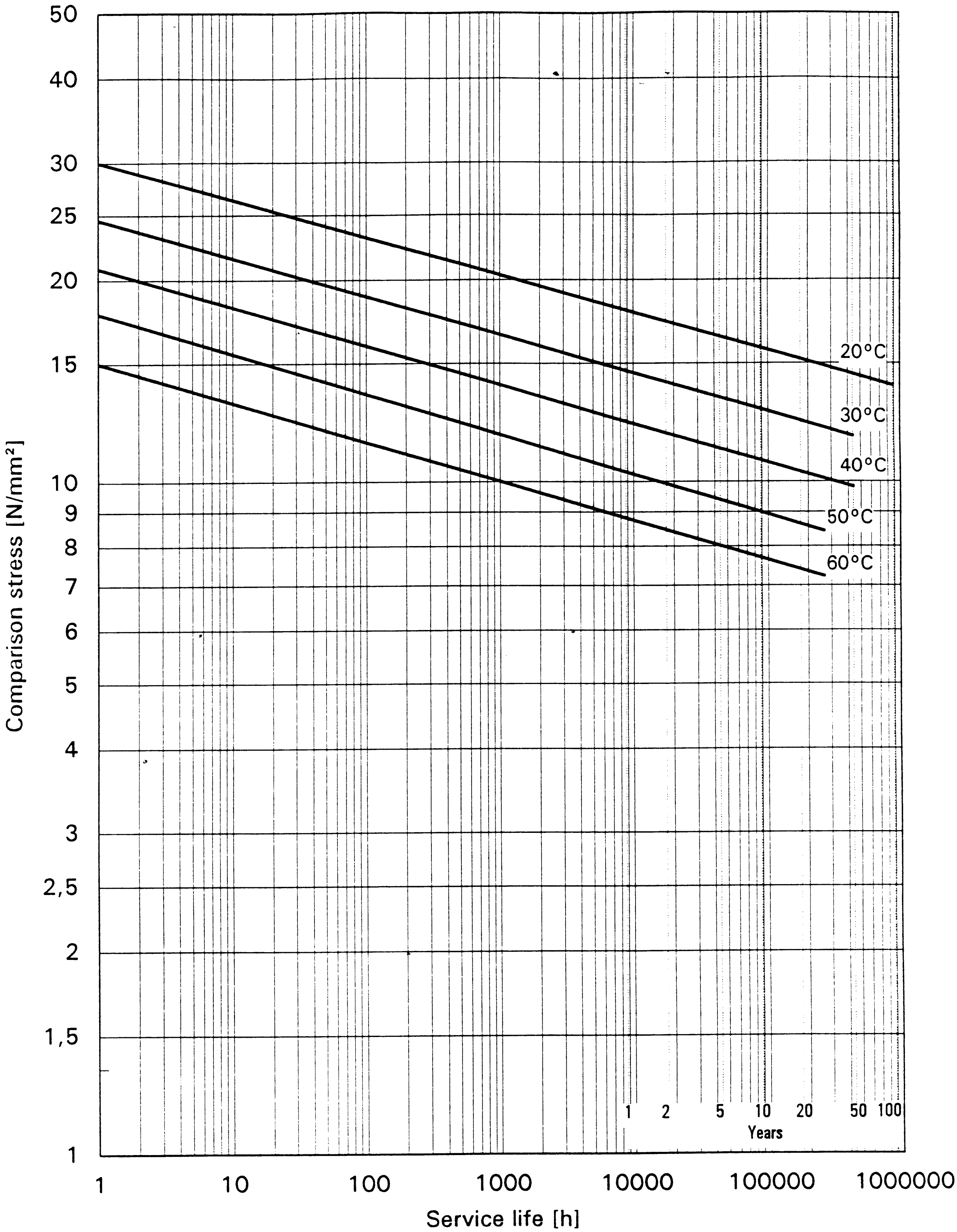


Figure A.9: Creep strength of pipes made from modified raised impact unplasticized polyvinylchloride (PVC-RI) Type 1: Mix of vinylchloride-homopolymerisate and pfropfcopolymerisate on basis of acrylicacid-vinylchloride

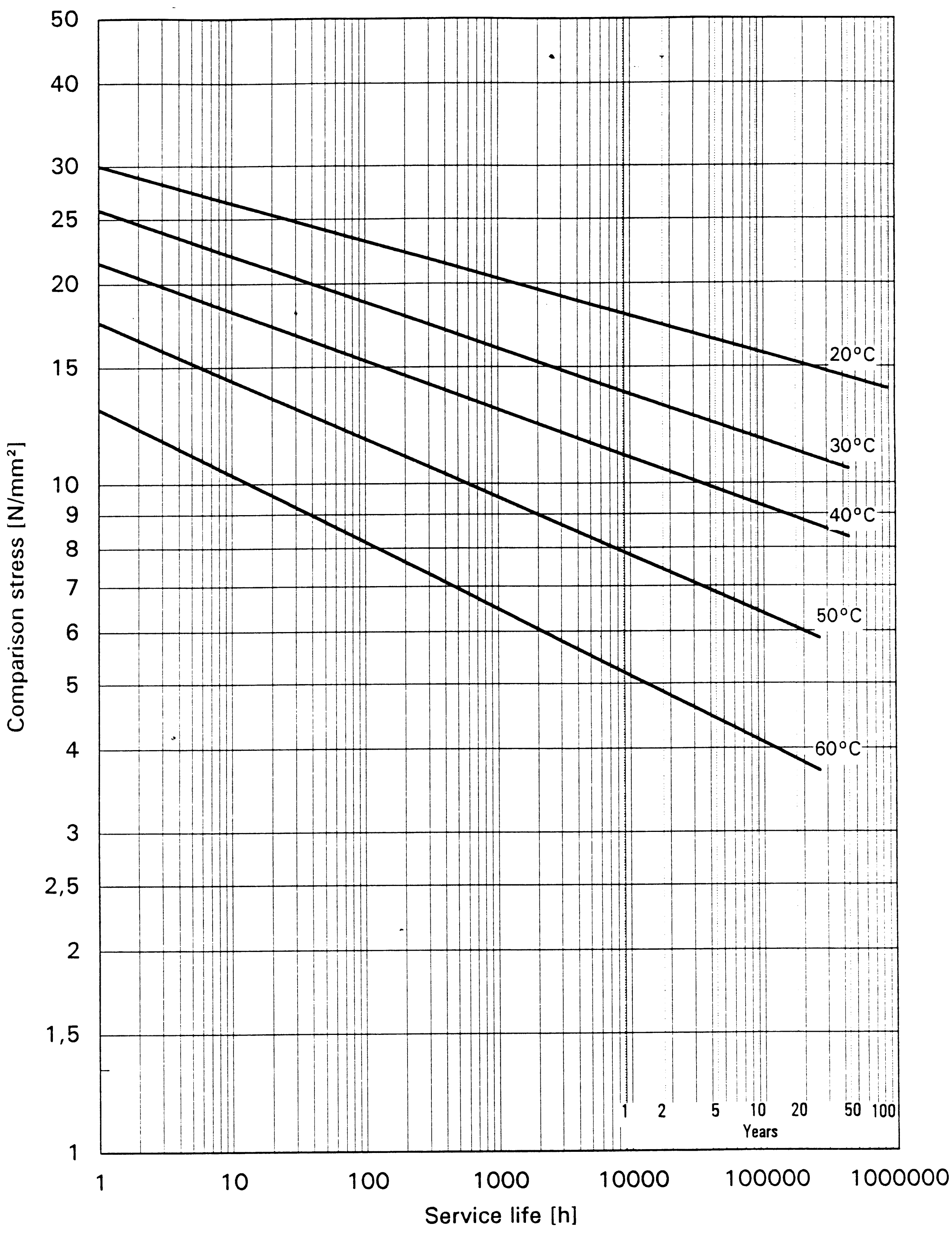


Figure A.10: Creep strength of pipes made from modified raised impact unplasticized polyvinylchloride (PVC-RI) Type 2: Mix of vinylchloride-homopolymerisate on chlorinated polyethylene

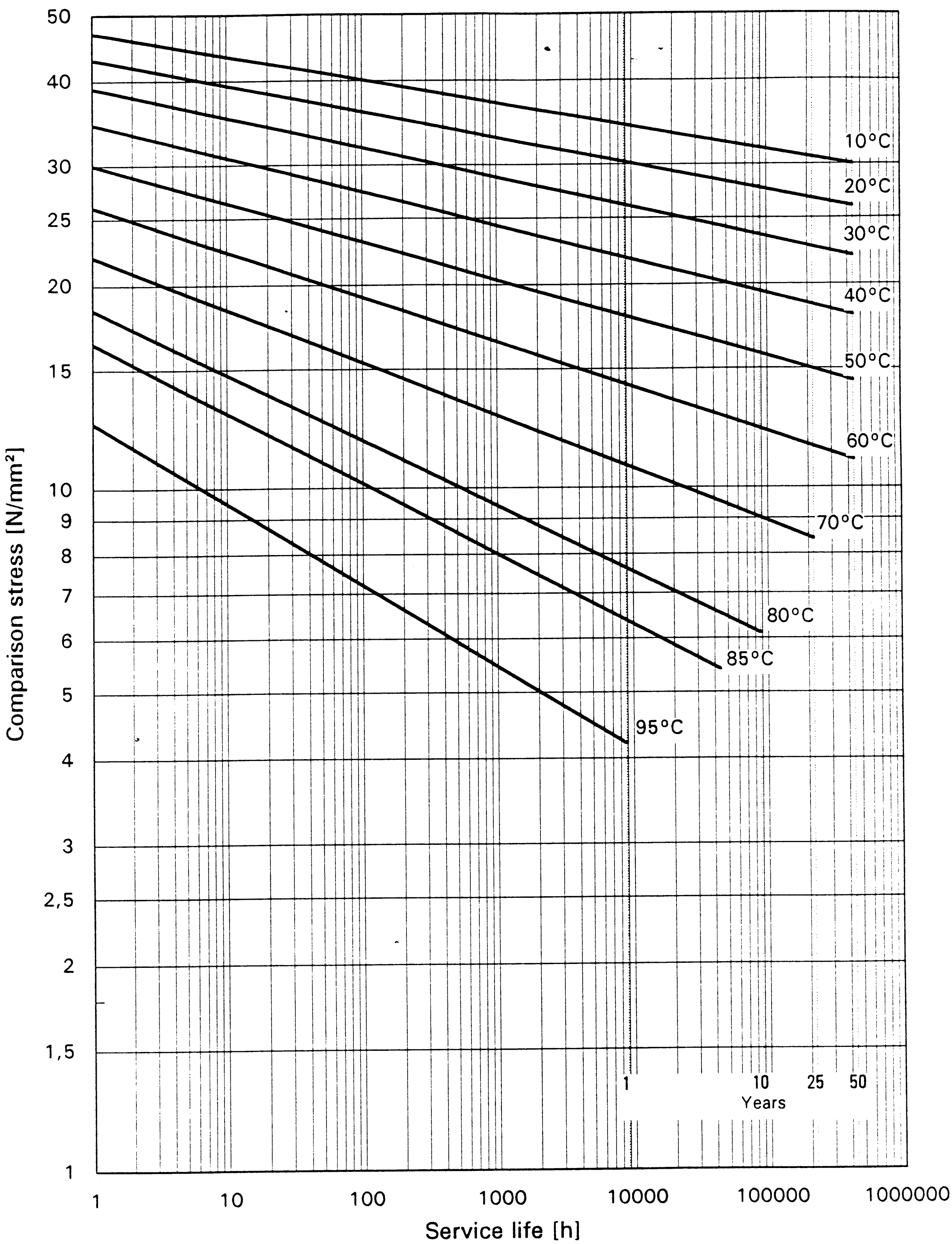


Figure A.11: Creep strength of pipes made from chlorinated polyvinylchloride (PVC-C)

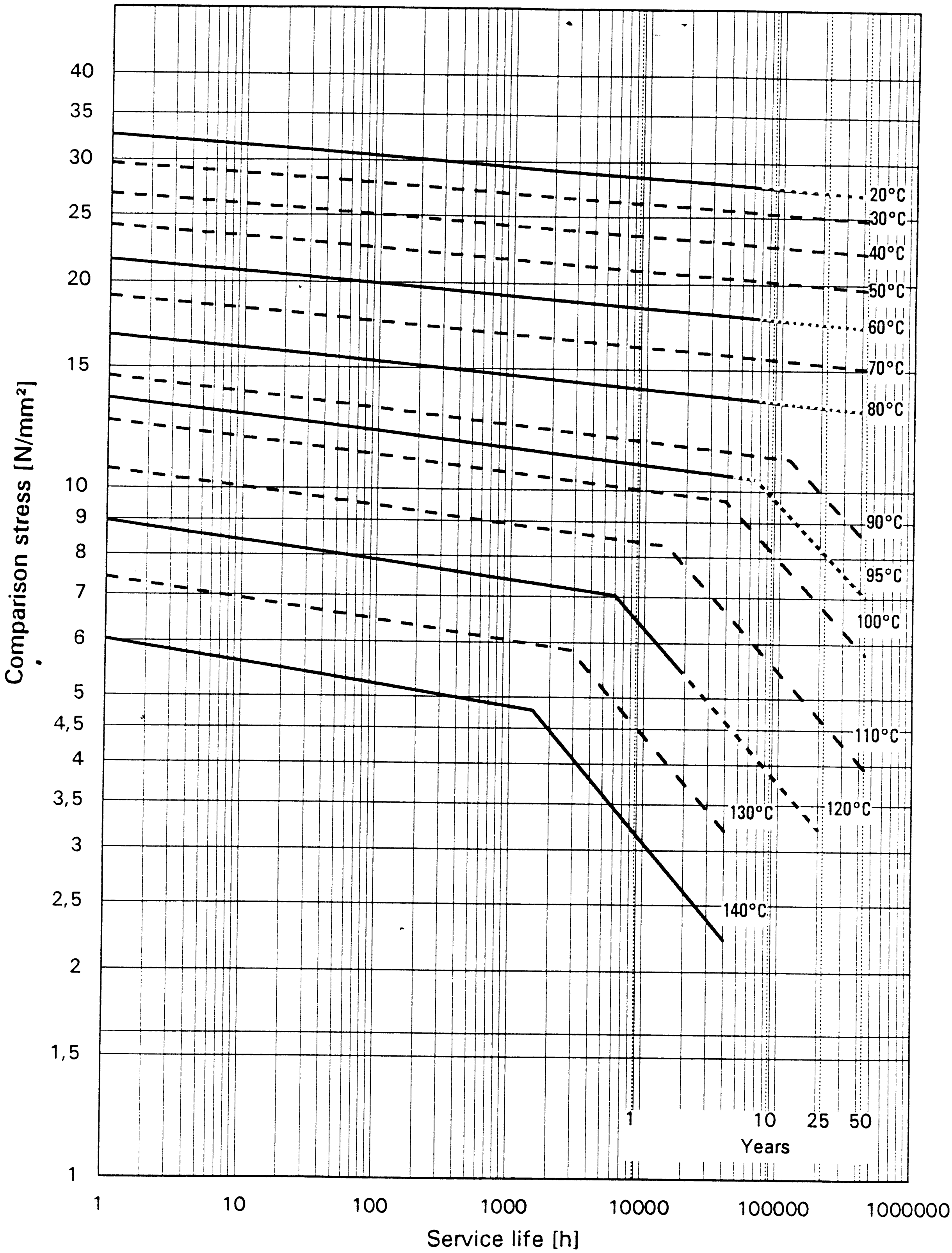


Figure A.12: Creep strength of pipes made from polyvinylidene fluoride (PVDF)

A.1.2 Creep modulus diagrams (Figures A.13 to A.27)

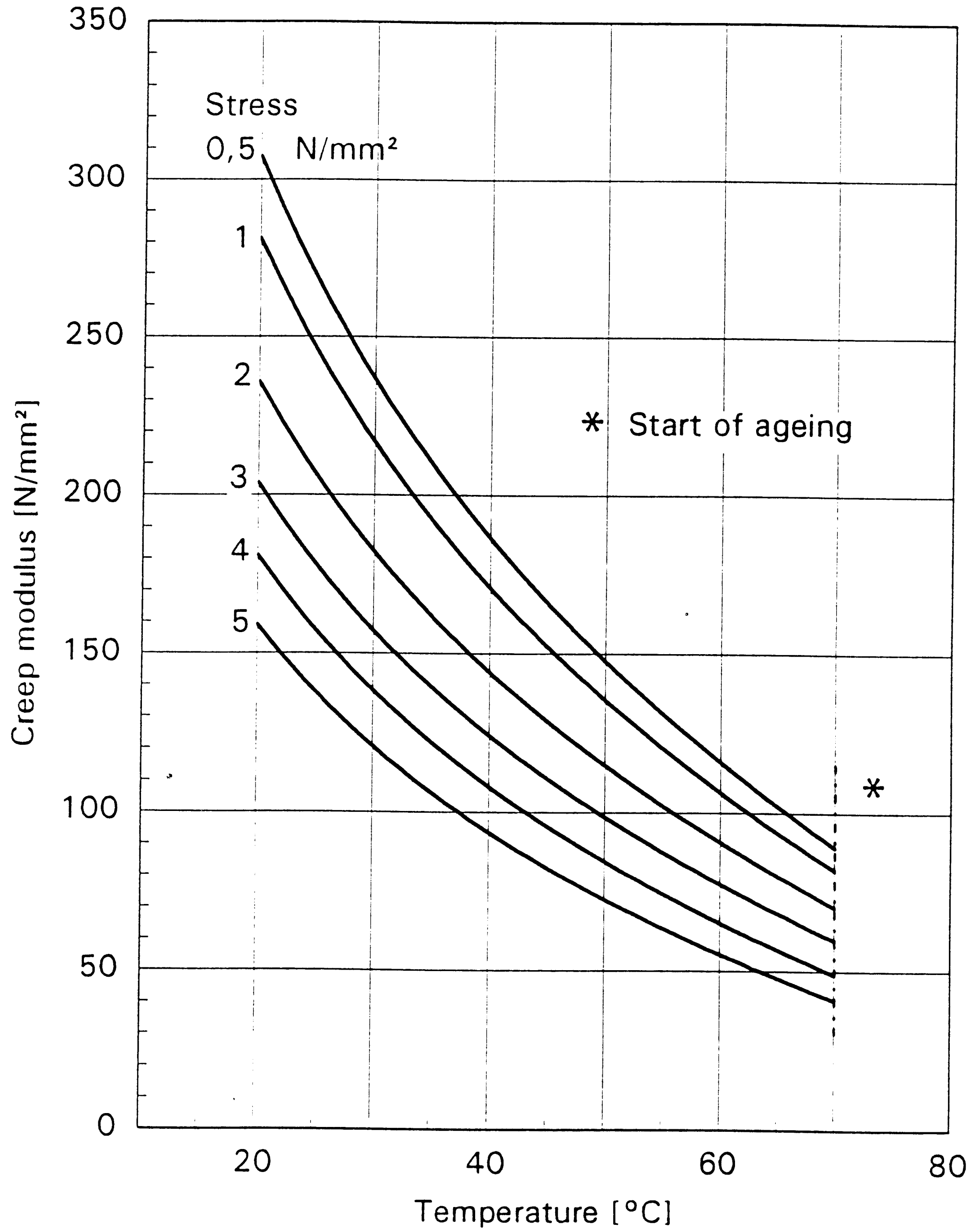


Figure A.13: Creep modulus of high-density polyethylene (PE-HD) for 1 year

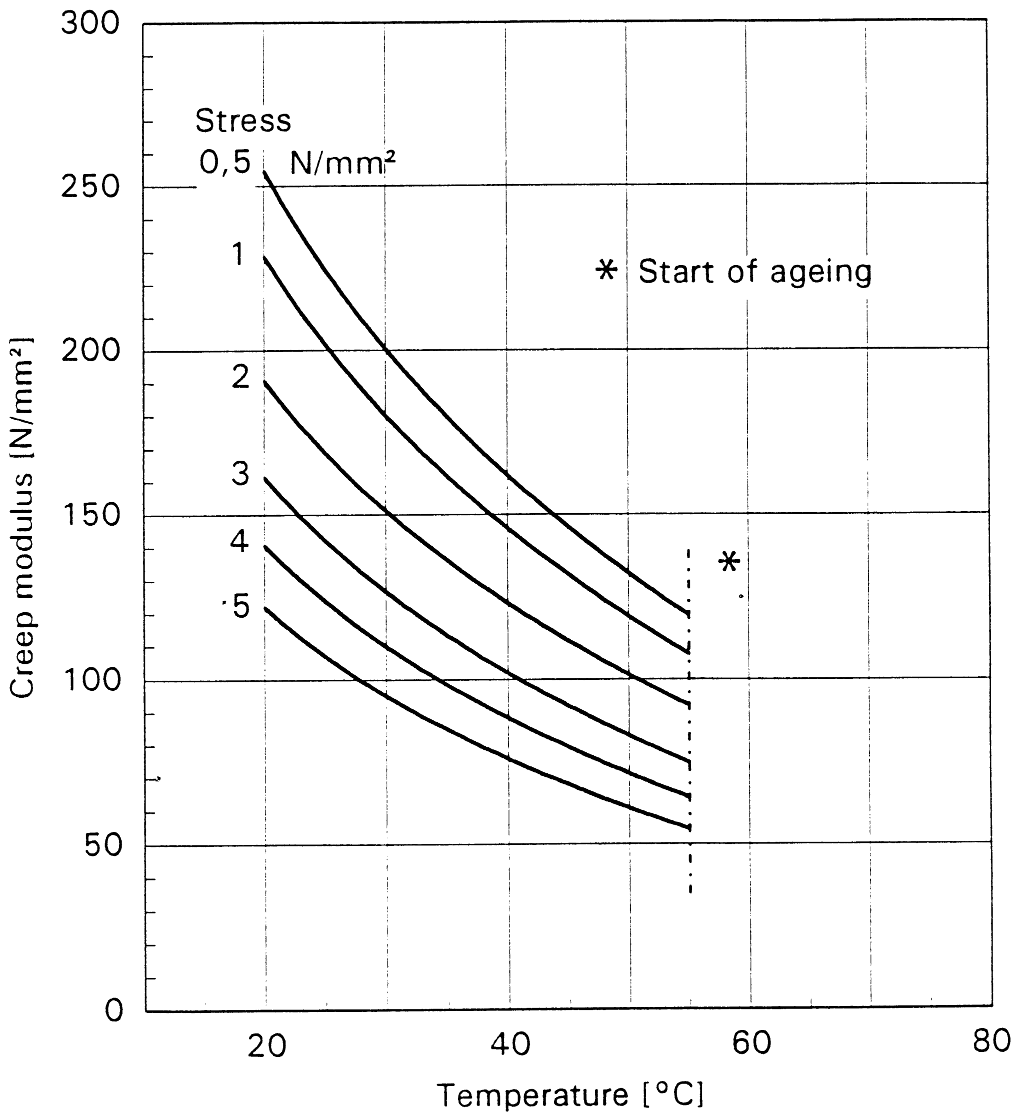


Figure A.14: Creep modulus of high-density polyethylene (PE-HD) for 10 years

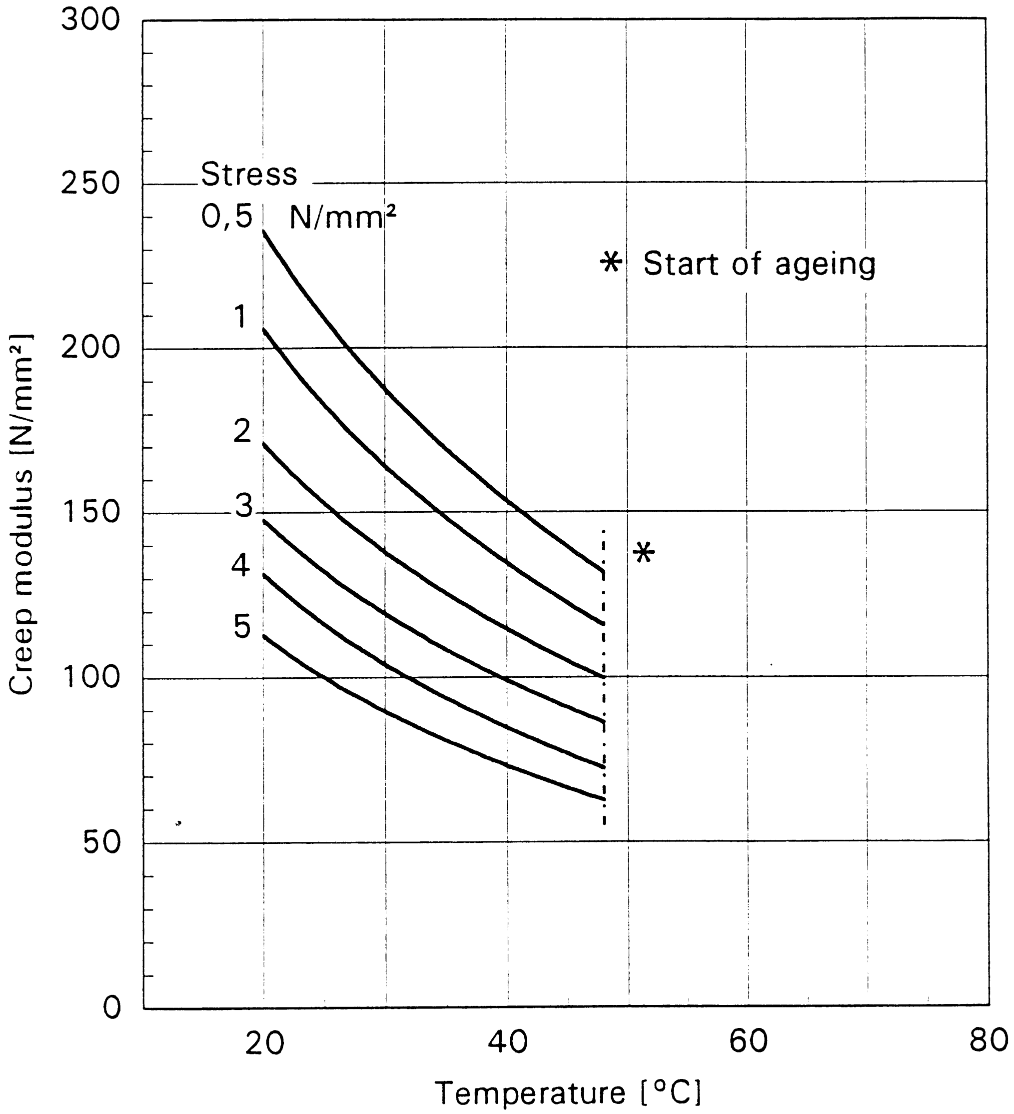


Figure A.15: Creep modulus of high-density polyethylene (PE-HD) for 25 years

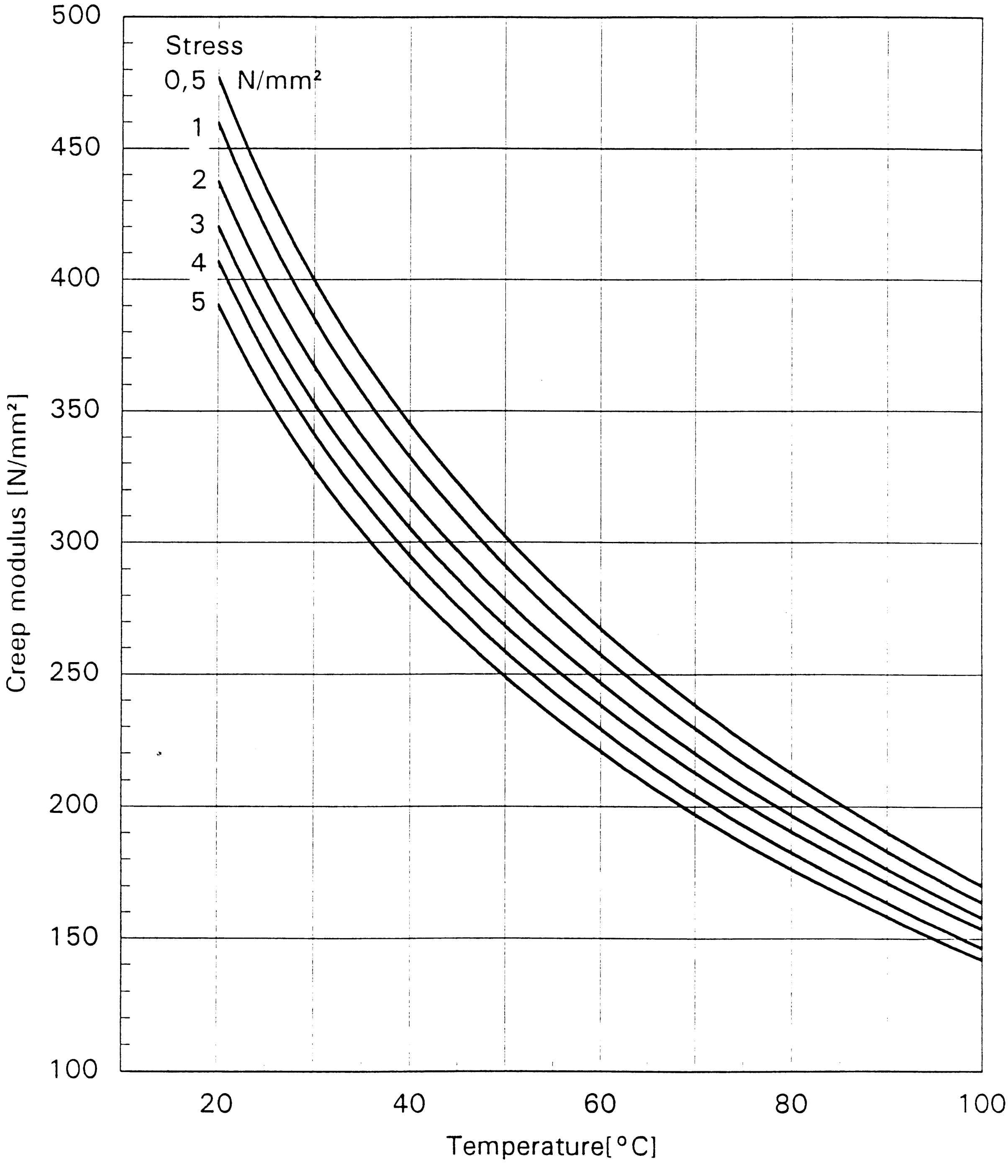


Figure A.16: Creep modulus of polypropylene (PP-H) for 1 year

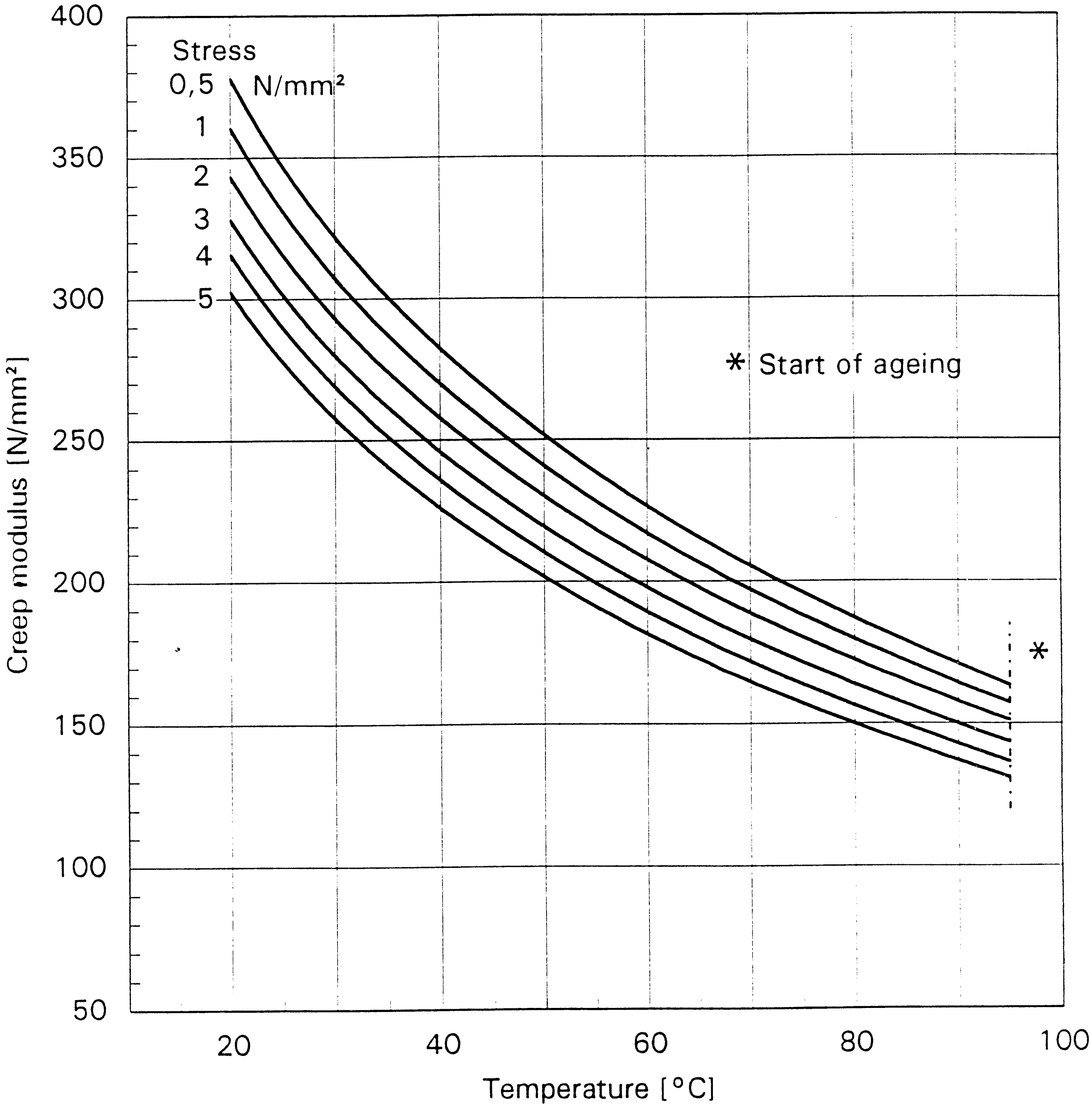


Figure A.17: Creep modulus of polypropylene (PP-H) for 10 years

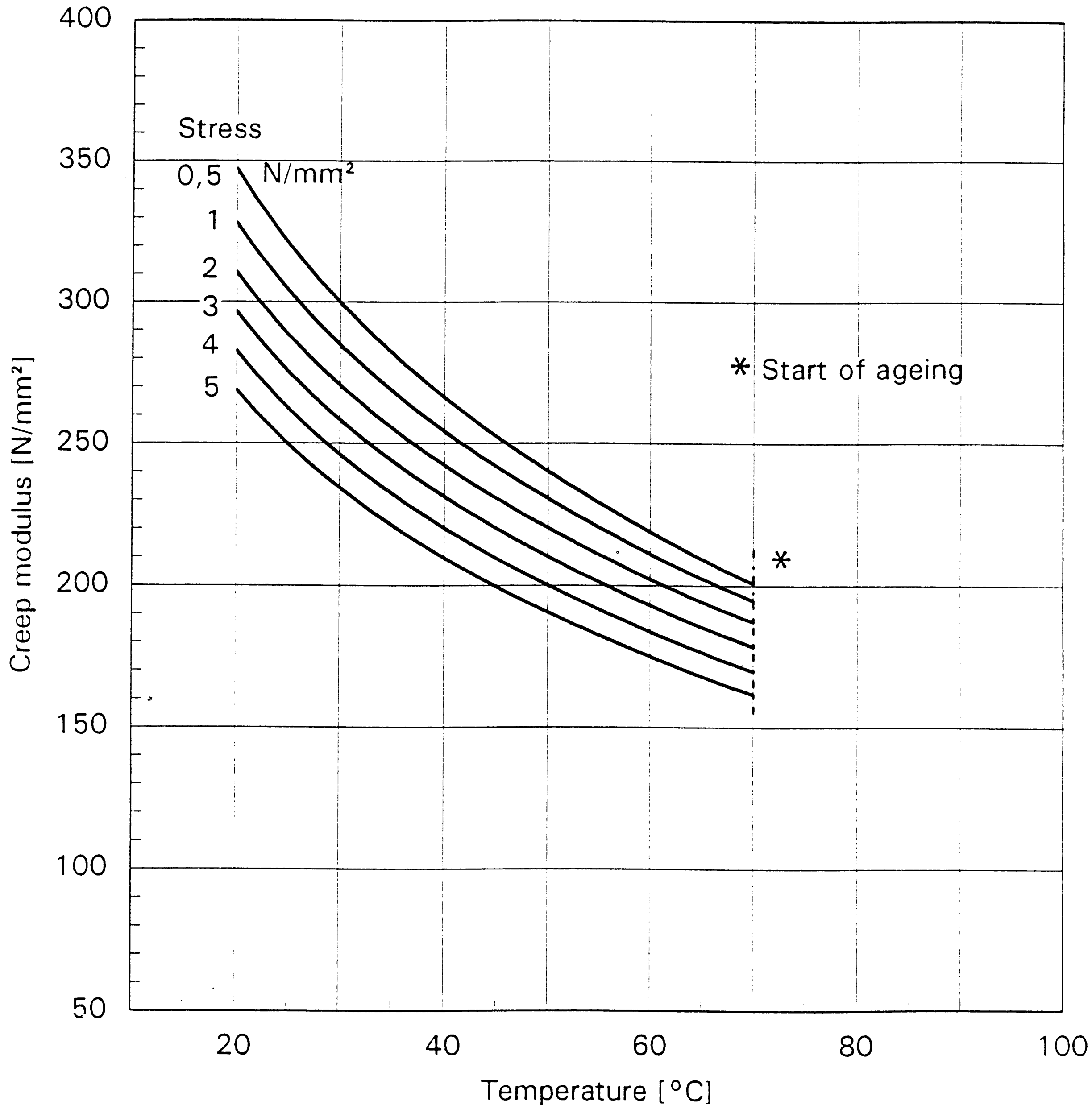


Figure A.18: Creep modulus of polypropylene (PP-H) for 25 years

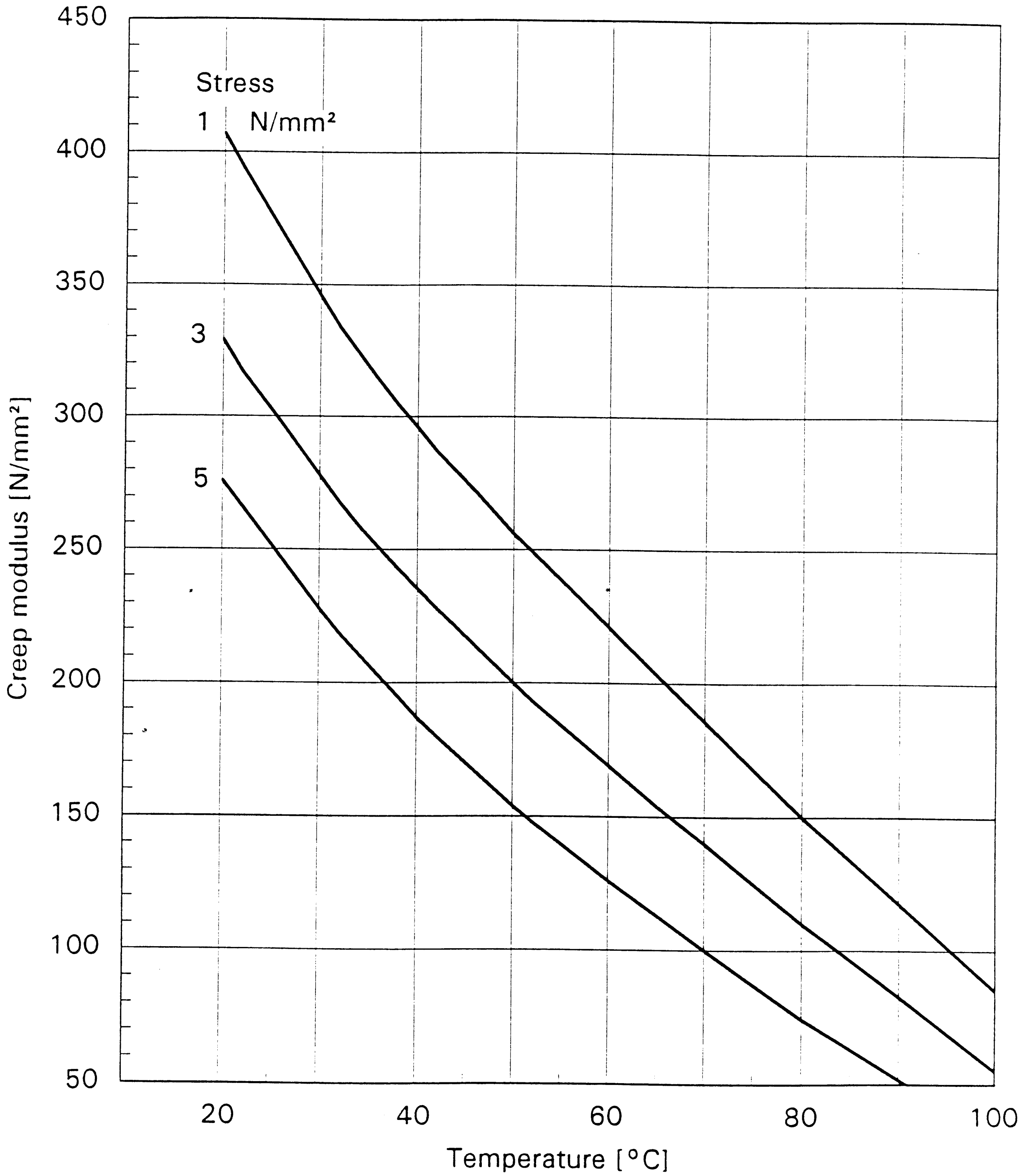


Figure A.19: Creep modulus of polypropylene (PP-B) for 1 year

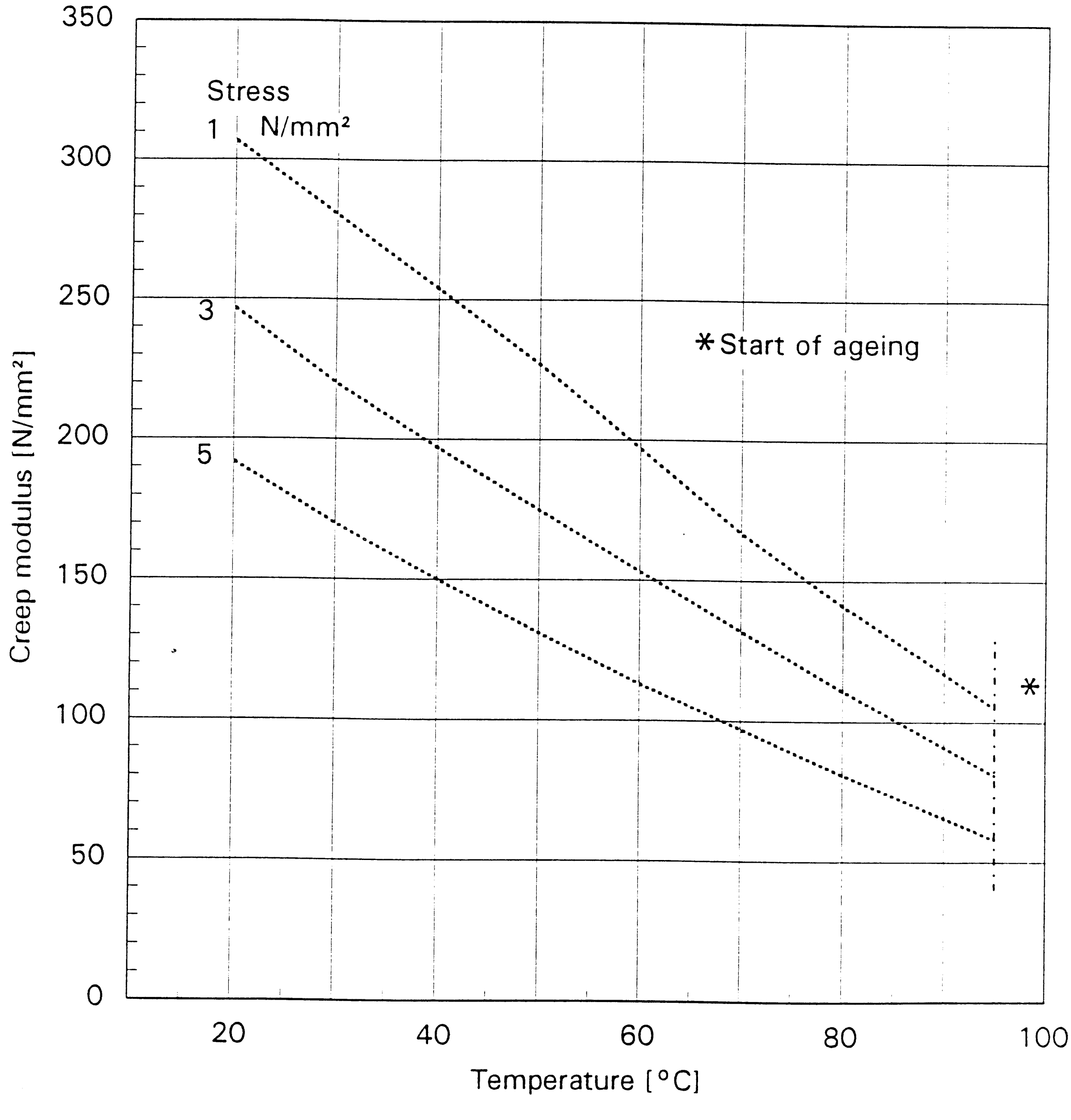


Figure A.20: Creep modulus of polypropylene (PP-B) for 10 years

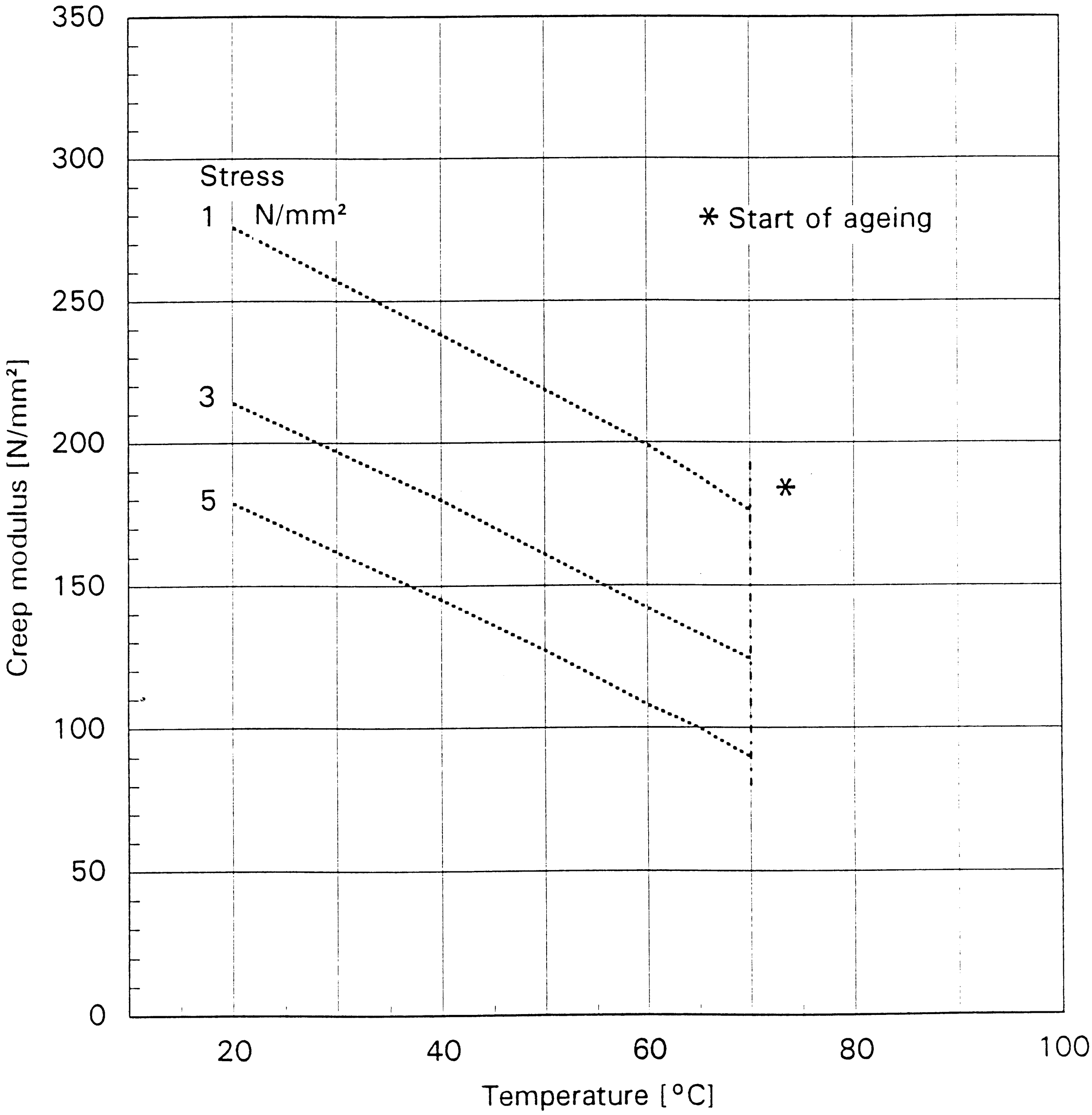


Figure A.21: Creep modulus of polypropylene (PP-B) for 25 years

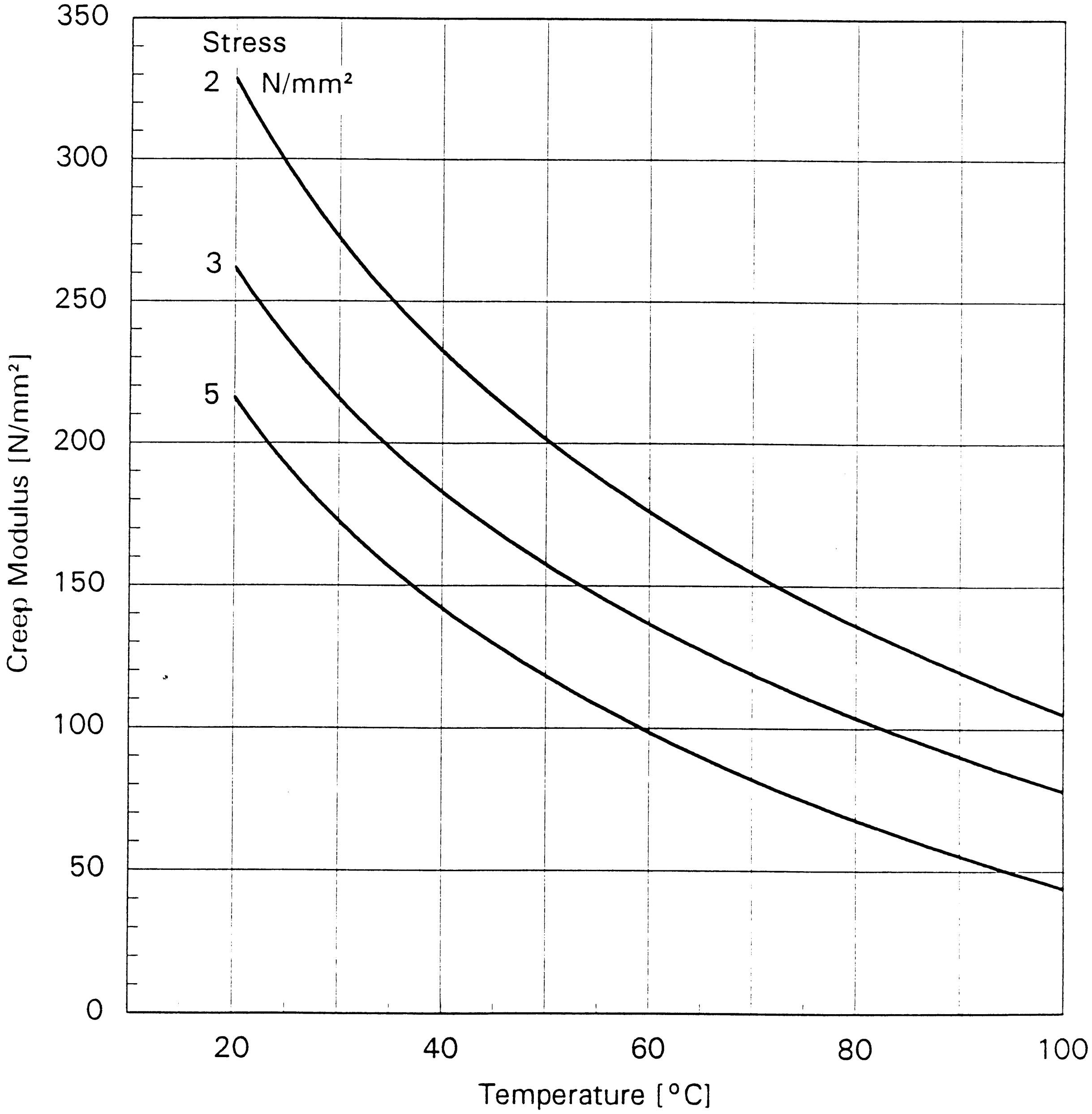


Figure A.22: Creep modulus of polypropylene (PP-R) for 1 year

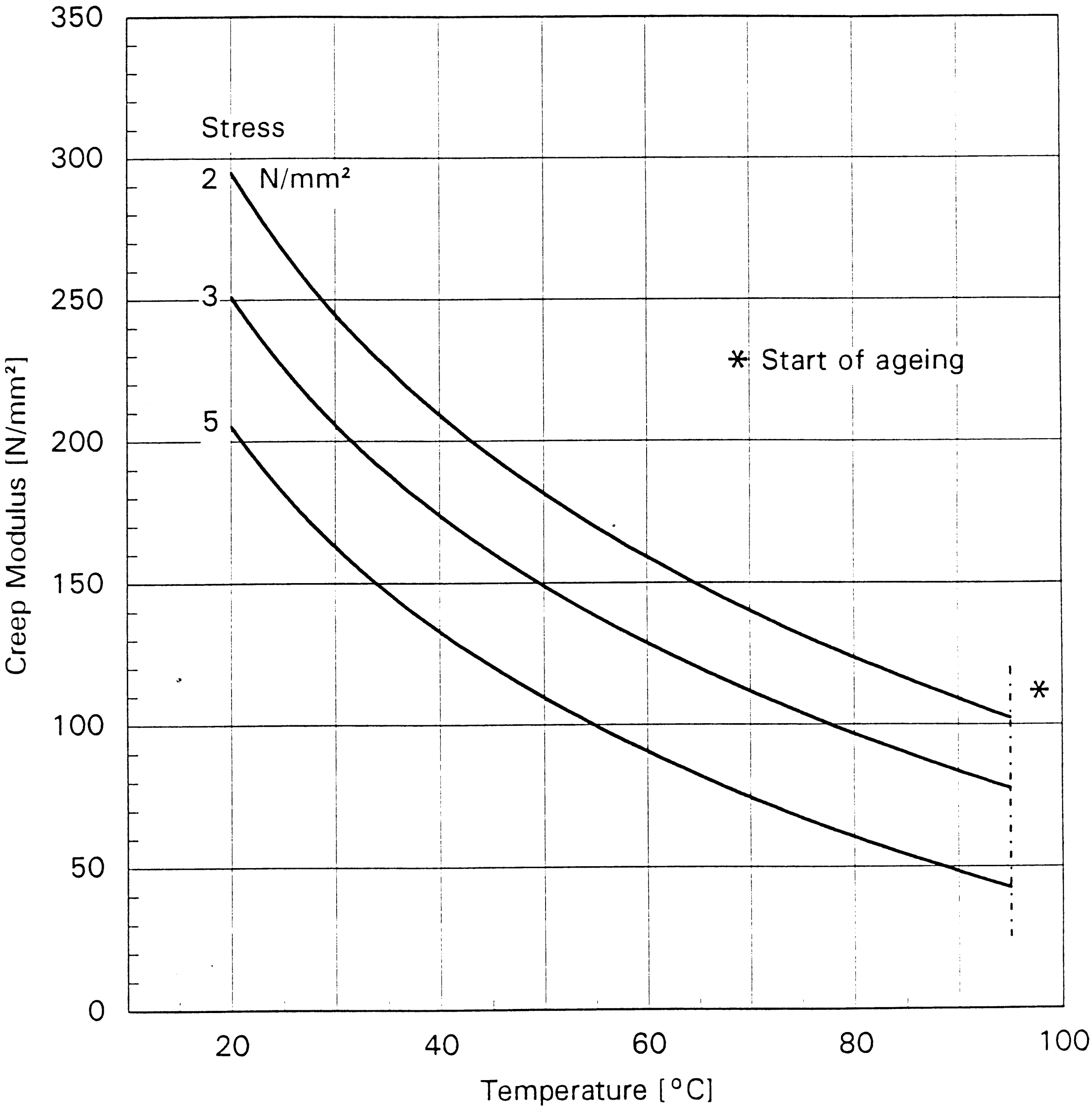


Figure A.23: Creep modulus of polypropylene (PP-R) for 10 years

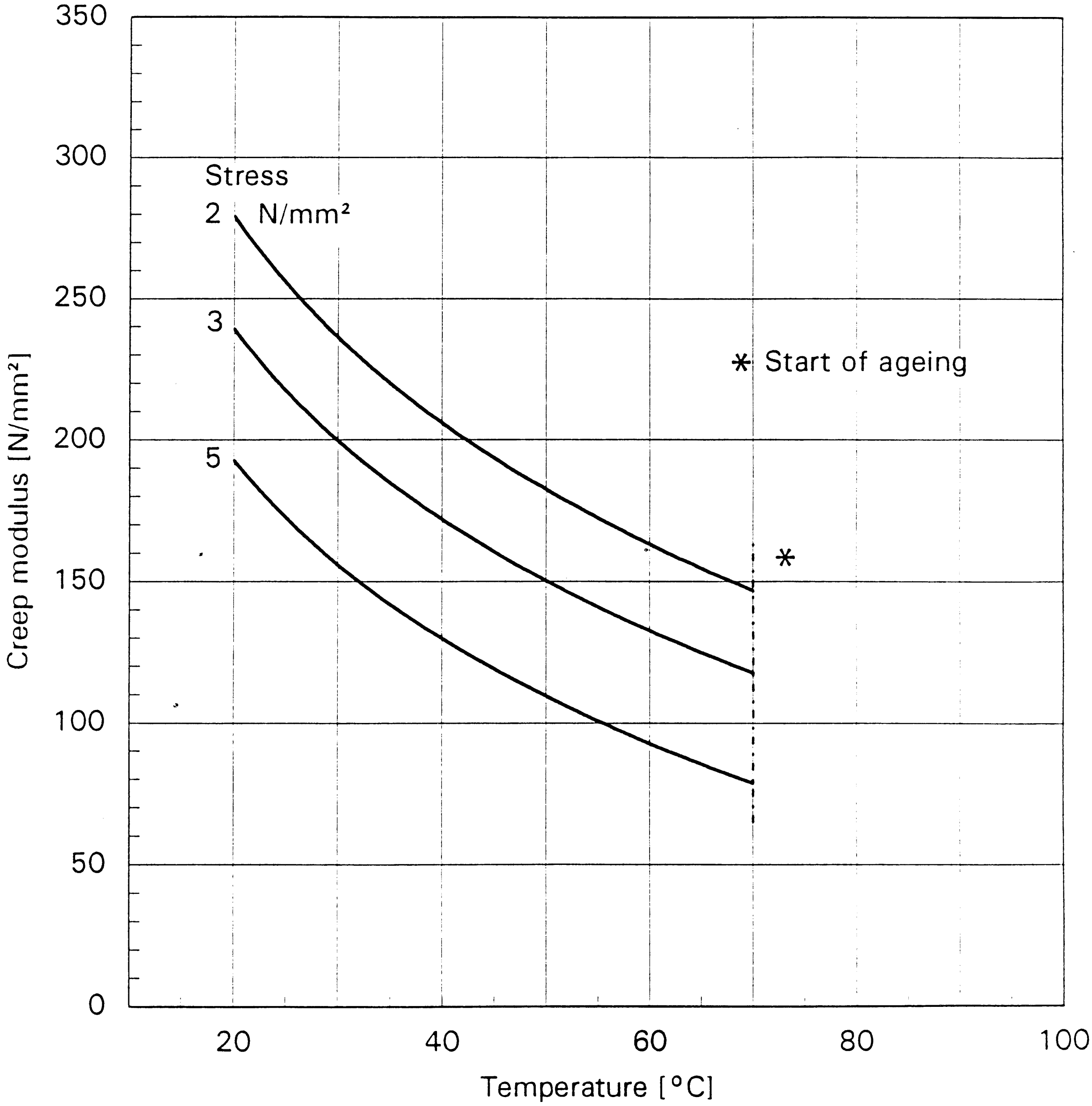


Figure A.24: Creep modulus of polypropylene (PP-R) for 25 years

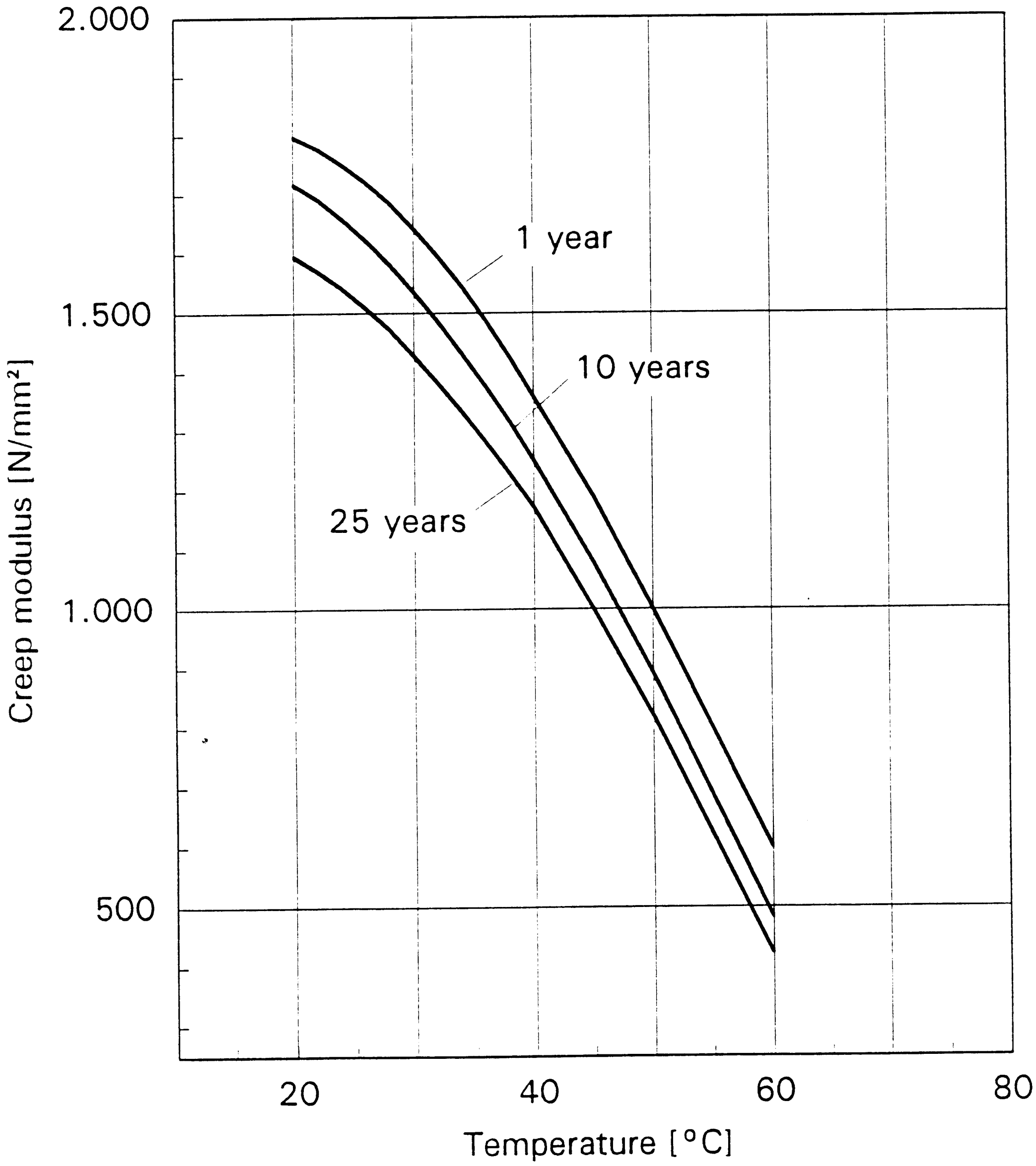


Figure A.25: Creep modulus of unplasticized polyvinylchloride (PVC-NI) for the stress range σ = 2,5 to 10 N/mm^2

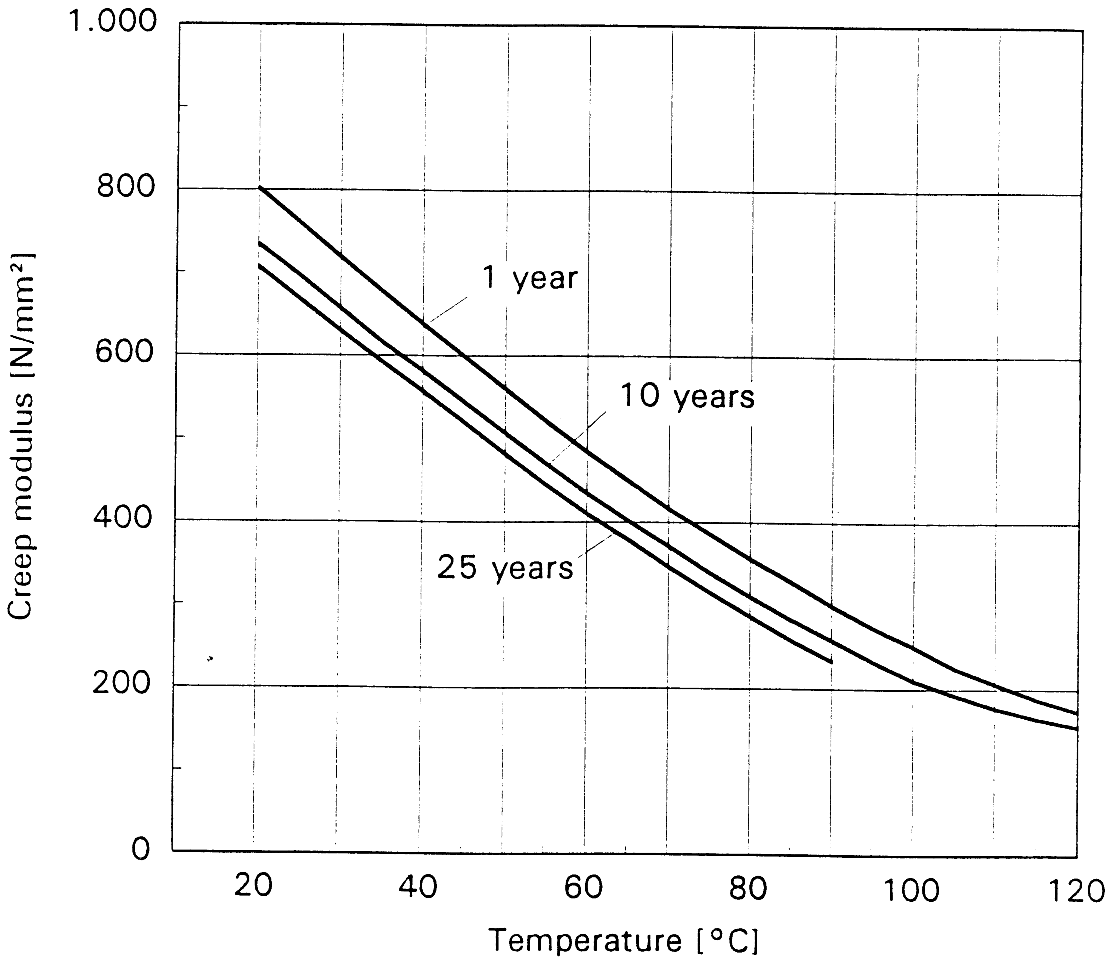


Figure A.26: Creep modulus of polyvinylidene fluoride (PVDF-H) for the stress range σ = 2 to 5 N/mm^2

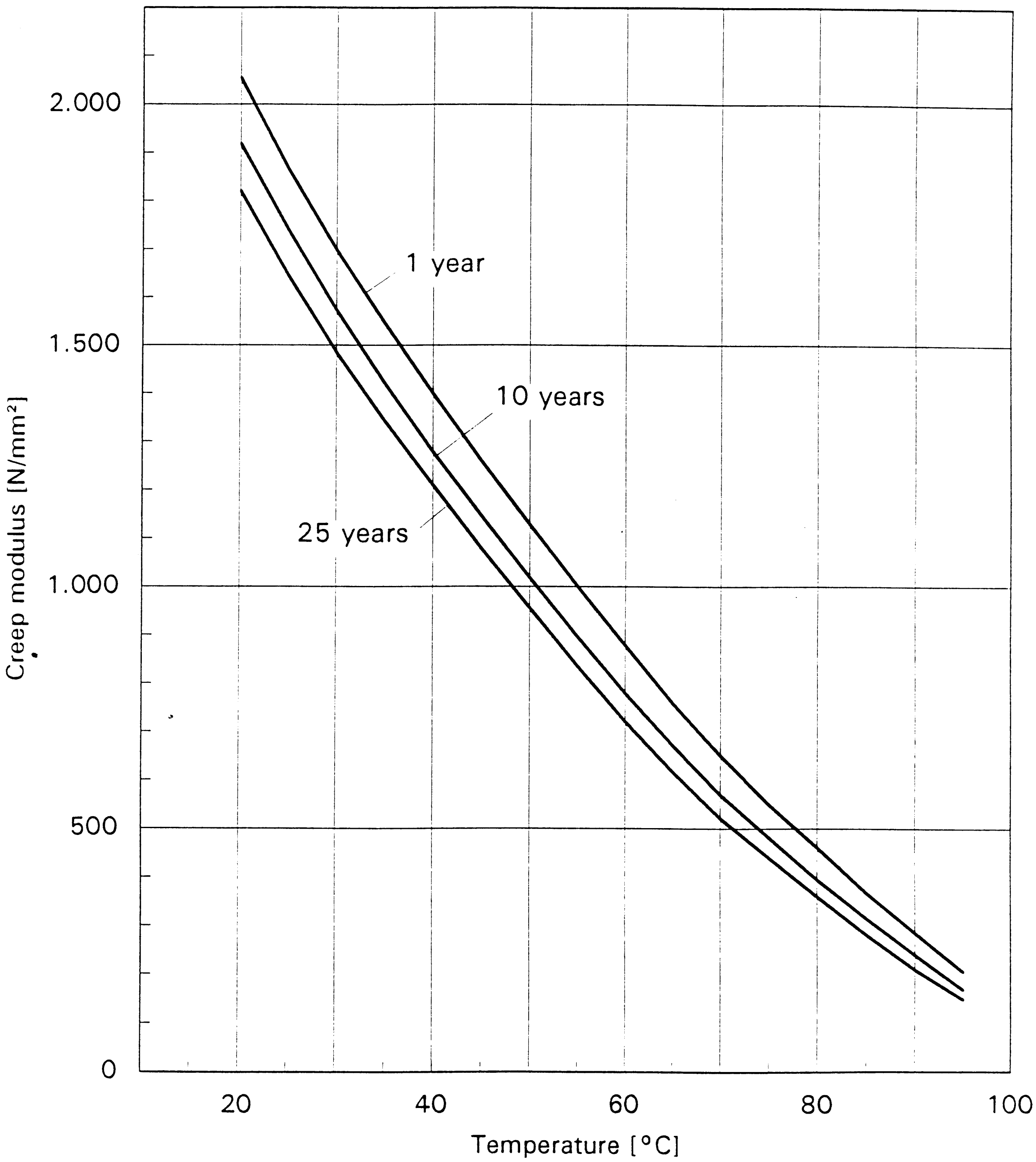


Figure A.27: Creep modulus of chlorinated polyvinylchloride (PVC-C) for the stress range σ = 5 to 20 N/mm^2

A.1.3 Reduction factors allowing for effect of the medium (A_{2K})

Table A.1: Reduction factors allowing for effect of the medium (A_{2K})

Medium	Chemical Formula	[1]	Concentration[2] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Acetic acid [9]	CH_3COOH	O	60	1,85[6,8]	1,72[6,8]	1,43[8]	1,25[8]								
			98	8,33[8]	8,33[8]	7,69[8]	1,67[8]								
Acetoacetic methyl ester	$CH_3COCH_2COOCH_3$	O	100				1,18								
Acetoacetic ethyl ester[9]	$CH_3COCH_2COOC_2H_5$	O	100				1 [7]								
Air	O_2/N_2	I	100	1	1	1	1	1	1	1	1	1	1	1	1
Alkeline solution [4]		M	100				2								
Alum(Me(I)-Me(III)-sulfate [5]		I	≤ S	1	1	1		1	1	1			1	1	1
Aluminium chloride [5]	$AlCl_3$	I	≤ S	1	1	1		1	1	1			1	1	1
Aluminium potassium sulfate [5]	$KAl(SO_4)_2$	I	>10										1	1	1
Aluminium sulfate [5]	$Al_2(SO_4)_3$	I	≤ S	1	1	1		1	1	1			1	1	1
Ammonia, gaseous [5]	NH_3	I	TP	1	1	1		1	1	1			1	1	1
Ammonia, liquid [5]	NH_3	I	TP	1	1	1		1							
Ammonia liquor [5]	NH_4OH	I	≤ S	1	1	1		1	1	1			1	1	1
Ammonium acetate [5]	CH_3COONH_4	M	≤ S	1	1	1		1	1	1					
Ammonium bromide [5]	NH_4Br	I	≤ S	1	1	1		1	1	1			1	1	1
Ammonium carbonate [5]	$(NH_4)_2CO_3$	I	≤ S	1	1	1		1	1	1			1	1	1
Ammonium chloride [5]	NH_4Cl	I	≤ S	1	1	1		1	1	1			1	1	1
Ammonium fluoride [5]	NH_4F	I	>10	1	1	1		1	1	1			1	1	1
Ammonium hydrogen carbonate [5]	$(NH_4)HCO_3$	I	≤ S	1	1	1		1	1	1			1	1	1

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	1)	Concentration[2] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Ammonium nitrate [5]	NH_4NO_3	I	≤ S	1	1	1		1	1	1	1	1	1	1	1
Ammonium phosphate[5]	$NH_4H_2PO_4$	I	≤ S	1	1	1		1	1	1	1	1	1	1	1
Ammonium sulfate [5]	$(NH_4)_2SO_4$	I	≤ S	1	1	1		1	1	1	1	1	1	1	1
Ammonium sulfide [5]	$(NH_4)_2S$	I	≤ S	1	1	1		1	1	1			1	1	1
Antifreeze agents		M	100				1								
			50				1[7]								
Apple juice [5]		O	C	1	1	1		1	1	1	1	1	1	1	1
Barium carbonate [5]	$BaCO_3$	I	≤ S	1	1	1		1	1	1			1	1	1
Barium chloride [5]	$BaCl_2$	I	≤ S	1	1	1		1	1	1			1	1	1
Barium hydroxide [5]	$Ba(OH)_2$	I	≤ S	1	1	1		1	1	1	1	1	1	1	1
Barium nitrate [5]	$Ba(NO_3)_2$	I	≤ S	1	1	1		1	1	1			1	1	1
Barium salts [5]		IM	≤ S	1	1	1		1	1	1	1	1	1	1	1
Barium sulfate [5]	$BaSO_4$	I	≤ S	1	1	1		1	1	1			1	1	1
Barium sulfide [5]	BaS	I	≤ S	1	1	1		1	1	1			1	1	1
Battery acid [5]	H_2SO_4	I	≤ 51	1	1	1		1	1	1			1	1	1
Beer [5]		O	C	1	1	1		1	1	1	1	1	1	1	1
Benzenesulfonic acid[5]		O	40										1	1	1
Benzine [9]	C_5H_{12} to $C_{12}H_{26}$	O	100	1,1[6,8]	1,1[6,8]	1,08[6]	1,06[8]								
Benzol [9]	C_6H_6	O	100	1[6,8]	1[6,8]	1 [8]	1 [8]								
Boric acid [5]		I	TP										1	1	1
Brandy of any kind [5]		O	C	1	1	1		1	1	1			1	1	1

(continued)

ble A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	[1)]	Concentration[2)] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Butanedioic acid [5)]		O	TP										1	1	1
Buttermilk [5)]		O	C	1	1	1		1	1	1	1	1	1	1	1
Cadmium chloride [5)]	$CdCl_2$	I	$\leq$ S	1	1	1		1	1	1			1	1	1
Cadmium cyanide [5)]	$Cd(CN)_2$	I	$\leq$ S	1	1	1		1	1	1			1	1	1
Cadmium sulfate [5)]	$CdSO_4$	I	$\leq$ S	1	1	1		1	1	1			1	1	1
Calcium acetate [5)]	$(CH_3COO)_2Ca$	M	$\leq$ S	1	1	1		1	1	1			1	1	1
Calcium bromide [5)]	$CaBr_2$	I	$\leq$ S	1	1	1		1	1	1			1	1	1
Calcium carbonate [5)]	$CaCO_3$	I	$\leq$ S	1	1	1		1	1	1	1	1	1	1	1
Calcium chloride [5)]	$CaCl_2$	I	$\leq$ S	1	1	1		1	1	1	1	1	1	1	1
Calcium fluoride [5)]	CaF_2	I	$\leq$ S	1	1	1		1	1	1			1	1	1
Calcium hydroxide [5)]	$Ca(OH)_2$	I	$\leq$ S	1	1	1		1	1	1			1	1	1
Calcium nitrate [5)]	$Ca(NO_3)_2$	I	$\leq$ S	1	1	1		1	1	1			1	1	1
Calcium sulfate [5)]	$CaSO_4$	I	$\leq$ S	1	1	1		1	1	1			1	1	1
Calcium sulfide	CaS	I	$\leq$ S	1	1			1	1				1	1	1
Calcium sulfite [5)]	$CaSO_3$	I	$\leq$ S	1	1	1		1	1	1			1	1	1
Carbon dioxide, gaseous [5)]	CO_2	I	any	1	1	1		1	1	1			1	1	1
Carbon tetrachloride [9)]	CCl_4	O	100	1,85[6,7)]	1,67[6,7)]	1,54[7)]	1,43[7)]								
Casein [5)]			TP										1	1	1
Caustic soda solution	NaOH	I	30								1,43		1	1	1
			40										1	1	
			50		1,1		1		1,1				1	1	1

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	1)	Concentration[2)] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Chlorine water	$Cl_2 \cdot H_2O$	I	any	1,4	1,4			1,4	1,4				1	1	
Chloroform [9)]	$ChCl_3$	O	100			2,22									
Chromic acid	H_2CrO_4	I	10	2,04[6)]	1,89	1,61	1,43								
			20	9,1	5	3,57	2,63								
Chromic acid + sulfuric acid	$H_2Cr_2O_4$+H_2SO_4+ H_2O	I	100			>100									
Chromic alum [5)]		I	≤ S										1	1	1
Cider		O	C	1	1	1		1	1	1			1	1	1
Citric acid [5)]	$(CO_2H)CH_2CO_2H$	O	≤ 10	1	1	1		1	1	1	1	1	1	1	1
Common salt solution	NaCl	I	≤ S	1	1	1	1	1	1	1	1	1	1	1	1
Copper(II)-nitrate	$Cu(NO_3)_2$	I	≤ S	1	1			1	1				1	1	1
Copper dichloride [5)]	$CuCl_2$	I	≤ S	1	1	1		1	1	1			1	1	1
Copper monocyanide [5)]	CuCN	I	≤ S	1	1	1		1	1	1			1	1	1
Copper sulfate [5)]	$CuSO_4$	I	≤ S	1	1	1		1	1	1			1	1	1
Decane [9)]	$C_{10}H_{22}$	O	100				1,05[7)]								
Detergents, various		M													
Dextrose [5)]		O	≤ 20	1	1	1		1	1	1			1	1	1
Dichloroethylene [9)]	$CH_2 = CCl_2$	O	100			>100									
Diethylene triaminepenta acetic acid (e. g. Trilon C)		O	100	1,4	1,4			1,4	1,4						

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	1)	Concentration[2] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Dimetyl sulfate	$(CH_3)_2SO_4$	O	100				1,15								
Disinfectants		M	100				1,54								
Effluent from cellulose factory	[4]	M	100				1,05								
Effluent from cellulose factory	alkaline [4]	M	100									1			
	acidic [4]											1			
Effluent from dairy product processing plant [3]		M	100				1,37								
Effluent from man-made-fibre factory [3]		M	100				1,33								
Ethylamine [9]	$CH_3CH_2NH_2$	O	100									1			
Ethylene diamine tetra acetate acid		O	C	1,4	1,4			1,4	1,4						
Ethylene dichloride [9]	$C_2H_4Cl_2$	O	100				1,11								
Ethylene glycol [9]	$CH_2OH{\cdot}CH_2OH$	O	TP		1,1	1,1	1		1,1				1	1	1
Fatty acids		O	TP										1	1	1
Ferrous and ferric chloride [5]	$FeCl_2$ $FeCl_3$	I	≤ S	1	1	1		1	1	1			1	1	1
Ferrous chloride sulfate	$Fe_3(ClSO_4)_2$	I	≤ S		1,1				1,1				1	1	1
Ferrous sulfate [5]	$FeSO_4$	I	≤ S		1,2				1,2				1	1	1
Tetrafluoro boric acid	HBF_4	I	≤ 50	1,4	1,4			1,4	1,4						
Formaldehyde	CH_2O	O	40		1,61										

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	[1]	Concentration[2] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Formic acid	HCOOH	O	≤ 60	1	1			1,4	1,4				1	1	
			≤ 85	1,4											
Fructose (fruit sugar)[5]		O	>10	1	1	1		1	1	1	1	1	1	1	1
Fruit drinks and juices[5]		O	C	1	1	1		1	1	1	1	1	1	1	1
Fuel oil[9]		O	100			1,06[7]									
Glycolic acid[5]		O	30		1,1				1,1				1	1	1
Grape sugar, aqueous[5]		I	≤ 20	1	1	1		1	1	1	1	1	1	1	1
Hexanol[9]	$C_6H_{13}OH$	O	100				1[7]								
Household ammonia[5]	NH_4OH	I	≤ S	1	1	1		1	1	1			1	1	1
Hydraulic fluid[9]		O	100									2,33			
Hydrazine hydrate	$N_2H_4 \cdot H_2O$	O	≤ 24	1	1			1	1				1	1	
Hydrochloric acid	HCl	I	20									1,11	1	1	1
			30								1,75	2,13	1	1	1
			≤ 37		1,2		1,33		1,2				1	1	1
Hydrofluoric acid	HF	I	≤ 75	1,4	1,4			1,4	1,4						
Hydrogel emulsion	(pH value = 9,5)		100									1			
Hydrogen peroxide[5]	H_2O_2	I	≤ 70										1	1	
Hydrogensulfide		I	TP										1	1	1
Hydroxy ethylenediamine triacetate acid (e. g. Trilon D)		O	C	1,4	1,4			1,4	1,4						

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	1)	Concentration[2)] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Hydroxylammonium sulfate [5)]	$(NH_2OH)_2 \cdot H_2SO_4$	I	≤ 12	1	1	1			1	1	1		1	1	1
Iron(III)-chloride sulfate	$FeClSO_4$	I	≤ S	1	1			1	1				1	1	1
Lactic acid [5)]		O	C										1	1	1
Lead acetate [5)]	$Pb(CH_3COO)_2$	I	≤ S					1	1	1			1	1	1
Lead nitrate [5)]	$Pb(NO_3)_2$	I	≤ S										1	1	1
Lead sulfate [5)]	$PbSO_4$	I	≤ S	1	1	1		1	1,1				1	1	1
Liquid fertilizer			C	1	1			1	1						
Lithium sulfate [5)]	Li_2SO_4	I	≤ S										1	1	1
Magnesium carbonate[5)]	$MgCO_3$	I	≤ S	1	1	1		1	1	1			1	1	1
Magnesium chloride [5)]	$MgCl_2$	I	≤ S	1	1	1		1	1	1	1	1	1	1	1
Magnesium hydrogen carbonate	$MgHCO_3$	I	≤ S	1	1	1		1	1	1			1	1	1
Magnesium salts [5)]		IM	≤ S	1	1	1		1	1	1			1	1	1
Magnesium sulfate [5)]	$MgSO_4$	I	≤ S	1	1,1			1	1	1	1	1	1	1	1
Manure salts [5)]		I	≤ S	1	1	1		1	1	1			1	1	1
Mercury chloride	$HgCl_2$	I	≤ S	1	1			1	1				1	1	1
Mercury nitrate	$Hg(NO_3)_2$	I	S	1	1			1	1				1	1	1,1
Mercury salts [5)]		IM	≤ S	1	1	1		1	1	1			1	1	1
Mercury sulfate	$HgSO_4$	I	≤ S	1	1			1	1				1	1	
Methanol [9)]	CH_3OH	O	100			1							1	1	1

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	1)	Concentration[2)] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Methylene dichloride [9)]	CH_2Cl_2	O	100	1,09[6,7)]	1,08[6,7)]	1,06[7)]	1,05[7)]								
Milk [5)]		O	C	1	1	1		1	1	1	1	1	1	1	1
Mineral water [5)]		I	C	1	1	1	1	1	1	1	1	1	1	1	1
Natural gas	Main component CH_4	O	100				1						1	1	1
Natural gas condensate [9)]		O	100				1 [7)]								
Nickel(II)-sulfate [5)]	$NiSO_4$	I	≤ S		1,1				1,1				1	1	1
Nickel nitrate	$Ni(NO_3)_2$	I	≤ S		1,1			1	1				1	1	1
Nickel chloride [5)]	$NiCl_2$	I	≤ S	1	1	1		1	1	1			1	1	1
Nicotinic acid [5)]		O	TP										1	1	1
Nitric acid	HNO_3	I	15								1,67				
			≤ 30										1	1	1
			50								3,13		1,2	1,2	1,2
			53				3,3								
			65				3,3								
Nitric acid and hydrofluoric acid	HNO_3+HF	I	15+4								2				
Nitrilo triacetic acid (Trilon A)		I	C					1,4	1,4						
Octanol [9)]	$C_8H_{17}OH$	O	100		1	1	1								
Oleic acid [5)]		O	TP										1	1	1

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	1)	Concentration[2)] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Olive oil [5,9)]		O	C		1,1				1,1				1	1	1
Oxalic acid [5)]		O	≤S										1	1	1
Oxigen	O_2	I	100				1						1	1	1
Palm oil [6,9)]		O	C										1	1	1
Peanut oil [9)]		O	100				1,37								
Phosphate [5)]		I	≤S	1	1	1		1	1	1			1	1	1
Phosphoric acid	H_3PO_4	I	≤30										1	1	1
			75				1				1,43				
			≤95		1,2		1		1,2		1,43			1,1	
Photo chemicals		I	C	1	1			1	1				1	1	
Polysulfide	Me_2S	I	100				1,33	1	1	1			1	1	1
Potassium borate [5)]	K_3BO_3	I	≤S	1	1	1		1	1	1			1	1	1
Potassium bromate, aqueous [5)]	$KBrO_3$	I	≤10	1	1	1		1	1	1			1	1	1
Potassium bromide	KBr	I	≤S	1	1			1	1				1	1	
Potassium carbonate [5)]	K_2CO_3	I	≤S	1	1	1		1	1	1			1	1	1
Potassium chlorate [5)]	$KClO_3$	I	≤S	1	1	1		1	1	1			1	1	1
Potassium chloride [5)]	KCl	I	≤S	1	1	1		1	1	1			1	1	1
Potassium cyanide [5)]	KCN	I	>10	1	1	1		1	1	1			1	1	1
Potassium fluoride [5)]	KF	I	≤S	1	1	1		1	1	1			1	1	1

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	1)	Concentration 2) %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Potassium hexacyanoferrate(II) and (III) 5)	$K_4[Fe(CN)_6]$, $K_3[Fe(CN)_6]$	I	≤S	1	1	1		1	1	1			1	1	1
Potassium hydrogen carbonate 5)	$KHCO_3$	I	≤S	1	1	1		1	1	1			1	1	1
Potassium hydroxide 5)	KOH	I	≤50	1	1	1		1	1	1				1	1
Potassium hypochlorite	KOCl	I	≤12,5	1,9	1,9			1,9	1,9						
Potassium iodide 5)	KJ	I	≤S	1	1	1		1	1	1			1	1	1
Potassium nitrate 5)	KNO_3	I	≤S	1	1,1			1	1,1				1	1	1
Potassium persulfate 5)	$K_2S_2O_8$	I	≤S										1	1	1
Potassium phosphate 5)	K_3PO_4	I	≤S	1	1	1		1	1	1			1	1	1
Potassium sulfate 5)	K_2SO_4	I	≤S	1	1,1			1	1,1				1	1	1
Seawater 5)		I	C	1	1	1		1	1	1	1	1	1	1	1
Silvernitrate 5)	$AgNO_3$	I	≤S	1	1	1		1	1	1			1	1	1
Silver salts 5)		M	≤S	1	1	1		1	1	1			1	1	1
Sodium aluminium sulfate 5)	$NaAl(SO_4)_2$	I	>10										1	1	1
Sodium carbonate	Na_2CO_3	I	≤50	1	1	1		1	1	1			1	1	1
Sodium acetate 5)	CH_3COONa	M	≤S	1	1	1		1	1	1	1	1	1	1	1
Sodium bisulfite 5)	$NaHSO_3$	I	≤S										1	1	1
Sodium bromide 5)	NaBr	I	≤S	1	1	1		1	1	1			1	1	1
Sodium carbonate, aqueous 5)	Na_2CO_3	I	≤50	1	1	1		1	1	1			1	1	1
Sodium chlorate 5)	$NaClO_3$	I	≤S	1	1	1		1	1	1			1	1	1

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	[1]	Concentration[2] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Sodium chloride [5]	$NaCl$	I	≤S	1	1	1	1	1	1	1	1	1	1	1	1
Sodium chlorite	$NaClO_2$	I	≤S	1,4	1,4			1,4	1,4				1,2	1,2	
Sodium chromate	$Na_2Cr_2O_7$	I	≤S	1	1			1	1				1	1	
Sodium cyanide [5]	$NaCN$	I	≤S		1,1				1,1				1	1	1
Sodium disulfite [5]	$Na_2S_2O_5$	I	≤S										1	1	1
Sodium hydrogencarbonate [5]	$NaHCO_3$	I	≤S	1	1	1		1	1	1	1	1	1	1	1
Sodium hydrogen sulfate [5]	$NaHSO_4$	I	≤S	1	1	1		1	1	1			1	1	1
Sodium hydrogen sulfite [5]	$NaHSO_3$	I	>10	1	1	1		1	1	1			1	1	1
Sodium nitrate [5]	$NaNO_3$	I	≤S	1	1	1		1	1	1			1	1	1
Sodium nitrite [5]	$NaNO_2$	I	≤S	1	1	1		1	1	1			1	1	1
Sodium perborate [5]		I	≤S										1	1	1
Sodium phosphate [5]	Na_3PO_4	I	≤S	1	1	1		1	1	1	1	1	1	1	1
Sodium silicate [5]	(water glas)	I	>10	1	1	1		1	1	1			1	1	1
Sodium sulfate [5]	Na_2SO_4	I	≤S	1	1	1		1	1	1			1	1	1
Sodium sulfide [5]	Na_2S	I	≤S	1	1	1		1	1	1			1	1	1
Sodium sulfite, aqueous [5]	Na_2SO_3	I	≤40	1	1	1		1	1	1	1	1	1	1	1
Sodium tetra borate [5]	$Na_2B_4O_7$	I	≤S	1	1	1		1	1	1			1	1	1
Sodium thiosulfate [5]	$Na_2S_2O_3$	I	≤S	1	1	1		1	1	1			1	1	1

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (continued)

Medium	Chemical Formula	[1]	Concentration[2] %	PE-HD 20 °C	PE-HD 40 °C	PE-HD 60 °C	PE-HD 80 °C	PP 20 °C	PP 40 °C	PP 60 °C	PP 80 °C	PP 95 °C	PVC-NI 20 °C	PVC-NI 40 °C	PVC-NI 60 °C
Stannic chloride [5]	$SnCl_4$	I	≤S	1	1	1		1	1	1			1	1	1
Stannous chloride [5]	$SnCl_2$	I	≤S	1	1	1		1	1	1			1	1	1
Starch [5]		O	any	1	1	1		1	1	1			1	1	1
Stearic acid [5]		O	TP										1	1	1
Sugar syrup [5]		O	C	1	1	1		1	1	1			1	1	1
Sulfuric acid	H_2SO_4	I	40				1						1	1	1
Sulfuric acid	H_2SO_4	I	78		1,4	1	1		1,4		1,67		1	1	1
Sulfuric acid	H_2SO_4	I	85				3,3						1	1	
Sulfuric acid	H_2SO_4	I	90				9,1						1	1	
Sulfuric acid	H_2SO_4	I	95				>100						1	1,1	1,2
Sulfuric acid	H_2SO_4	I	98	10	5,56	7,69	>100								
Tartaric acid [5]		O	≤10	1	1	1		1	1	1			1	1	1
Toluene [9]	$C_6H_5CH_3$	O	100	1,05[7]											
Transformer oil [9]		O	100	1 [6,7]	1 [6,7]	1 [7]	1 [7]								
Triacetin [9]	(glycerol triacetate)	O	100				1						1	1	1
Trichlorofluoromethane[9]	CCl_3F	O	100	1 [6]	1,12 [6]	1,43	1,82								
1,3,5 trimethylbenzene[9]	$C_6H_3(CH_3)_3$	O	100				1,11[7]								
Unfractionated oil [9]		O	100			1 [7]									
Urea [5]	$CO(NH_2)_2$	O	≤S	1	1	1		1	1	1			1	1	1
Urine [5]			C										1	1	1

(continued)

Table A.1: Reduction factors allowing for effect of the medium (A_{2K}) (concluded)

Medium	Chemical Formula	1)	Concentration[2] %	PE-HD				PP					PVC-NI		
				20 °C	40 °C	60 °C	80 °C	20 °C	40 °C	60 °C	80 °C	95 °C	20 °C	40 °C	60 °C
Vegetable oil [9]		O	TP		1,1			1	1				1	1	
Vinegar [5]		O	C	1	1	1		1	1	1	1	1	1	1	1
Water	H_2O	I	100	1	1	1	1	1	1	1	1	1	1	1	1
Water with wetting agent		M	2				1,67								
Wines [5]		M	C	1	1	1		1	1	1			1	1	1
Yeast [5]		O	any	1	1	1		1	1	1			1	1	1
Zinc chloride	$ZnCl_2$	I	≤S	1	1			1	1				1	1	1
Zinc nitrate	$Zn(NO_3)_2$	I	≤S	1	1			1	1				1	1	1
Zinc salts [5]		IM	≤S	1	1	1		1	1	1			1	1	1
Zinc sulfate [5]	$ZnSO_4$	I	≤S		1,1				1,1				1	1	1

1) I: inorganic substances
O: organic substances
M: mixture of inorganic and organic substances

2) S: saturated (at 20 °C) aqueous solution
TP: technically pure medium
C: commercial composition or as occuring in nature

3) Cannot be transferred to other effluent

4) 88,25 parts water, 10 parts sodium perchlorate, 1 part sodium hydroxide, 0,25 parts aniline, 0,25 parts monochlorobenzene, 0,25 parts toluene diamine

5) Based on many years of practical experience, A_2 = 1 (see also 5.1)

6) Values extrapolated according to ISO/TC 138 SC 3 N 382 document

7) For further information see B.4 [6]

8) Only valid for stresses ≤2 N/mm^2

9) Medium causing swelling

Annex B (informative) Explanations and calculation examples

B.1 Explanation to reduction factor A_1

The figures quoted are based on a Charpy Notch Test given in ISO 179/eA at 23 °C. The factor of $A_1 = 1$ is equivalent to a notch energy of 16 kJ/m^2 at 23 °C.

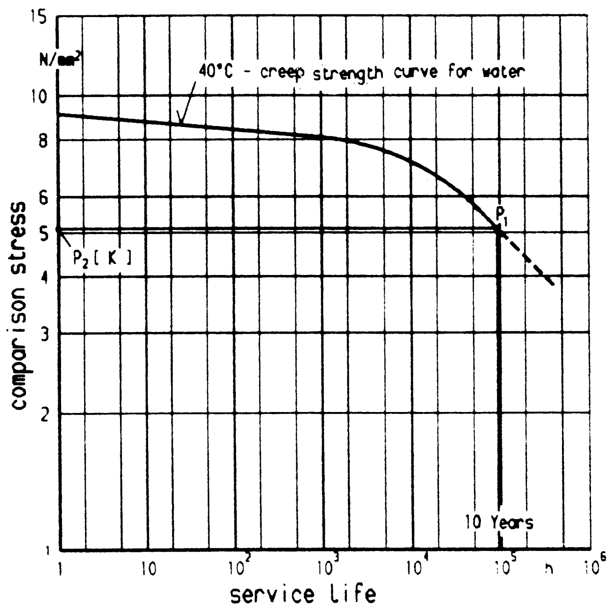
The product of safety factor case 1 and A_1 ($S \times A_1$) is comparable to the safety factor of tubes made from the same material.

B.2 Examples of design calculation

Examples which illustrate the determination of characteristic values of materials for different applications are given below.

B.2.1 Stress coefficient with constant loading

Required:	Creep strength	K
Known:	Design temperature	T = 40 °C
	Required service life	t = 10 years
	Contents of tank	Water



The creep strength K is obtained from the creep strength diagram for pipes, for example pipes made from PE-HD (see Figure B.1). The line for a service life of 10 years intersects the 40 °C creep strength curve for water at point P_1. A line parallel to the X-axis through point P_1 gives point P_2 on the Y-axis and a value of K = 5,1 N/mm^2.

Figure B.1: Determination of the creep strength *K* with constant loading for PE-HD

B.2.2 Design life with intermittent loading

To estimate the design life t_x in the case of intermittent loading, the relevant material creep strength K is initially determined using the effective stresses (σ_{ef}) of the individual fractional loadings and the specified reduction factors A_1 and A_2 as well as the factor of safety S and, if applicable, the weld factor f_l. Equation (B.1) states that:

$$K = \frac{\sigma_{ef} \times A_1 \times A_2 \times S}{f_l} \qquad \textbf{(B.1)}$$

This creep strength is used to read off the relevant service life in the case of fractional loading on the creep strength curve of the material used at the appropriate temperature. With the help of Miner's rule (see equation 4), this can be used to calculate the expected resultant design life t_x.

B.2.3 to B.2.5 illustrate the procedure for various load cases taking simple examples. In these basic examples, K is equivalent to an actual material loading. The design life t_x therefore becomes a time-to-fracture.

B.2.3 Alternating temperatures with constant stress, see Figure B.2

Required: Design life t_x

Known: Creep strength K
Design temperature T_1, T_2

The design life t_x lies between the service lives for fractional loadings t_1 (K, T_1) and t_2 (K, T_2) depending on the proportion of time at the individual temperatures. The line parallel to the stress axis through t_x gives the point P with the stated stress K (P lies on a creep strength curve which would be obtained at a constant temperature T_x between T_1 and T_2).

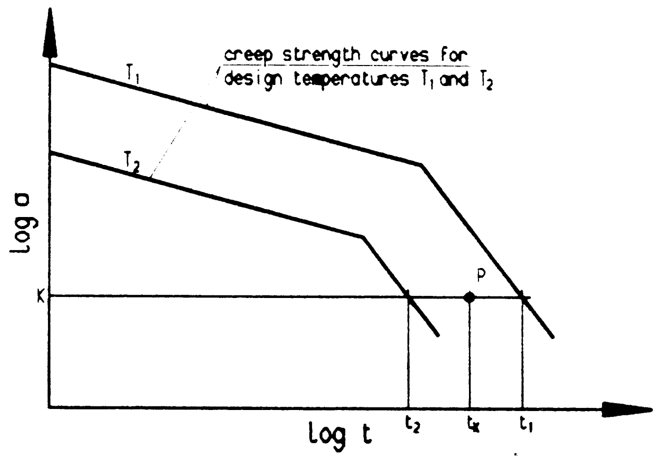


Figure B.2: Service life with alternating temperatures and constant stress

Table B.1: Example for PE-HD, see Figure A.1

Fractional loading	Creep strength K N/mm²	Temperature T °C	Proportion of time a	Service life at fractional loading t years
1	5	30	90 %	80
2		50	10 %	1,5

The expected design life according to equation (4) is:

$$t_x = \frac{100 \times 80 \times 1{,}5}{90 \times 1{,}5 + 10 \times 80} = 12{,}8 \text{ years}$$ [1)]

B.2.4 Alternating stresses with constant temperature, see Figure B.3

Required: Design life t_x

Known: Creep strength K_1, K_2
Design temperature T

The design life t_x lies between the service lives for fractional loadings t_1 (K_1, T) and t_2 (K_2, T) depending on the proportion of time at the individual stresses. The line parallel to the stress axis through t_x intersects the creep strength curve at point P (this gives the equivalent creep strength K_x).

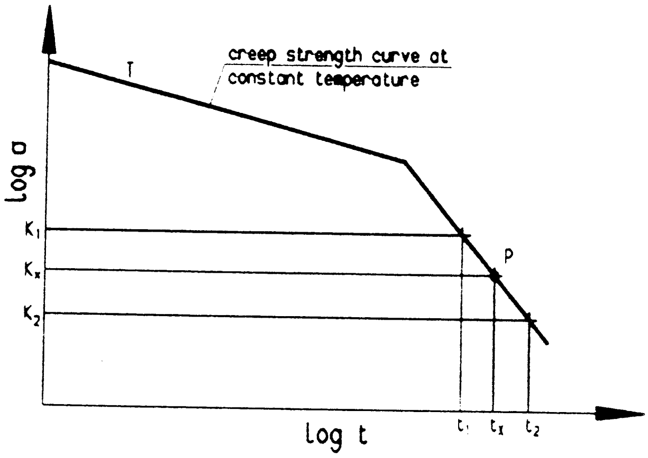


Figure B.3: Service life with alternating stresses and constant temperature

Table B.2: Example for PP-B, see Figure A.6

Fractional loading	Creep strength K N/mm²	Temperature T °C	Proportion of time a	Service life at fractional loading t years
1	3,5	60	20 %	9,1
2	2		80 %	103

The expected design life according to equation (4) is:

$$t_x = \frac{100 \times 9{,}1 \times 103}{20 \times 103 + 80 \times 9{,}1} = 33{,}6 \text{ years}$$ [2)]

[1)] The same design life would be achieved with K = 5 N/mm² and a constant temperature of 40 °C.
[2)] The same design life would be achieved at a temperature of 60 °C and a constant stress K_x = 2,6 N/mm².

B.2.5 Alternating stresses and alternating temperatures, see Figure B.4

Required: Design life t_x

Known: Creep strength K_1, K_2
Design temperatures T_1, T_2

The design life t_x lies between the service lives for fractional loadings t_1 (K_1, T_1) and t_2 (K_2, T_2) depending on the proportion of time at the various working conditions.

Table B.3: Example for PP-H, see Figure A.5

Fractional loading	Creep strength *K* N/mm^2	Temperature *T* °C	Proportion of time *a*	Service life at fractional loading *t* years
1	5	50	75 %	80
2	2	80	25 %	14,3

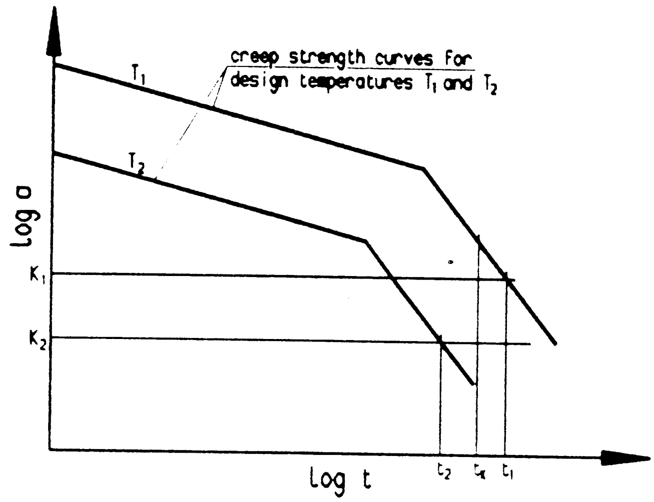


Figure B.4: Service life with alternating stresses and alternating temperatures

The expected design life according to equation (4) is:

$$t_x = \frac{100 \times 80 \times 14,3}{75 \times 14,3 + 25 \times 80} = 37,2 \text{ years}$$

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