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Vodocevni kotli in pomožne napeljave - 4. del: Spremljanje poteka obratovanja in izračuni pričakovane življenjske dobe

Water-tube boilers and auxiliary installations - Part 4: In-service boiler life expectancy calculations

Wasserrohrkessel und Anlagenkomponenten - Teil 4: Betriebsbegleitende Berechnung der Lebensdauererwartung

Chaudieres a tubes d'eau et installations auxiliaires - Partie 4: Calculs de la durée de vie prévisible des chaudieres en service

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Water-tube boilers and auxiliary installations – Part 4: In-service boiler life expectancy calculations

Chaudières à tubes d'eau et installations auxiliaires – Partie 4: Calculs de la durée de vie prévisible des chaudières en service

Wasserrohrkessel und Anlagenkomponenten – Teil 4: Betriebsbegleitende Berechnung der Lebensdauererwartung

This European Standard was approved by CEN on 24 December 1999.

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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
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Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 269, Shell and water tube boiler, the Secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by August 2000, and conflicting national standards shall be withdrawn at the latest by August 2000.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

The standard concerning water-tube boilers and auxiliary installations consists of the following parts:

Part 1: General
Part 2: Materials for pressure parts of boilers and accessories
Part 3: Design and calculation for pressure parts
Part 4: In-service boiler life expectancy calculations
Part 5: Workmanship and construction of pressure parts of the boiler
Part 6: Inspection during construction, documentation and marking of pressure parts of the boiler
Part 7: Requirements for equipment for the boiler
Part 8: Requirements for firing systems for liquid and gaseous fuels for the boiler
Part 9: Requirements for firing systems for pulverized solid fuels for the boiler
Part 10: Requirements for safeguards against excessive pressure
Part 11: Requirements for limiting devices, and safety circuits of the boiler and accessories
Part 12: Requirements for boiler feedwater and boiler water quality
Part 13: Requirements for flue gas cleaning systems
Part 14: Requirements for flue gas DENOX-systems
Part 15: Acceptance tests
Part 16: Requirements for grate and fluidized bed firing systems for solid fuels for the boiler

Although these parts may be obtained separately, it should be recognized that the parts are inter-dependent. As such, the design and manufacture of boilers requires the application of more than one part in order for the requirements of the standard to be satisfactorily fulfilled.

The annexes A and B of this European Standard are informative.

1 Scope

This part of the European Standard applies to water-tube boilers as defined in prEN 12952-1:1997.

This part describes procedures for calculating the creep and/or the fatigue damage of boiler components during operation. These calculations are not required to be carried out by the manufacturer as part of his responsibilities within this standard.

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

prEN 12952-1:1997
Water-tube boilers and auxiliary installations – Part 1: General

prEN 12952-3:1997
Water-tube boilers and auxiliary installations – Part 3: Design and calculation for pressure parts

3 Definitions

For the purposes of this standard the definitions given in prEN 12952-1:1997 apply.

4 Symbols and abbreviations

For the purposes of this standard, the symbols and abbreviations indicated in table 4-1 of prEN 12952-1:1997 shall apply.

5 General

The calculations may be carried out, using transposed design equations. The measured (actual) wall thickness of the components shall be used in the calculations, i.e. taking into account any wall thickness reduction that may have occurred due to corrosion or erosion during the service life up to the time of the analysis, see 5.7 of prEN 12952-3:1997.

Operating temperature, pressure and especially the magnitude of load changes often differ from the estimations used for the design. Thus, these calculations may help to prevent unexpected early failure of components. The results may be used as a guideline for the decision to inspect a component for fatigue cracks or to inspect for creep pores by the replica method or any other suitable method.

NOTE: In some cases, the influence of both creep and fatigue damage will be significant. It is normally conservative to combine the creep and fatigue damage mechanisms by adding the calculated usage factors. If necessary, more detailed methods of assessment may be used (see [1] PD 6539 Published by British Standards Institution, London, UK). Thus, the components are not necessarily to be replaced, if the calculated usage factor exceeds the value of 1.

The highest loaded components shall be chosen for monitoring purposes.

6 Calculations

Annex A describes the creep damage calculation. Annex B describes the fatigue damage calculation.

Annex A
(informative)

Calculation of in-service creep damage

A.1 General

This annex describes a procedure for calculating the creep damage of boiler and major components during operation. It is based on measured values of pressure and temperature, from which the actual primary stress and the expected lifetime at these conditions may be determined.

Design lifetime is not necessarily identical with the operating lifetime. It is therefore necessary to make projections at various stages throughout the operating lifetime of the boiler to determine its expected lifetime.

A.2 Symbols and abbreviations

In addition to the symbols given table 4-1 of prEN 12952-1:1997 the symbols given in table A.2-1 apply.

Table A.2-1: Symbols

Symbol	Description	Unit
f_{op}	Membrane stress at operating conditions	N/mm^2
T_{op}	Operated time at operating conditions	h
T_{al}	Time to reach the theoretical rupture by creep	h
D_c	Creep damage	–

A.3 Calculation of in-service lifetime and creep damage

A.3.1 General

The calculation of the usage factor due to creep is a method that retrospectively takes into consideration the previous modes of operation. It is carried out for highly loaded components on the basis of the measured operating temperatures and gauge pressures.

In order to limit the number of the required calculations and to more clearly present the results, the pressure and temperature range over which the component has been operated, shall be broken down into increments.

The membrane stress f_{op} at the highest loaded point in the component shall be obtained by transposing the design formula using the mean pressure of each pressure increment. If the operating pressure is not measured continuously during operation the separation into increments is not valid and under such circumstances the operating pressure for 100 % load may be used, thus resulting in more conservative predictions. If available, the measured minimum wall thickness may be used. If this was not measured, the guaranteed minimum wall thickness of the material as delivered shall be used.

The theoretical lifetime T_{al} shall be calculated for each rating temperature/pressure. According to figure A.3-1 T_{al} is obtained at the intersection of the stress line f_{op} and the lower limit curve of the scatter band of the creep rupture strength (= 0,8 $R_{m\,T\,tc}$) at the mean temperature of each temperature increment.

The respective portion of the creep damage $\Delta D_{ci\,k}$ for each incremental temperature/pressure is obtained by the ratio of the operating time T_{op} for this increment divided by the theoretical lifetime T_{al} for the same increment.

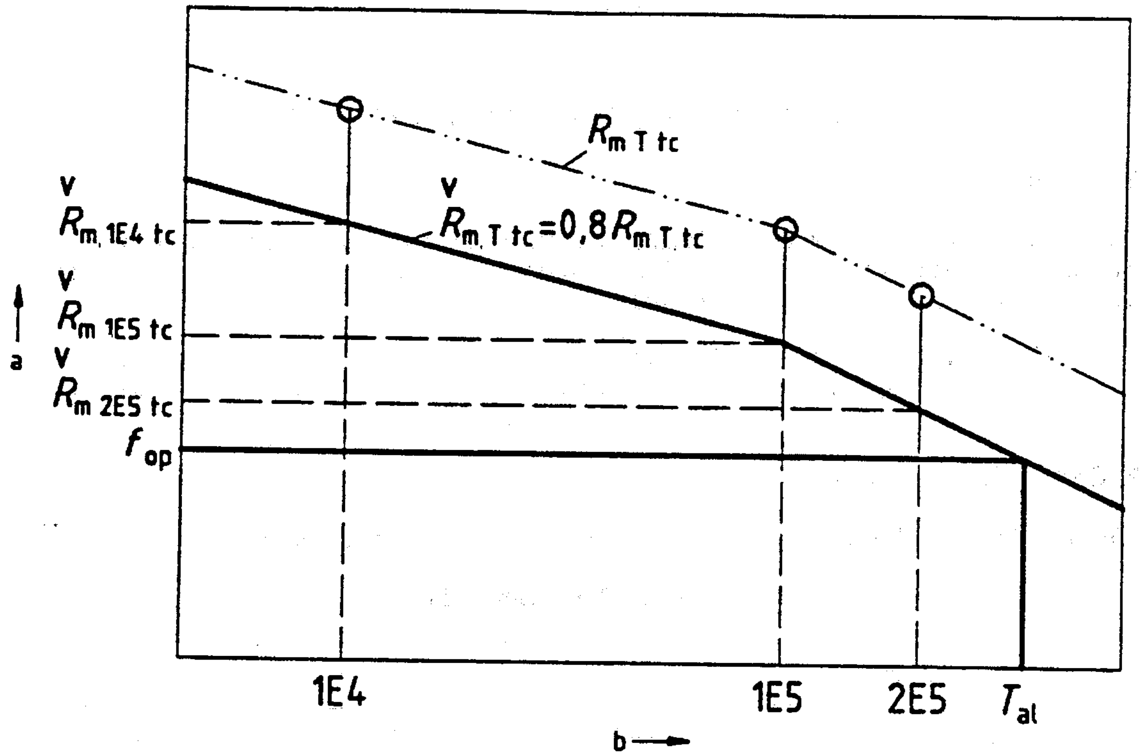

Figure A.3-1: Diagram for the determination of T_{al}

The operating times in the temperature/pressure increment shall be summarized, taking into account the temperature allowances for measuring uncertainties and for temperature asymmetries in due consideration at this classification.

The usage portion for each increment is given by:

$$\Delta D_{ci\,k} = \frac{T_{op}}{T_{al}} \tag{A.3-1}$$

The creep damage D_c during the evaluated period shall be obtained from the linear damage rule by summing up the values $\Delta D_{c\,i\,k}$ for all temperature increments and, if any, pressure as follows:

$$D_c = \sum_i \sum_k \Delta D_{ci\,k} \tag{A.3-2}$$

A.3.2 Online computerized data storage

In the case of on-line data storage by means of a data processing system a separation into increments may be waived. For calculation of the theoretical lifetime T_{al} the on-line measured values of pressure and temperature including the above mentioned allowances shall be used instead of the mean values of the increments. The increase of creep damage is obtained in this case from the measured time divided by the theoretical lifetime (see table A.3-1 and A.3-2).

The computer program used shall permit the results to be verified by at least a random test.

Table A.3-1: Summation of data for the calculation of in-service creep damage

User and boiler plant:	XY	
Power station:	XY	
Boiler:	3	
Works-No.:	12345	
Year built:	1999	
Maximum allowable pressure	HP: 84 bar	Reheater: - bar
Superheated steam temperature:	HP: 525 °C	Reheater: - °C
Steam output:	128 t/h	

1	2	3	4	5	6	7	8	9	10	11	12	13
No.	Component Material; Steel group	[a]	[b]	d mm	[c]	e_s mm	e_{rs} mm	p_c bar	t_o °C	t_c °C	f_{ap} N/mm²	T_{al} 10^3 h
1	HP-line 13 CrMo 44; 5.1	m	A B	292,0	o	24,0	21,0	75,5	525	530	48,7	208
2	Superheater 2 – header 13 CrMo 44; 5.1	n	A B	419,0	o	39,0	39,0	75,5	510	525	56,3	186
3	Superheater 2 – outlet line 13 CrMo 44; 5.1	n	A B	241,0	o	17,5	17,5	75,5	510	525	48,2	304
4	Superheater 2 – outlet header 16 CrMo 44; 5.1	n	A B	250,0	i	20,0	28,0	75,5	510	525	47,1	329
7	Fitting at control 20 Mo 3; 1.2	m	A B	225,0	i	28,0	20,0	80,4	460	465	86,6	> 500
11	Superheater 1 – outlet line 16 Mo 3; 1.1	n	A B	241,0	o	14,0	14,0	80,4	460	475	65,2	> 500
12	Superheater 1 – outlet header 20 Mo 3; 1.2	n	A B	250,0	i	22,0	22,0	80,4	460	475	67,0	> 500

[a] Column 3: Temperature allowances according to table 6.1-1 of prEN 12952-3:1997

m unheated = mixed or controlled (+ 5 °C)
n unheated (+ 15 °C)

[b] Column 4: A Nominal or design values
B Operational or actual values

[c] Column 6: i Inside diameter
o Outside diameter

Table A.3-2: Summation of data for the calculation of in-service creep damage

User and boiler plant:	XY
Power station:	XY
Boiler:	6
Works-No.:	12345
Component:	Connecting pipes between primary superheater and secondary superheater ∅ 90 × 8
Commissioning:	1999
Material:	Steel group 5.1 (13 CrMo44)
Calculation pressure p_c:	100 bar
Mean wall temperature t_c:	530 °C
Stress at p_c:	57,5 N/mm^2
Evaluated period:	from to

1	2			3	4	5	6	7
Evalu-ation range	At outlet of component t_0			Opera-ting pressure p_c	Operating temperature t_c	Related to mean wall temperature T_{al}	Elapsed operating time T_{op}	Creep damage for evaluated period ΔD_c
	from	to	mean					
	°C			bar	°C	10^3 h	h	%
1		< 500	< 500	100	515	430	1 250	0,29
2	500	510	505	100	520	260	820	0,31
3	510	515	512,5	100	527,5	162	6 800	4,20
4	515	520	517,5	100	532,5	106	5 760	5,45
5	520	525	522,5	100	537,5	80	610	0,76
						Sum for evaluated period	15 240	11,01
						Sum prior to evaluated period	20 000	14,00
						Total	35 240	25,01

Annex B
(informative)

Calculation of in-service fatigue damage

B.1 General

This annex describes a procedure for calculating the low cycle fatigue damage of boiler components during operation. It is based on measured values of temperature, temperature difference, pressure, strain, displacement etc. from which the actual stress may be determined.

In order to carry out this analysis it is essential that a computerized data logging system shall be employed.

B.2 Symbols and abbreviations

In addition to the symbols shown in table 4-1 of prEN 12952-1:1997 and 13.2 and B.3 of prEN 12952-3:1997 the following symbols and abbreviations of table B.2-1 shall be used.

Table B.2-1: Symbols and abbreviations

Symbol	Description	Unit
ε	Strain	–
σ	Stress	N/mm^2
σ_1, σ_2, ...	Successive values of σ	N/mm^2
x	Relative extreme value of the stress (maximum or minimum)	N/mm^2
x_1, x_2 ...	Successive values of x (shall be alternating maxima or minima)	N/mm^2
Δx_e	Upper limit of stress range that does not cause fatigue damage (elastic stress range ≈ 190 N/mm^2, depends on material and temperature)	N/mm^2
LC	Boolean Value: LC = 'true': there is a load cycle LC = 'false': there is no load cycle	–

B.3 Calculation of stress due to fatigue

B.3.1 General

Fatigue is a phenomenon of material failure, that occurs as a result of repeated variations of the stress. Therefore the actual stress at the highly loaded points of the boiler components, where fatigue is expected to occur, shall be determined continuously in short time steps, (e.g. 1 minute intervals), from measured values of pressure p, and temperature differences Δt etc. so that relative maximums and minima can be determined with sufficient accuracy.