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Wasserrohrkessel und Anlagenkomponenten - Teil 3: Konstruktion und Berechnung für drucktragende Teile

Chaudières à tubes d'eau et installations auxiliaires - Partie 3: Conception et calcul des parties sous pression

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Water-tube boilers and auxiliary installations - Part 3: Design and calculation for pressure parts of the boiler

Chaudières à tubes d'eau et installations auxiliaires - Partie 3: Conception et calcul des parties sous pression de la chaudière

Wasserrohrkessel und Anlagenkomponenten - Teil 3: Konstruktion und Berechnung für drucktragende Kesselteile

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Foreword

This document (EN 12952-3:2011) has been prepared by Technical Committee CEN/TC 269 “Shell and water-tube boilers”, 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of an identical text or by endorsement, at the latest by June 2012, and conflicting national standards shall be withdrawn at the latest by June 2012.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 12952-3:2001.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive 97/23/EC, see informative Annex ZA, which is an integral part of this document.

Annex E provides details of significant technical changes between this European Standard and the previous edition.

The European Standard series EN 12952 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 of the boiler;*

— *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 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 using liquified pressurized ammonia and ammonia water solution;*

— *Part 15: Acceptance tests;*

— *Part 16: Requirements for grate and fluidized-bed firing systems for solid fuels for the boiler;*

— *CR 12952 Part 17: Guideline for the involvement of an inspection body independent of the manufacturer.*

NOTE 1 A Part 18 on operating instructions is currently in preparation.

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

NOTE 2 Part 4 and Part 15 are not applicable during the design, construction and installation stages.

NOTE 3 A "Boiler Helpdesk" has been established in CEN/TC 269 which may be contacted for any questions regarding the application of European Standards series EN 12952 and EN 12953, see the following website: http://www.boiler-helpdesk.din.de

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard specifies the requirements for the design and calculation of water-tube boilers as defined in EN 12952-1.

The purpose of this European Standard is to ensure that the hazards associated with water-tube boilers are reduced to a minimum by the proper application of the design according to this part of EN 12952.

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.

EN 1092-1:2007, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, PN designated — Part 1: Steel flanges*

EN 1759-1:2004, *Flanges and their joints — Circular flanges for pipes, valves, fittings and accessories, Class designated — Part 1: Steel flanges NPS ½ to 24*

EN 10028-1:2007+A1:2009, *Flat products made of steels for pressure purposes — Part 1: General requirements*

EN 10164:2004, *Steel products with improved deformation properties perpendicular to the surface of the product — Technical delivery conditions*

EN 10266:2003, *Steel tubes, fittings and structural hollow sections — Symbols and definitions of terms for use in product standards*

EN 12952-1:2001, *Water-tube boilers and auxiliary installations — Part 1: General*

EN 12952-2:2011, *Water-tube boilers and auxiliary installations — Part 2: Materials for pressure parts of boilers and accessories*

EN 12952-5:2011, *Water-tube boilers and auxiliary installations — Part 5: Workmanship and construction of pressure parts of the boiler*

EN 12952-6:2011, *Water-tube boilers and auxiliary installations — Part 6: Inspection during construction; documentation and marking of pressure parts of the boiler*

EN 12952-12:2003, *Water-tube boilers and auxiliary installations — Part 12: Requirements for boiler feedwater and boiler water quality*

EN 12953-3:2002, *Shell boilers — Part 3: Design and calculation for pressure parts*

EN 13445-3:2009, *Unfired pressure vessels — Part 3: Design*

EN 13480-3:2002, *Metallic industrial piping — Part 3: Design and calculation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12952-1:2001 apply.

4 Symbols and abbreviations

For the purposes of this document, the symbols given in EN 12952-1:2001, Table 4-1 apply. Throughout this European Standard, additional terminology and symbols have been included where necessary to meet the requirements of the specific text concerned.

5 General

5.1 Purpose

Water-tube boiler pressure parts shall be designed in accordance with the requirements of this European Standard. The resulting designs shall be reproduced in the form of approved drawings and specifications to ensure the proper application of the design requirements during the manufacturing and inspection stages.

5.2 Dimensions of pressure parts

The wall thickness and other dimensions of pressure parts sufficient to withstand the calculation pressure at calculation temperature for the design lifetime shall be determined in accordance with this European Standard using materials in accordance with EN 12952-2:2011.

The design for loadings arising from the following situations shall also be determined in accordance with this European Standard:

a) the bending of a drum or header as a beam under self weight and imposed loads;

b) local support loads on drums;

c) thermally induced forces and moments within or arising from systems of integral tubing;

d) local loading of tubes by structural attachments;

e) rapid and frequent changes of pressure and temperature.

Methods for calculating stresses caused by external loads applied to nozzles and to attachments shall be in accordance with EN 13445-3:2009.

NOTE The purpose of this part is to give specific design rules for common forms of loadings to which boiler parts are normally subjected to and general rules on how other loadings are to be considered. It does not give specific design rules for loadings other than those described in a) to e).

These design rules are adequate for boilers of established construction, installed and operated in accordance with the manufacturer's instructions.

Determination of the dimensions of pressure parts shall be given special consideration not included in this European Standard, when abnormal conditions are present, such as:

— abnormally high corrosive products of combustion;

— highly pressurized products of combustion;

— poor feedwater.

Deviations from the requirements of this European Standard by the use of alternative design methods shall be permitted, provided it can be shown that the adoption of such methods does not impair the safety of the component. A record of all deviations shall be recorded in the manufacturer’s dossier. See also EN 12952-1:2001, Clause 7.

5.3 Strength of pressure parts

The strengths of the pressure parts shall be such as to withstand the following loads:

a) internal pressure;

b) the weight of all pressure parts and their contents, the weight of components suspended from them and any superimposed slag, fuel, ash or dust;

c) loads caused by gas pressure differentials over the boiler furnace and flue gas passes;

d) loads arising at connections between the boiler system and other parts.

If applicable, the pressure parts shall be adequate to withstand wind and earthquake loads. The conditions applicable for such loads shall be determined by the customer. These determinations shall be considered by the manufacturer under his responsibility.

5.4 Design by analysis

It shall be permissible to design by analysis provided the safety and functional requirements of the components are not impaired.

The results of any stress calculations carried out for loadings not explicitly covered by equations in this Clause 5 shall be determined by using the criteria given in EN 13445-3:2009.

5.5 Cyclic loading

Boiler components are deemed to be exposed to cyclic loading if the boiler is designed for more than 500 cold start-ups. Where cylindrical or spherical pressure parts with openings are subject to cyclic loading, the following calculation for the allowable temperature change rate v_t shall be carried out:

$$v_t = \left(X - p_o \left(\frac{\alpha_m \times d_m}{n_s \times e_{ms}} - 0{,}5 \right) \right) \frac{Z}{e_{ms}^2} \qquad (5.5\text{-}1)$$

where

v_t allowable rate of temperature change in K/s;

p_o is the maximum operating pressure;

d_m is the mean diameter of the shell;

e_{ms} is the minimum wall thickness;

n_s = 2 for cylindrical shells or

n_s = 4 for spherical shells;

α_m = 4 or if there is any doubt that this value is conservative, the exact value α_m for cylindrical shells taken from Figure 13.4-5 or α_{sp} for spherical shells, taken from Figure 13.4-7 shall be used;

X = 550 N/mm^2;

Z = 2 K mm^4/(Ns) for ferritic steels, or

Z = 1 K mm^4/(Ns) for austenitic and martensitic steels, or

$$Z = -\frac{0{,}5 D_{th}}{\gamma_{cyl/sp} \alpha_t \beta_t E/(1-\nu)} \qquad (5.5\text{-}2)$$

where exact values D_{th}, β_t, E, ν may be taken from Annex D, $\gamma_{cyl/sp}$ from Figures 13.4-6 or 13.4-9 and α_t from Figure 13.4-8.

If the result of this calculation is smaller than the required temperature transient at start-up, or if it is negative, then 13.4 shall apply.

For designs subject to cyclic loading, careful attention shall be paid to the design configuration in order to avoid stress raising features and to ensure good stress distribution. Stamping of materials shall not be done in critical areas.

In considering operating conditions, the design shall make adequate allowance for corrosion and fatigue.

The level of non-destructive testing adopted shall meet the acceptance criteria for main drum welds in EN 12952-6:2011.

5.6 Other design requirements

5.6.1 General

In particular, cognizance shall be taken of the following requirements in EN 12952-5:2011 and EN 12952-6:2011:

a) the design shall be such that manufacturing and welding in accordance with EN 12952-5:2011 and inspection in accordance with EN 12952-6:2011 shall be possible;

b) where partial penetration welds are to be used, the depth of the required weld preparation groove shall be specified on the drawing;

c) the welds attaching branches, nozzles, stubs and supports to drums and headers shall not involve any combination of austenitic and ferritic steel;

d) the requirements covering the attachment of nozzles and branches to drums and headers without strength welding shall be in accordance with EN 12952-5:2011, 9.3;

e) the requirements covering tube connections to drums and headers without strength welding shall be in accordance with EN 12952-5:2011, 9.4;

f) limits of operation for nodular graphite cast iron valves and fittings;

g) where random NDE of welds is permitted by EN 12952-6:2011, it shall be demonstrated that the welding is adequate for the imposed loading when a weld joint factor of 0,85 is applied;

h) the special requirements applicable to coil boilers are given in EN 12952-5:2011, Annex D;

i) the special requirements applicable to chemical recovery boilers are given in EN 12952-5:2011, Annex E.

For major components operating in the creep range, facilities shall be provided for monitoring the creep in relation to operation.

5.6.2 Access

The boiler shall be designed to ensure adequate access is provided to facilitate the internal examination of the drums and headers. The examination may be either manual or remote in accordance with the physical size of the components. The requirements and limitations of access and inspection openings shall be in accordance with EN 12952-5:2011, 9.2.

5.6.3 Drainage and venting

The boiler shall be provided with adequate means of drainage and venting in order to avoid water hammer and vacuum collapse, and to enable internal inspections to be carried out.

5.7 Design, calculation and test pressures

5.7.1 Design pressure

For the purpose of EN 12952-3 the design pressure p_d shall be equal to/or greater than the maximum allowable pressure PS.

For each compartment of the water-tube boiler, the design pressure shall be at least the highest set pressure of any safety valve mounted on that compartment.

NOTE A compartment is any pressurized section of plant which can be isolated by shut-off valves.

5.7.2 Calculation pressure

Each compartment may be divided into sections, each with its own calculation pressure p_c and calculation temperature t_c. The design of each section shall be based on one of the following:

a) for parts whose design stress has been derived from tensile strength R_m or minimum yield proof strength $R_{p0,2\,tc}$ the calculation pressure shall be the design pressure increased to the highest pressure possible when the plant is operating at the calculation temperature. Any difference between design pressure and calculation pressure might be caused by hydrostatic pressure and by pressure drop caused by fluid flow. Differences in hydrostatic height less than or equal to 0,05 MPa can be ignored;

b) for parts whose design stress has been derived from the creep rupture strength, the calculation pressure shall be the lowest set pressure of any safety valve at the superheater/reheater outlet, as appropriate, increased by the highest pressure difference possible under maximum continuous rating conditions.

A check shall be made of the thickness calculated by method b), using the calculation pressure of a) above with a design stress derived from tensile strength R_m or minimum yield/proof strength $R_{p0,2\,tc}$ at the calculation temperature used in b), and the greater thickness used.

If the minimum yield strength data at higher temperatures are not available, linear extrapolation may be allowed.

5.7.3 Calculation pressure for pressure differences

For parts with a design pressure not less than 1 MPa, which are simultaneously subject to both internal and external pressure, e.g. surface type attemperators in boiler drums, and where the design ensures that both pressures always occur together, the calculation pressure shall be the maximum pressure difference, but not less than 1 MPa. The loading occurring during hydrostatic testing shall be taken into account.

5.7.4 Hydrostatic test

5.7.4.1 General

In order to demonstrate the strength and integrity of individual components and of the completely assembled water-tube boiler, and to establish that no major error or defect has occurred, completely assembled water-tube boilers shall be hydrostatically tested to the test pressure specified in 5.7.4.2 and individual components shall be hydrostatically tested in accordance with 5.7.4.2 without any sign of weakness or defect.

The hydrostatic tests shall be carried out on welded components or the completed water-tube boiler after all welding and heat treatment has been completed, but may be carried out prior to the drilling of holes for expanded tubes in the boiler drum.

All components which are not reasonably accessible for inspection after assembly into the water-tube boiler shall be individually hydrostatically tested to the test pressure specified in 5.7.4.2 before assembly into the water-tube boiler.

5.7.4.2 Test pressure

A boiler assembly comprises of a number of components each having its own specific calculation pressure p_c and calculation temperature t_c. The test pressure p_t for components as defined in 5.7.4.1 shall be determined directly in accordance with 5.7.4.3.

As there can be only one hydrostatic test pressure for a boiler assembly or separately isolated compartment as defined in EN 12952-1:2001, 1.2, it shall be necessary to carry out a series of individual calculations on selected components throughout the assembled boiler or isolated compartment, if applicable, in accordance with 5.7.4.3, to determine the individual apparent test pressure for each selected component. The hydrostatic test pressure for the whole assembly shall be the pressure which ensures that none of the components selected shall be subjected under test conditions to a stress greater than that given in 6.3.7.

Where the hydrostatic test is harmful or impractical, other tests of a recognized value may be carried out. For tests other than the hydrostatic pressure test, additional measures, such as non-destructive tests or other methods of equivalent validity, shall be applied before those tests are carried out.

5.7.4.3 Calculation of hydrostatic test pressure

The hydrostatic test pressure for a component or completely assembled boiler shall be determined as follows:

$$p_t = 1{,}43 \cdot PS \tag{5.7-1}$$

or

$$p_t = 1{,}25 \cdot PS \cdot \frac{R_{p0,2\,20}}{R_{p0,2\,t_c}} \tag{5.7-2}$$

whichever is the greater, where

p_t is the test pressure for the component under consideration;

PS is the maximum allowable pressure or if higher the calculation pressure for the component under consideration.

The ratio $R_{p0,2\,20}/R_{p0,2\,tc}$ or in the case of austenitic steels, if its elongation after rupture exceeds 30 %, the ratio $R_{p1,0\,20}/R_{p1,0\,tc}$ to be used shall be the lowest of those permitted for the components under consideration, based on the material properties and the specific calculation temperature and should not be less than 1, see also 6.3.

If the minimum yield strength data at higher temperatures are not available, linear extrapolation may be allowed.

5.8 Metal wastage[1)]

5.8.1 Internal wastage

Internal wastage is normally small and shall not be considered for boilers operated with feedwater in accordance with EN 12952-12:2003. For components exposed to risk of greater than normal wastage (e.g. erosion by turbulence), appropriate countermeasures shall be provided.

The magnetite layer shall be protected in accordance with 13.4.1.1.

5.8.2 External wastage

External wastage of pressure parts not exposed to flue gases is normally small, and the thickness determined by this European Standard shall be adequate without further addition.

Tubes exposed to flue gases shall experience wastage to a varying extent. If the boiler design data indicates that wastage can be significant, the tubes shall be increased in thickness accordingly. In addition, other means of tube protection may occur. In this case the wall thickness allowance shall be specified by the manufacturer unless the purchaser has specified a higher allowance.

It shall be permitted to take account of wastage by means of metallurgically bonded, composite material tubing with corrosion resistant layers.

5.8.3 Requirements

Where an allowance for wastage is made, the amount shall be specified in the design documents stipulating whether this allowance is "internal or external". Strength calculations shall use the dimensions after the wastage allowances are removed.

However, for tubes designed using design strengths derived from creep rupture properties, integration over time of the effects of creep and wastage shall be permitted, so that failure can be predicted at a time not less than the design lifetime. In such cases the tube thickness towards the end of the design life might be less than required by Equations (11.2-2 to 11.2-5).

5.8.4 Stress corrosion

With boiler water quality controlled in accordance with EN 12952-12:2003, stress corrosion would not be expected to occur in ferritic tubing under normal boiler operating conditions. The risk of such corrosion in austenitic superheater materials can be satisfactorily reduced by ensuring no water droplets are carried over into the austenitic tubing. Carry over can be considered to have been adequately restricted if the steam has an enthalpy of 2 900 kJ/kg or greater, or the enthalpy corresponds to a temperature of 425 °C or higher.

Where it is predicted that exceptional conditions of chemical concentration may occur for prolonged periods of operation, the effects of stress corrosion and corrosion gouging shall be considered, and the materials selected accordingly.

NOTE It is not possible to compensate for stress corrosion by increasing the thickness of components.

5.8.5 Mechanical requirements

Where there is a likelihood of in-service relative movement or fretting between a pressure part and a non-pressure part in contact with it, consideration shall be given to wastage of the components. If necessary, wear-pads shall be welded to the pressure part, or other equivalent means shall be employed.

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1) For the purpose of design in accordance with this European Standard, metal wastage includes oxidation, corrosion, erosion and abrasion.

5.9 Attachment on pressure parts

5.9.1 Load carrying attachments

Load carrying attachments shall be defined by the design engineer and indicated as such on the drawing.

Load carrying attachments are:

a) attachments designed for primary loads which are completely definable and are usually for support purposes, or

b) attachments which are usually provided for alignment and/or restraint purposes where the loading is not easily defined. Such attachments may be loaded by either primary or secondary loads.

Stresses caused by load carrying attachments not covered in 11.5 shall be calculated in accordance with EN 13445-3:2009.

5.9.2 Non load carrying attachments

Non load carrying attachments are attachments which carry no significant loads during manufacture, erection, testing or any operating condition.

6 Calculation temperature and nominal design stress

6.1 Calculation temperature

6.1.1 General

For the purpose of EN 12952 the maximum allowable temperature TS shall be that at the steam/hot water outlet.

The reference temperature t_{or} shall the mean fluid operation temperature of the component under consideration, which is to be expected during use.

Where steam or water flows through components in parallel, t_{or} for each component shall take account of variations in heat transfer and fluid flow between the parallel parts.

The calculation temperature t_c of a component may be calculated by taking account of variations in heat transfer and fluid flow in the boiler. If such calculations are not carried out then the calculation temperature t_c shall be composed of the reference temperature t_{or} and the temperature allowance in accordance with 6.1.2 to 6.1.10. The temperature allowances in Table 6.1-1 shall be regarded as minimum values, except where calculations of t_c are carried out, and is allowed by 6.1.5.