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Water-tube boilers and auxiliary installations - Part 15: Acceptance tests

Wasserrohrkessel und Anlagenkomponenten - Teil 15: Abnahmeversuche

Chaudieres a tubes d'eau et installations auxiliaires - Partie 15: Essais de réception

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Water-tube boilers and auxiliary installations - Part 15: Acceptance tests

Chaudières à tubes d'eau et à tubes de fumée - Partie 15: Essais de réception

Wasserrohrkessel und Anlagenkomponenten - Teil 15: Abnahmeversuche

This European Standard was approved by CEN on 12 June 2003.

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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 Management Centre has the same status as the official versions.

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

Management Centre: rue de Stassart, 36 B-1050 Brussels

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Contents

Page

Foreword

This document EN 12952-15:2003 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of an identical text or by endorsement, at the latest by March 2004, and conflicting national standards shall be withdrawn at the latest by March 2004.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association. This European Standard is considered as a supporting standard to other application and product standards which in themselves support an essential safety requirement of a New Approach Directive and should appear as a normative reference in them.

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.*

— *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.*

— *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.

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

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

Annex A is normative.

This document includes a Bibliography.

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, Hungary, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope and field of application

1.1 Field of application

This European Standard covers direct-fired steam boilers and hot water generators, including the auxiliaries. For the purposes of this standard, steam boilers and hot water generators are vessels and pipework systems in which:

— steam at a pressure higher than atmospheric pressure is generated for use external to the system;

— water is heated to a temperature higher than the saturation temperature at atmospheric pressure for use external to the system.

A steam generator normally consists of the flue gas-heated evaporator, the superheater, the reheater, the feedwater heater, the air heater, the fuel heater, if any, and the fuel burning equipment.

The term 'direct-fired' relates to equipment by means of which the chemical heat in the fuel of known composition is converted to sensible heat. Such equipment can involve stoker firing, fluidized-bed combustion or burner systems.

The auxiliaries include the fuel feeders, the pulverizer, the FD (forced draught) fan, the ID (induced draught) fan, the facilities for removal of the refuse (combustion residues), the steam air heater, the main air heater, the fuel heater, if any, and the dust collector.

This standard does not cover:

— units fired with special fuels (e.g. refuse);

— pressurized steam generators (e.g. pressurized fluidized-bed combustion (PFBC) boilers);

— steam generators in combined cycle systems.

This standard can be applied by analogy to the acceptance testing of:

— indirect-fired units (e.g. waste heat boilers);

— units operated using other heat carriers (e.g. gases, thermal oils, sodium).

Where this standard is to serve as the basis for the acceptance testing of heat-transfer systems, an agreement should have been reached by the time the contract has been concluded with regard to any special features which may have an effect on the measurements and interpretation of test results.

1.2 Scope

This standard is intended as the basis for the thermal performance (acceptance) testing of direct-fired steam boilers and hot water generators. Such tests are designed to demonstrate that the guarantees with respect to efficiency and output or other parameters have been met.

This standard includes (among other things):

— recommendations for the performance of acceptance tests (see clause 6);

— a definition of the envelope boundary of the steam generating unit and of the efficiency (see clause 8);

— details on the uncertainty of measurement (see clause 10).

1.3 General information

The standard provides information on agreements relating to the type and scope of acceptance tests. Such agreements should be made prior to testing or at the time when the steam or hot water generator is ordered.

The agreements can refer to the following:

— scope of supply, envelope boundary, reference temperature;

— method of determining thermal efficiency, direct (input-output) method or indirect (heat loss) method;

— additional measurements;

— test conditions, such as degree of cleanliness, time to reach steady-state condition and test duration;

— any deviating test conditions;

— blowdown and sootblowing;

— functional use of instrumentation other than specified in clause 6;

— steam table and tables for other thermodynamic properties to be used;

— any special correction methods;

— location and position of measuring points.

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 (including amendments).

EN 837-1, *Pressure gauges — Part 1: Bourdon tube pressure gauges — Dimensions, metrology, requirements and testing.*

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

EN 26801, *Rubber or plastics hoses — Determination of volumetric expansion (ISO 6801:1983).*

EN 60584-1, *Thermocouples — Part 1: Reference tables (IEC 60584-1:1995).*

EN 60584-2, *Thermocouples — Part 2: Tolerances (IEC 60584-2:1982 + A1:1989).*

EN 60751, *Industrial platinum resistance thermometer sensors (IEC 60751:1983 + A1:1986).*

EN ISO 3170, *Petroleum liquids — Manual sampling (ISO 3170:1988, including Amendment 1:1998).*

EN ISO 3993, *Liquefied petroleum gas and light hydrocarbons — Determination of density or relative density — Pressure hydrometer method (ISO 3993:1984).*

EN ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices — Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full (ISO 5167-1:1991).*

ISO 157, *Coal — Determination of forms of sulfur.*

ISO 334, *Solid mineral fuels — Determination of total sulfur — Eschka method.*

ISO 589, *Hard coal — Determination of total moisture.*

ISO 609, *Solid mineral fuels — Determination of carbon and hydrogen — High temperature combustion method.*

ISO 625, *Solid mineral fuels — Determination of carbon and hydrogen — Liebig method.*

ISO 1217, *Displacement compressors — Acceptance tests.*

ISO 1928, *Solid mineral fuels — Determination of gross calorific value by the bomb calorimetric method, and calculation of net calorific value.*

ISO 1988, *Hard coal — Sampling.*

ISO 5389, *Turbocompressors — Performance test code.*

3 Terms and definitions

For the purposes of this European Standard, the terms and definitions given in EN 12952-1 and the following apply.

3.1
direct method
input-output method
efficiency is determined as the ratio of heat absorbed by the working fluids (water and steam) to the heat input (chemical heat plus heat credits added to the steam generator)

3.2
indirect method
heat loss method
determination of all accountable heat losses, heat credits and the heat in the fuel. The efficiency is then equal to 100 minus the ratio of the sum of all heat losses to the sum of heat in the fuel plus heat credits

3.3
standard condition
embraces the condition at p_n = 1,01325 bar and t_n = 0 °C

3.4
refuse
combustion residues that are obtained in the form of flue dust or in the molten and/or agglomerated solid state (slag), including the fuel contained in them

4 Symbols and abbreviations and coefficients

4.1 Symbols and abbreviations

For the purpose of this part, the symbols given in EN 12952-1:2001, Table 4-1 and those given in Table 4.1-1 and Table 4-1-2 shall apply.

Table 4.1-1 — Latin Letters

Symbol	Description	Unit
A	Ash content of fuel related to daf-based fuel	—
A_U	Influence factor	—
c	Specific heat capacity[a]	kJ/(kgK)
$\bar{c}$	Integral specific heat capacity[a]	kJ/(kgK)
f	factor (transient fraction of heat output)	—
f	Limit of (permissible) error	—
H	Calorific value (CV)	kJ/kg
h	Specific enthalpy	kJ/kg
i	Number of samples	—
J	Enthalpy of flue gas or combustion air related to fuel mass flow	kJ/kg
L	Latent heat (heat of vaporization)	kJ/kg
l	Single loss	—
l	Inflow length	m
l_u	Ratio of unburned combustibles to supplied fuel mass flow	—
M	Molar mass	—
$\dot{m}$	Mass flow (rate)	kg/s
n	Air factor at boiler outlet	—
n	Lime ratio	—
P	Power	kW
p	Pressure	N/mm^2
$\dot{Q}$	Heat flow	kW
T	Thermodynamic temperature	K
t	Temperature Celsius	°C
u	Unburned combustibles content (by mass)	kg/kg
u_M	Uncertainty of measurement	—
V	Combustion air and flue gas volume (per unit mass of fuel)	m^3/kg
$\dot{V}$	Volume flow (rate)	m^3/h
v	Specific volume	m^3/kg
w	Velocity	m/s
W	Moisture content of fuel related to dry, ash free based fuel	—
x	Flue gas/combustion air components content by mass	kg/kg
x_{Ad}	Combustion air content by mass	kg/kg
y	Content by volume	m^3/m^3
y_{Ad}	Combustion air content by volume	m^3/m^3

NOTE 1 1 N/mm^2 = 1 MN/m^2 = 1 MPa

NOTE 2 The units shown are those normally used. Conversion can be necessary for use in the dimensionless equations.

[a] "specific heat", for short.

Table 4.1-2 — Greek letters

Symbol	Quantity	Unit
α	Heat transfer coefficient	W/(m^2/K)
∂	Partial differential	—
Δ	Difference	—
ε	Relative uncertainty of measurement	—
ε	Emissivity	—
η	Thermal efficiency	—
$\eta_{S'L}$	Ash collection efficiency	—
η_S	Desulfurization efficiency	—
γ	Fuel content (by mass)	kg/kg
υ	Volatile matter content of ash	kg/kg
ρ	Density	kg/m^3
σ	Standard deviation	—
μ	Combustion air/flue gas mass to fuel mass ratio	kg/kg
τ	test duration	h or s

Table 4.1-3 — Subscripts

Symbol	Description
A	Air
Ash	Ash
AS	Atomizing steam or air
B	Boiler
BD	Blowdown water
c	corrected
Cn	Convection
C	Carbon
Ca	Calcium (lime)
CO	Carbon monoxide
CO2	Carbon dioxide
d	Dry (basis)
daf	Dry, ash-free
DC	Dust collector
e	Final value
EC	External cooling
FA	Flue dust (fly ash)
F	Fuel, burned fuel
Fo	Fuel supplied
FW	Feedwater
G	Flue gas (combustion gas)
(G)	Gross value
g	Guaranteed
H	Hydrogen
H2O	Water
K	Lime (when used as additive)
L	Loss
LA	Leakage (infiltrated) air / tramp air
M	Pulverizer
m	Average
meas	Measured
min	Minimum
N	Useful, effective
N	Nitrogen
(N)	Net value
n	Standard condition
o	Stoichiometric
O; O2	Oxygen
p	Constant pressure

Table 4.1-3 (*continued*)

Symbol	Description
r	Reference
R	Radiation
RC	Radiation and convection
RH	Reheat steam
S	Sulfur
SS	Spray water
SA	Steam air heater
SL	Slag
Sam	Sampling
Sen	Sensor
ST	Live steam
tot	Total
tr	True (value)
u	Unburned matter
U	Circulating pump or recirculating fan
VM	Volatile matter
W	Wall
Z	Heat input
0	At 0 °C
1	Upstream, inlet
2	Downstream, outlet
I, II	Reheater stages
^	Maximum

4.2 Coefficients

For the purpose of this part, the coefficients given in Table 4.2-1 shall apply.

Table 4.2-1 — Coefficients

Designation	Symbol	Value	Unit
Specific latent heat at 25 °C	L_r	2442,5	kJ/kg
Specific heat of steam between 25 °C and 150 °C	$\bar{c}_{pSt}$	1,884	kJ/(kg K)
Specific heat of water between 25 °C and 150 °C	$\bar{c}_{pW}$	4,21	kJ/(kg K)
Specific heat of air between 25 °C and 150 °C	$\bar{c}_{pA}$	1,011	kJ/(kg K)
Specific heat of ash and flue dust between 25 °C and 200 °C	$\bar{c}_{Ash,}$ $\bar{c}_{FA}$	0,84	kJ/(kg K)
Specific heat of slag			
Dry-bottom furnace	$\bar{c}_{SL}$	1,0	kJ/(kg K)
Slag-tap furnace	$\bar{c}_{SL}$	1,26	kJ/(kg K)
Specific heat of additives between 25 °C and 200 °C	$\bar{c}_{Ca}$		
	$CaCO_3$	0,97	kJ/(kg K)
	$Ca(HO)_2$	1,32	kJ/(kg K)
	CaO	0,84	kJ/(kg K)
Specific heat of dry and ash-free coal between 25 °C and 150 °C	$\bar{c}_{Fdaf}$	1,03	$(1 + \gamma_{Vm})$ kJ/(kg K)
CV of carbon monoxide	H_{COn}	12,633	MJ/m^3
CV of unburned matter:			
Hard coal	H_{uu}	33,0	MJ/kg
Brown coal	H_{uu}	27,2	MJ/kg
CV of total organic carbon (10 °C)	H_{uu}	33,0	MJ/kg

5 Guaranteed parameters

5.1 Basis for determining guaranteed parameters

The following factors shall be considered when establishing the guaranteed parameters:

— fuel properties (composition, net calorific value (NCV), grindability, ash fusibility) and fuel group, if relevant;

— feedwater and spray water characteristics (pressure, temperature);

— cold reheat steam pressure, temperature and mass flow;

— air temperature, relative humidity, air pressure, negative-pressure condition at boiler outlet.

Parameters and thermodynamic properties relate to the envelope boundary (see 8.1) only.

5.2 Parameters subject to guarantee

An acceptance test of a steam generator shall be carried out to verify compliance with the guarantees.

The main parameters that shall be guaranteed are:

— the maximum continuous rating (MCR);

— the pressure and temperature of the generated live and reheat steam;

— the efficiency or losses, or the flue gas temperature.

The following parameters may also be subject to guarantee:

— the efficiency or losses for given fuels and/or partial loads;

— the steam condition for given fuels and at partial loads;

— the pressure drop across boiler high pressure (HP) system and reheater;

— the pressure loss in the combustion air and flue gas flows at agreed points;

— the air factor (ratio of actual to stoichiometric combustion air masses) at agreed points;

— the maximum throughput of reheater spray water;

— the unburned combustibles content of flue dust;

— the emission of flue gas.

Unless otherwise agreed, guarantees shall relate to steady-state conditions.

5.3 Additional measurements

The following parameters may also be taken into consideration when evaluating the steam generating unit:

— pressure and temperature of water and steam at different points;

— combustion air pressure, temperature and velocity (flow rate) at different points along the ducting system;

— flue gas composition, pressure, temperature and velocity (flow rate) at different points along the ducting system.

5.4 Supply of steam generator components by several manufacturers

If steam generator components are supplied by several manufacturers, additional measurements may be necessary in order to provide proof of conformance to the guarantees.

6 Basic test conditions

6.1 Methods of determining efficiency

The thermal efficiency of steam generators shall be determined using the direct or indirect method (see clause 3).

It is recommended that the major heat losses also should be determined when using the direct method.

Which method is to be given preference depends on the technical resources. Where solid fuels are used, for example, it is not possible or extremely difficult to accurately measure large mass flows. Here, the only viable choice is the indirect method, which should also be adopted when the fuel properties are subject to large fluctuations. If it is possible to take accurate measurements of fuel flow, the direct method may be the better choice, especially for small steam generators, owing to the uncertainty involved in the measurement of radiation and convection losses. The two methods have different levels of uncertainty. The method with the highest accuracy should always be employed.

The method shall be agreed with the purchaser, and stated in the contract.

6.2 General conditions

The parameters listed in 5.1 shall be determined before carrying out acceptance tests. If the operating conditions do not allow this, the tests may, subject to prior agreement, be performed under different conditions. However, deviations shall be kept to a minimum. It shall then be necessary to correct the efficiency to the guaranteed conditions. See clause 9 for details.

6.3 Preliminary test runs

Prior to the regular acceptance test, the supplier shall be given the opportunity to conduct preliminary test runs which serve to check the accuracy of test equipment and methods and to train test personnel.

If a preliminary test yields satisfactory results, it may be declared an acceptance test, subject to agreement of all parties involved.

6.4 Condition of steam generator

It shall be assumed that a steam generator is so designed that the guaranteed values can be attained with normal fouling. The supplier shall be given the opportunity to inspect the heating surface prior to the acceptance test. The time of the acceptance test shall be agreed between the operator and supplier. However the test should be carried out after optimization and the test run being carried out.

Where the steam generator has been supplied with cleaning equipment (e.g. sootblowers or a shot cleaning plant), such equipment shall be employed for cleaning before the acceptance test.

6.5 Steady-state conditions

6.5.1 Attaining steady-state conditions

As the guaranteed values refer to steady-state conditions only, it shall be ensured that the steam generator has reached equilibrium.

The time required to attain equilibrium shall vary widely with the boiler design. Normally, the steam generator shall have been in continuous operation for several days prior to the test.

Equilibrium shall have been reached before the test starts, which shall be established by all parties to the test.

For certain firing systems (e.g. slag-tap furnaces, fluidized-bed combustion systems) it may take an extremely long time to reach steady-state conditions.