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Heating systems in buildings — Method and design for calculation of the system energy performance — Combustion systems (boilers)

Systèmes de chauffage dans les bâtiments — Méthode de conception et de calcul de la performance énergétique des systèmes — Systèmes de combustion (chaudières)

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 205, *Building environment design*.

Introduction

This International Standard presents methods for calculation of the energy losses of a heat generation system. The calculation is based on the performance characteristics of the products given in product standards and on other characteristics required to evaluate the performance of the products as included in the system.

This method can be used for the following applications:

— judging compliance with regulations expressed in terms of energy targets;

— optimization of the energy performance of a planned heat generation system, by applying the method to several possible options;

— assessing the effect of possible energy conservation measures on an existing heat generation system, by calculating the energy use with and without the energy conservation measure.

Refer to other International Standards or to regional or national documents for input data and detailed calculation procedures not provided by this International Standard.

Heating systems also include the effect of attached systems such as hot water production systems.

This International Standard is a systems standards, i.e. it is based on requirements addressed to the system as a whole and not dealing with requirements to the products within the system.

Where possible, reference is made to applicable product standards. However, use of products complying with relevant product standards is no guarantee of compliance with the system requirements.

The requirements are mainly expressed as functional requirements, i.e. requirements dealing with the function of the system and not specifying shape, material, dimensions or the like.

Heating systems and cooling systems differ globally due to climate, traditions and national regulations. In some cases, requirements are given as classes so national or individual needs can be accommodated.

Heating systems in buildings — Method and design for calculation of the system energy performance — Combustion systems (boilers)

1 Scope

This International Standard is the general standard on generation by combustion sub-systems (boilers) for oil, gas, coal and biomass burning.

It specifies the

— required inputs,

— calculation method, and

— resulting outputs

for space heating generation by combustion sub-systems (boilers) including control.

This International Standard is also intended for the case of generation for both domestic hot water production and space heating.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7345:1987, *Thermal insulation — Physical quantities and definitions*

ISO 13790, *Energy performance of buildings — Calculation of energy use for space heating and cooling*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7345:1987 and the following apply.

3.1.1
auxiliary energy
electrical energy used by technical building systems for heating, cooling, ventilation and/or domestic water to support energy transformation to satisfy energy needs

Note 1 to entry: This includes energy for fans, pumps, electronics, etc. Electrical energy input to the ventilation system for air transport and heat recovery is not considered as auxiliary energy, but as energy use for ventilation.

3.1.2
boiler
gas, liquid or solid fuelled appliance designed to provide hot water for space heating

Note 1 to entry: It can also be designed to provide domestic hot water heating.

3.1.3
biomass boiler
biomass fuelled appliance designed to provide heating medium (e.g. water, fluid)

3.1.4
condensing boiler
oil or gas boiler designed to make use of the latent heat released by condensation of water vapour in the combustion flue products

Note 1 to entry: A condensing boiler allows the condensate to leave the heat exchanger in liquid form by way of a condensate drain.

Note 2 to entry: Boilers not so designed, or without the means to remove the condensate in liquid form, are called 'non-condensing'.

3.1.5
low temperature boiler
non-condensing boiler which can work continuously with a water supply temperature of 35 °C to 40 °C

3.1.6
modulating boiler
boiler with the capability to vary continuously (from a set minimum to a set maximum) the fuel burning rate whilst maintaining continuous burner firing

3.1.7
multistage boiler
boiler with the capability to vary the fuel burning rate stepwise whilst maintaining continuous burner firing

3.1.8
on/off boiler
boiler without the capability to vary the fuel burning rate whilst maintaining continuous burner firing

Note 1 to entry: This includes boilers with alternative burning rates set once only at the time of installation, referred to as range rating.

3.1.9
calculation period
period of time over which the calculation is performed

Note 1 to entry: The calculation period can be divided into a number of calculation steps.

3.1.10
calculation step
discrete time interval for the calculation of the energy needs and uses for heating, cooling, humidification and dehumidification

Note 1 to entry: Typical discrete time intervals are one hour, one month or one heating and/or cooling season, operating modes, and bins.

3.1.11
combustion power
product of the fuel flow rate and the net calorific power of the fuel

3.1.12
domestic hot water heating
process of heat supply to raise the temperature of cold water to the intended delivery temperature

3.1.13
external temperature
temperature of external air

Note 1 to entry: For transmission heat transfer calculations, the radiant temperature of the external environment is supposedly equal to the external air temperature; long-wave transmission to the sky is calculated separately.

Note 2 to entry: The measurement of external air temperature is defined in ISO 15927[3].

3.1.14
gross calorific value
quantity of heat released by a unit quantity of fuel, when it is burned completely with oxygen at a constant pressure equal to 101 320 Pa, and when the products of combustion are returned to ambient temperature

Note 1 to entry: This quantity includes the latent heat of condensation of any water vapour contained in the fuel and of the water vapour formed by the combustion of any hydrogen contained in the fuel.

Note 2 to entry: According to ISO 13602-2[2], the gross calorific value is preferred to the net calorific value.

3.1.15
heat recovery
heat generated by a technical building system or linked to a building use (e.g. domestic hot water) which is utilized directly in the related system to lower the heat input and which would otherwise be wasted

EXAMPLE Preheating of combustion air by a flue gas heat exchanger.

3.1.16
heat transfer coefficient
factor of proportionality of heat flow governed by a temperature difference between two environments

3.1.17
heated space
room or enclosure which for the purposes of the calculation is assumed to be heated to a given set-point temperature or set-point temperatures

3.1.18
load factor
ratio between the time with the boiler on and the total generator operation time

3.1.19
modes of operation
various modes in which the heating system can operate

EXAMPLE Set-point mode, cut-off mode, reduced mode, set-back mode, boost mode.

3.1.20
net calorific value
gross calorific value minus latent heat of condensation of the water vapour in the products of combustion at ambient temperature

3.1.21
operation cycle
time period of the operation cycle of a boiler

3.1.22
recoverable system thermal loss
part of a system thermal loss which can be recovered to lower either the energy need for heating or cooling or the energy use of the heating or cooling system

Note 1 to entry: This depends on the calculation approach chosen to calculate the recovered gains and losses (holistic or simplified approach).

3.1.23
recovered system thermal loss
part of the recoverable system thermal loss which has been recovered to lower either the energy need for heating or cooling or the energy use of the heating or cooling system

Note 1 to entry: This depends on the calculation approach chosen to calculate the recovered gains and losses (holistic or simplified approach).

3.1.24
space heating
process of heat supply for thermal comfort

3.1.25
system thermal loss
thermal loss from a technical building system for heating, cooling, domestic hot water, humidification, dehumidification or ventilation that does not contribute to the useful output of the system

Note 1 to entry: A system loss can become an internal heat gain for the building if it is recoverable.

Note 2 to entry: Thermal energy recovered directly in the subsystem is not considered as a system thermal loss but as heat recovery and directly treated in the related system standard.

3.1.26
total system thermal loss
total of the technical system thermal loss, including recoverable system thermal losses

3.2 Symbols and units

For the purposes of this document, the following symbols and units (Table 1) and indices (Table 2) apply.

Table 1 — Symbols and units

Symbol	Name of quantity	Unit
D	day	d/mth
A	area	m^2
E	energy in general [except quantity of heat, mechanical work and auxiliary (electrical) energy]	J[b] or Wh [a]
f	factor	-
P	power in general including electrical power	kW, W
Q	quantity of heat	J or Wh [a]
t	time, period of time	s or H/d, h/mth [a]
W	auxiliary (electrical) energy	J or Wh [a]
X	gas content	Vol-%
α	heat transfer coefficient	$W/(m^2 K)$
β	load factor	—
η	efficiency	—
θ	temperature	°C

[a] If seconds (s) is used as the unit of time, the unit for energy shall be J; if hours (h) is used as the unit of time, the unit for energy shall be Wh.

[b] The unit depends on the type of energy carrier.

Table 2 — Indices

C	cooling	day	day	od	operating day
CO_2	carbon dioxide	del	delivered	on	running
H	heating	dis	distribution system	op	operational
HC	heating circuit	dry	dry gases	out	output
O_2	oxygen	e	external	pa	partial area
Pn	at nominal load	env	envelope	prio	priority
Pint	at intermediate load	fg	flue gas	ren	renewable energy
P0	at zero load	gen	generation, generator	rbl	recoverable
RT	return	i,j,k	indices	res	reheating
V	ventilation	in	input	rvd	recovered
W	hot water	int	internal	sat	saturation
Hs/Hi	ratio of gross calorific/net calorific value	ls	loss	sim	simultaneous
an	annual	m	mean	sink	sink
air	air	max	maximum	st	stoichiometric
aux	auxiliary	mech	mechanical (ventilation system)	test	test
brm	boiler room	min	minimum	th	thermal
ch	chimney	meas	measured	tr	transmission
cond	condensation	mth	month	use	use
corr	corrected/correction	nrbl	non recoverable	ve	ventilation
ctr	control	n	radiator index	wfg	water to fluegas

4 Alignment of the parts of the heating system standards

4.1 Physical factors taken into account

The calculation method of the generation sub-system takes into account heat losses and/or recovery due to the following physical factors:

a) heat losses to the chimney (or flue gas exhaust) and through the envelope of the storage tank and the generator(s) during total time of generator operation (running and stand-by);

b) heat losses through the generator(s) envelope during total time of generator operation (running and stand-by);

c) auxiliary energy.

The relevance of these effects on the energy requirements depends on:

— type of heat generator(s);

— type of buffer tank(s);

— location of heat generator(s);

— type of buffer tank(s);

— part load ratio;

— operating conditions (temperature, control, etc.);

— control strategy (on/off, multistage, modulating, cascading, etc.).

4.2 Input quantities from other parts of the heating system standards

Table 3 — Input quantities

Notation	Meaning	Reference
H_{tr}	heat transfer coefficient of transmission	see ISO 13790
H_{ve}	heat transfer coefficient of ventilation	see ISO 13790
$P_{H,max}$	heat load	see heat load calculation
t_H	heating hours (in the calculation interval), in h/mth	see ISO 13790
t_W	availability period for hot water production – when connected, in h/mth	see input data
d_{mth}	number of days per month, in d/mth	see project data
β_{Pn}	load factor at full load	see input data
β_{Pint}	load factor at intermediate load	see input data
$\beta_{H,gen}$	actual load factor	see input data
θ_e	external air temperature, in °C	see external climate data
$\theta_{e,min}$	daily average design temperature, in °C;	see external climate data
$\theta_{HC,m}$	generator average water temperature (or return temperature to the generator for condensing boilers) as a function of the specific operating conditions	see input data
$\theta_{HC,RT}$	average return temperature to the generator for condensing boilers as a function of the specific operating conditions	
θ_{int}	ambient temperature, in °C	
$\theta_{nt,H,op}$	space temperature during the operation time, in °C	see project data

[a] $\theta_{int,H}$ is to be used for system components in a heated zone, taking into account reduced heating operation (without taking into account weekends and holidays).

$\theta_{int,C}$ is to be used for system components in a cooled zone (the user shall decide whether a cooled zone exists).

θ_e is to be used for system components in an unheated and uncooled zone.

If a zone is heated and cooled in the same month, it shall be determined which occurred more often and the appropriate temperature used.

The daily operation is taken into account by the heating time (operating hours/period of duration), $t_{H,op}$. The assumption is made that there is always only one user. Where there are a number of different loads, a differentiation must be made between the individual requirements for each case.

Only if the useful heat demand $Q_{H,dis,in}$ > 1 kWh (in the calculation interval) is heating necessary.

4.3 Output quantities for other parts of the heating system standards

The calculation of the values takes place basically for the zones defined in ISO 13790.

If a number of parts of systems are contained in the various process domains then the values are to be added together for further analysis.

Here it is to be taken into account that the heating data are to be related to the gross calorific value.

In the following sections the thermal and auxiliary energy components of the different process domains are determined for further analysis.

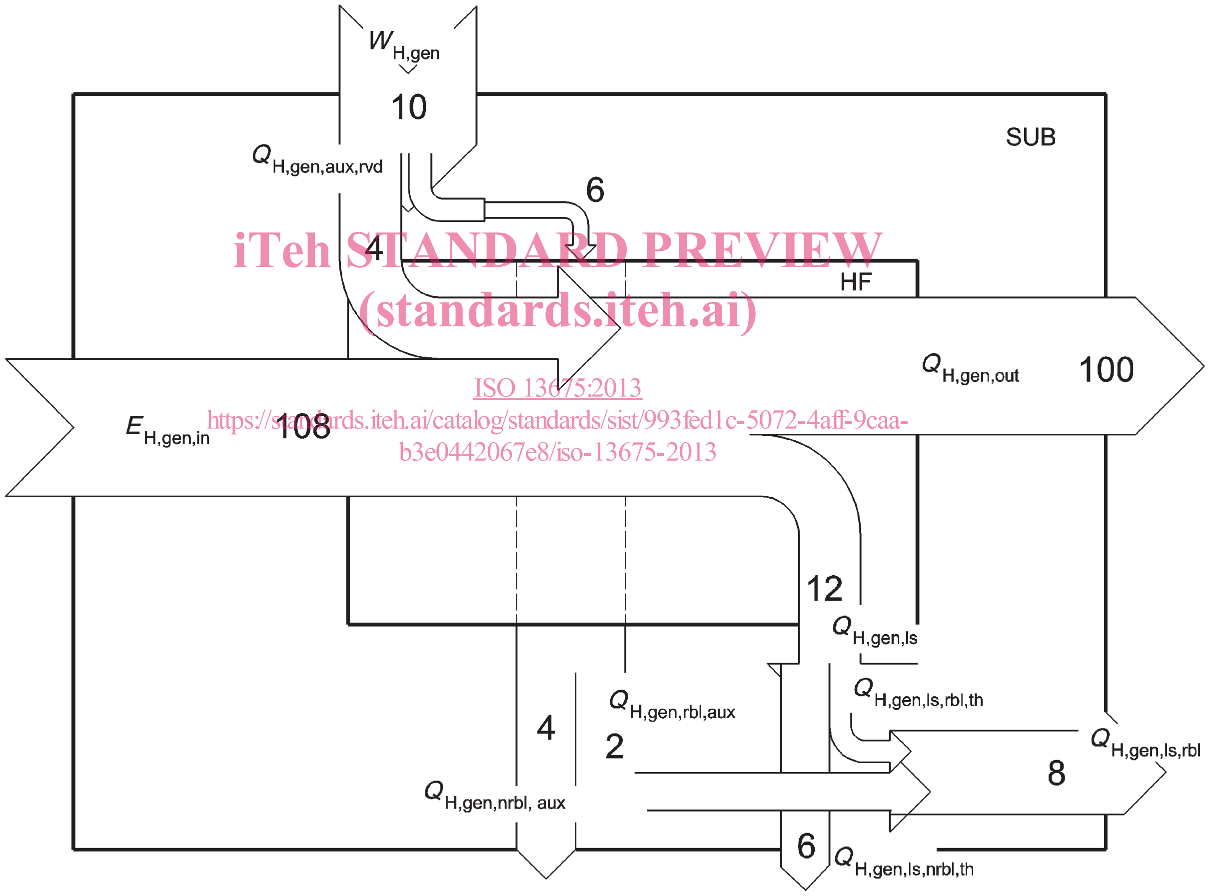
Table 4 — Output quantities

Notation	Description	Reference
$E_{H,gen,in}$	Fuel heat requirement	see 4.5
$Q_{H,gen,ls,rbl}$	Recoverable generation heat losses for heating system (in the calculation interval), in kWh	see 5.2.4.2
$W_{H,gen,}$	heat generation auxiliary energy for the heating system (in the calculation interval), in kWh	see 5.2.3

4.4 Heat balance of the generation sub-system, including control of heat generation

Figure 1 shows the calculation inputs and outputs of the generation sub-system.

NOTE For commercial purpose, Figure 1 can be simplified by grouping the different type of losses.



Key

SUB	Generation sub-system balance boundary
HF	Heating fluid balance boundary (see Formula 1)
$Q_{H,gen,out}$	Generation sub-system heat output [input to distribution sub-system(s)]
$E_{H,gen,in}$	Generation sub-system fuel input (energyware)
$W_{H,gen}$	Generation sub-system total auxiliary energy
$Q_{H,gen,aux,rvd}$	Generation sub-system recovered auxiliary energy

$Q_{H,gen,ls}$	Generation sub-system total thermal losses
$Q_{H,gen,ls,rbl}$	Generation sub-system thermal loss recoverable for space heating
$Q_{H,gen,ls,rbl,th}$	Generation sub-system thermal loss (thermal part) recoverable for space heating
$Q_{H,gen, rbl,aux}$	Generation sub-system recoverable auxiliary energy
$Q_{H,gen,ls,nrbl,th}$	Generation sub-system thermal loss (thermal part) non recoverable
$Q_{H,gen,nrbl,,aux,}$	Generation sub-system non recoverable auxiliary energy

NOTE Figures shown are sample percentages.

Figure 1 — General generation sub-system inputs, outputs and energy balance

4.5 Generation sub-system basic energy balance

The basic energy balance of the generation sub-system is given by

$$E_{gen,in} = Q_{gen,out} - Q_{gen,aux,rvd} + Q_{gen,ls} - Q_{gen,ren} \quad (1)$$

where

$E_{gen,in}$ is the energy input of the generation sub-system (fuel input) (in the calculation interval), in kWh;

$Q_{gen,out}$ is the energy supplied to the distribution sub-systems (e.g. space heating and domestic hot water) (in the calculation interval), in kWh;

$Q_{gen,aux,rvd}$ is the auxiliary energy recovered by the generation sub-system (e.g. pumps, burner fan, etc.) (in the calculation interval), in kWh;

$Q_{gen,ls}$ is the thermal losses of the generation sub-system (e.g. through the chimney, generator envelope, etc.) (in the calculation interval), in kWh;

$Q_{gen,ren}$ is the regenerative energy contribution (in the calculation interval), in kWh.

NOTE 1 $Q_{gen,ls}$ takes into account flue gas and generator envelope losses, part of which may be recoverable for space heating according to location of the generator. See 5.2.2.

NOTE 2 Generally biomass boilers are not designed for controlling the emission part of heating systems.

NOTE 3 $Q_{gen,ren}$ is normally not used with boilers.

The heat output from the boiler equals the sum of heat input to the connected distribution systems:

$$Q_{\text{gen,out}} = f_{\text{ctr,ls}} \cdot \sum_i Q_{\text{H,dis,in,i}} + \sum_j Q_{\text{W,dis,in,j}} \qquad (2)$$

where

$f_{\text{ctr,ls}}$ is the factor taking into account emission control losses. Default value of $f_{\text{ctr,ls}}$ is given in Table B.1. Other values may be specified in a national annex, provided that emission control losses have not been already taken into account in the emission part or in the distribution part;

$Q_{\text{H,dis,in}}$ is the heat input to the connected heat distribution system (in the calculation interval), in kWh;

$Q_{\text{W,dis,in}}$ is the heat input to the connected DHW distribution system (in the calculation interval), in kWh.

If there are multiple generation sub-systems or multiple boilers, see input data “generator systems”.

If the generator provides heat for heating, cooling, ventilation and domestic hot water, the index H shall be replaced by C, V or W. In the following only H is used for simplicity.

The heat load calculation will be written in another standard.

5 Generation sub-system calculation

5.1 Available methodologies

This subclause describes the calculation method for the heat generation sub-system.

This method takes into account the specific operation conditions of the individual installation by taking the certified product value provided either by the manufacturer or taken from informative Annex A, or by measuring the needed values on-site.

The considered calculation step can be the heating season but may also be a shorter period (month, week and/or the operation modes according to ISO 13790). The method is not limited and can be used with the default values given in informative Annex A.

For existing boilers the calculation by measured values takes the losses of a generator which occurs during boiler cycling (i.e. combustion losses) in consideration. This method is well adapted for existing buildings and to take into account condensation heat recovery according to operating conditions.

The calculation methods for biomass combustion systems differ with respect to:

— type of stoking device (automatic or by hand);

— type of biomass fuel (pellets, chipped wood or log wood).

Data to characterize the boiler shall be taken from one of the following sources, listed in priority order:

a) measured data (see 5.2.1);

b) product data from the manufacturer, if the boiler has been tested and certified (see 5.2.2);

c) default data from Annex A (see 5.2.2).

It shall be recorded if the efficiency values include or not auxiliary energy recovery.

NOTE Biomass boilers with automatic stocking fired by pellets or chipped wood.

