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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)

Reference number
ISO 13675:2013(E)

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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.

INTERNATIONAL STANDARD ISO 13675:2013(E)

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
$P_{\text{H,max}}$	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
$\beta_{\text{H,gen}}$	actual load factor	see input data
θ_{e}	external air temperature, in °C	see external climate data
$\theta_{\text{e,min}}$	daily average design temperature, in °C;	see external climate data
$\theta_{\text{HC,m}}$	generator average water temperature (or return temperature to the generator for condensing boilers) as a function of the specific operating conditions	see input data
$\theta_{\text{HC,RT}}$	average return temperature to the generator for condensing boilers as a function of the specific operating conditions	
θ_{int}	ambient temperature, in °C	
$\theta_{\text{nt,H,op}}$	space temperature during the operation time, in °C	see project data

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

$\theta_{\text{int,C}}$ 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), $t_{\text{H,op}}$. 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 $Q_{\text{H,dis,in}}$ > 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.

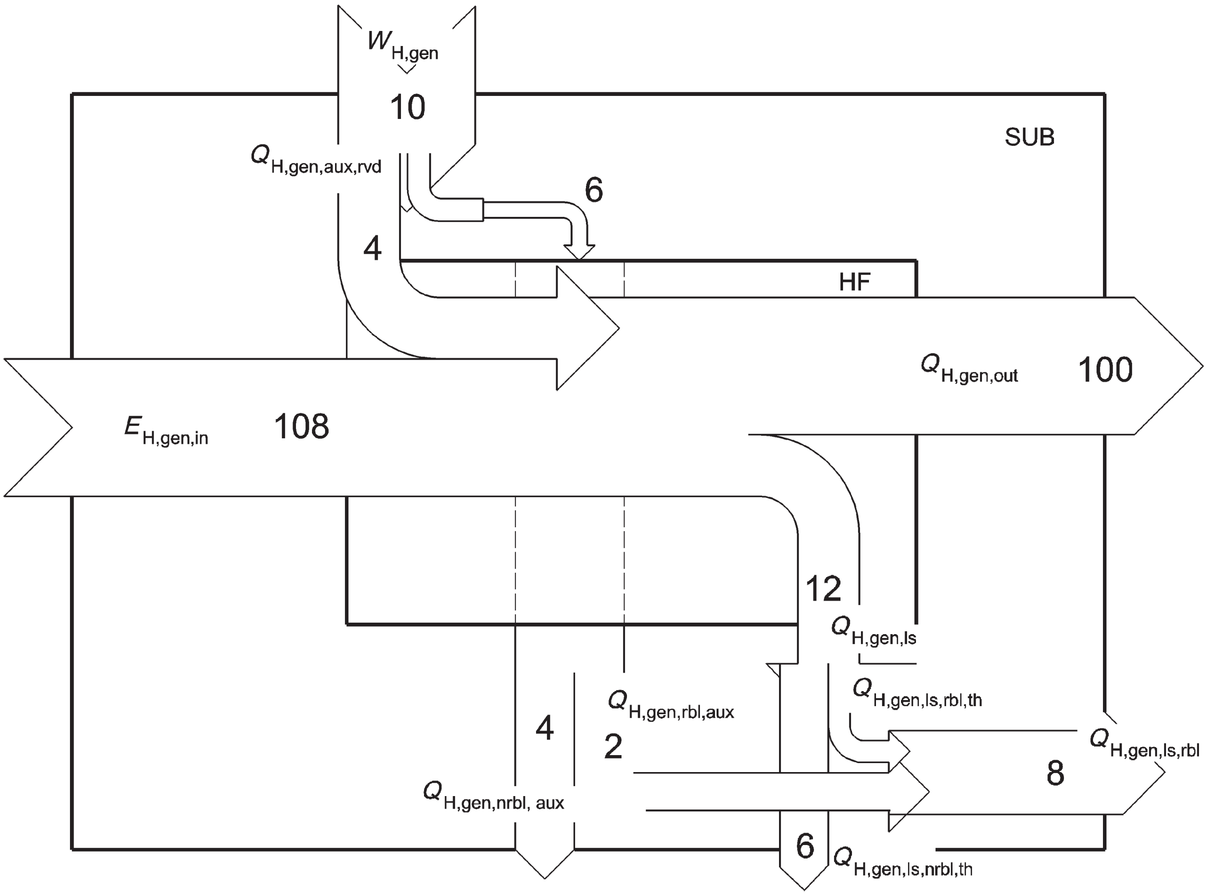
Table 4 — Output quantities

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

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

$$E_{\mathrm{gen,in}} = Q_{\mathrm{gen,out}} - Q_{\mathrm{gen,aux,rvd}} + Q_{\mathrm{gen,ls}} - Q_{\mathrm{gen,ren}} \tag{1}$$

where

$E_{\mathrm{gen,in}}$	is the energy input of the generation sub-system (fuel input) (in the calculation interval), in kWh;
$Q_{\mathrm{gen,out}}$	is the energy supplied to the distribution sub-systems (e.g. space heating and domestic hot water) (in the calculation interval), in kWh;
$Q_{\mathrm{gen,aux,rvd}}$	is the auxiliary energy recovered by the generation sub-system (e.g. pumps, burner fan, etc.) (in the calculation interval), in kWh;
$Q_{\mathrm{gen,ls}}$	is the thermal losses of the generation sub-system (e.g. through the chimney, generator envelope, etc.) (in the calculation interval), in kWh;
$Q_{\mathrm{gen,ren}}$	is the regenerative energy contribution (in the calculation interval), in kWh.

NOTE 1 $Q_{\mathrm{gen,ls}}$ 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 $Q_{\mathrm{gen,ren}}$ is normally not used with boilers.

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

$$Q_{\text{gen,out}} = f_{\text{ctr,ls}} \cdot \sum\nolimits_{\text{i}} Q_{\text{H,dis,in,i}} + \sum\nolimits_{\text{j}} Q_{\text{W,dis,in,j}} \tag{2}$$

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.

5.2 Boiler efficiency

5.2.1 Generator thermal losses measurement

5.2.1.1 Thermal losses through the chimney with the burner on at full load $f_{\mathrm{ch,on}}$

Thermal losses through the chimney with the burner on $f_{\mathrm{ch,on}}$ can be calculated according to the flue gas analysis results:

Measuring O_2

$$f_{\mathrm{ch,on,meas}} = (\theta_{\mathrm{ch}} - \theta_{\mathrm{brm}}) \cdot \left(\frac{c_{10}}{21\,\% - X_{\mathrm{O2}}} + c_{11} \right) \tag{3}$$

where measured values are as follows:

θ_{ch} is the flue gas temperature, in °C;

θ_{brm} is the installation room (combustion air) temperature (see Table A.7), in °C;

X_{O2} is the flue gas oxygen contents, in Vol%.

The constants c_{10} and c_{11} are given in Table A.9.

The measured value shall be corrected to reference conditions according to water temperature using the formula:

$$f_{\mathrm{ch,on}} = \left[f_{\mathrm{ch,on,meas}} - (\theta_{\mathrm{gen,ref}} - \theta_{\mathrm{gen,meas}}) \cdot f_{\mathrm{corr,ch,on}} \right] \tag{4}$$

where

$f_{\mathrm{ch,on,meas}}$ is the measured losses through the chimney with burner on;

$\theta_{\mathrm{gen,ref}}$ is the reference average water temperature in the boiler at test conditions (average of flow and return temperature, usually flow temperature 80 °C, return temperature 60 °C);

$\theta_{\mathrm{gen,meas}}$ is the average water temperature in the boiler during measurement of $f_{\mathrm{ch,on,meas}}$;

$f_{\mathrm{corr,ch,on}}$ is the correction factor for $f_{\mathrm{ch,on}}$. Default values for $f_{\mathrm{corr,ch,on}}$ = 0,045 [%/°C].

5.2.1.2 Thermal losses through the generator envelope, $f_{\mathrm{gen,env}}$

Actual specific thermal losses through the generator envelope, $f_{\mathrm{gen,env}}$, are given by measurement in site:

$$f_{\mathrm{gen,env}} = \frac{\sum (A_{\mathrm{pa}} \cdot \alpha \cdot \Delta\theta_{\mathrm{pa}})}{1\,000 \cdot P_{\mathrm{gen,del}}} \tag{5}$$

where

A_{pa}	is the partial area of the envelop of the boiler, in m^2;
α	is the heat transfer coefficient, normally $\alpha = 10$ [for a more exact calculation see Figure A.1], in W/(m^2 K);
$\Delta\theta_{\mathrm{pa}}$	is the average temperature difference of the partial area of the envelope and the ambient temperature, in K;
$P_{\mathrm{gen,del}}$	is the power input, in kW.

The average water temperature in the boiler at actual conditions has to be about 70 °C but higher than 60 °C.

5.2.1.3 Thermal losses through the chimney with the burner off, $f_{\mathrm{ch,off}}$

$f_{\mathrm{ch,off}}$ is the heat losses through the chimney when the burner is off at test conditions. $f_{\mathrm{ch,off}}$ is expressed as a percentage of the nominal power P_{n}.

For existing systems, $f_{\mathrm{ch,off}}$ can be calculated by measuring the flow rate and the temperature at the boiler flue gas outlet.

If no data are available, default values are given in Table A.11.

The source of data shall be clearly stated in the calculation report.

5.2.1.4 Measured total thermal losses, power input and calculated gains

Thermal losses through the chimney with the burner on $P_{\mathrm{gen,ls,ch,on}}$ are given by:

$$P_{\mathrm{gen,ls,ch,on}} = \frac{f_{\mathrm{ch,on}}}{100} \cdot P_{\mathrm{gen,del}} \tag{6}$$

Thermal losses through the chimney with the burner off $P_{\mathrm{gen,ls,ch,off}}$ are given by:

$$P_{\mathrm{gen,ls,ch,off}} = \frac{f_{\mathrm{ch,off}}}{100} \cdot P_{\mathrm{gen,del}} \tag{7}$$

Thermal losses through the generator envelope $P_{\mathrm{gen,ls,env}}$ are given by:

$$P_{\mathrm{gen,ls,env}} = f_{\mathrm{gen,env}} \cdot P_{\mathrm{gen,del}} \tag{8}$$

The calculation procedure for condensation at part load is based on gross calorific values to get positive values, so the recovered latent heat of condensation P_{cond} is calculated by (see A.6):

$$P_{\mathrm{cond}} = \frac{Q_{\mathrm{cond}}}{H_{\mathrm{s}}} \cdot P_{\mathrm{gen,del}} \tag{9}$$

where

Q_{cond} is the specific condensation heat (see A.6);

H_{S} is the gross calorific value (see A.6).

The average power input to the generator $P_{\mathrm{gen,del}}$ in kW is calculated depending on the energy carrier:

$$P_{\mathrm{gen,del}} = E_{\mathrm{gen,in}} \cdot H_{\mathrm{i}} \left[\frac{\mathrm{kWh}}{3\,600\,\mathrm{kJ}} \right] \tag{10}$$

5.2.1.5 Boiler efficiencies from measured values

The efficiency of the boiler at full load $\eta_{\mathrm{gen,Pn}}$ is:

$$\eta_{\mathrm{gen,Pn}} = \frac{P_{\mathrm{gen,del}} - P_{\mathrm{gen,ls,ch,on}} - P_{\mathrm{gen,ls,env}}}{P_{\mathrm{gen,del}}} \tag{11}$$

The efficiency of the boiler at part load is:

$$\eta_{\mathrm{gen,Pint}} = \frac{P_{\mathrm{gen,del}} \cdot \beta_{\mathrm{Pint}} - \left(\beta_{\mathrm{Pint}} \cdot (P_{\mathrm{gen,ls,ch,on}} - P_{\mathrm{cond}} + P_{\mathrm{gen,ls,env}}) + (1 - \beta_{\mathrm{Pint}}) \cdot (P_{\mathrm{gen,ls,ch,off}} + P_{\mathrm{gen,ls,env}})\right)}{P_{\mathrm{gen,del}} \cdot \beta_{\mathrm{Pint}}} \tag{12}$$

For condensing boiler P_{cond} is needed, otherwise $P_{\mathrm{cond}} = 0$, see A.6.

The value for stand-by heat losses are:

$$f_{\mathrm{gen,ls,P0}} = f_{\mathrm{ch,off}} + f_{\mathrm{gen,env}} \tag{13}$$

5.2.2 Generator thermal loss calculation at full load

The efficiency at full load $\eta_{\mathrm{gen,Pn}}$ is measured at a reference generator average water temperature $\theta_{\mathrm{gen,\,test,Pn}}$. This efficiency shall be adjusted to the actual generator average water temperature of the individual installation.

The temperature corrected efficiency at full load for non-condensing boilers $\eta_{\mathrm{gen,Pn,corr}}$ is calculated by:

$$\eta_{\mathrm{gen,Pn,corr}} = \eta_{\mathrm{gen,Pn}} + f_{\mathrm{corr,Pn}} \cdot (\theta_{\mathrm{gen,test,Pn}} - \theta_{\mathrm{HC,m}}) \tag{14}$$

where

$\eta_{\mathrm{gen,Pn}}$	is the generator efficiency at full load. If the performance of the generator has been tested according to relevant standards (see Bibliography) or if the losses are calculated from measured values according to 5.2.1, it can be taken into account. If no values are available, default values shall be found in the relevant national annex or in Table A.1;
$f_{\mathrm{corr,Pn}}$	is the correction factor taking into account variation of the full load efficiency as a function of the generator average water temperature. The value should be given in a national annex. In the absence of national values, default values are given in Table A.4. If the performance of the generator has been tested according to relevant standards (see Bibliography), it can be taken into account;
$\theta_{\mathrm{gen,test,Pn}}$	is the generator average water temperature at test conditions for full load (see Table A.4);
$\theta_{\mathrm{HC,m}}$	is the generator average water temperature as a function of the specific operating conditions (see input data).

The generator efficiency at full load of condensing boilers is tested at a boiler average return temperature of 60 °C and 30 °C.

In that case the temperature corrected efficiency of condensing boilers at full load $\eta_{\mathrm{gen,Pn,corr}}$ is calculated by:

$$\eta_{\mathrm{gen,Pn,corr}} = \eta_{\mathrm{gen,Pn,60}} - \frac{\eta_{\mathrm{gen,Pn,60}} - \eta_{\mathrm{gen,Pn,30}}}{\theta_{\mathrm{gen,test,Pn,60}} - \theta_{\mathrm{gen,test,Pn,30}}} \cdot (\theta_{\mathrm{gen,test,Pn,60}} - \theta_{\mathrm{HC,RT}}) \tag{15}$$

where

$\eta_{\mathrm{gen,Pn,70}}$	is the generator efficiency at full load at a boiler average return temperature of 60 °C (80/60 °C). If the performance of the generator has been tested according to relevant standards (see Bibliography) or if the losses are calculated from measured values according to chapter 5.2.1, it can be taken into account. If no values are available, default values shall be found in the relevant national annex or in Table A.1;
$\eta_{\mathrm{gen,Pn,30}}$	is the generator efficiency at full load at a boiler average return temperature of 30 °C (50/30 °C). If the performance of the generator has been tested according to relevant standards (see Bibliography) or if the losses are calculated from measured values according to 5.2.1, it can be taken into account. If no values are available, default values shall be found in the relevant national annex or in Table A.1;
$\theta_{\mathrm{gen,test,Pn,60}}$	is the generator average return temperature at test conditions for full load (80/60 °C) (see A.1.1.1);
$\theta_{\mathrm{gen,test,Pn,30}}$	is the generator average return temperature at test conditions for full load (50/30 °C) (see A.1.1.1);
$\theta_{\mathrm{HC,RT}}$	is the generator average return temperature to the generator for condensing boilers as a function of the specific operating conditions (see input data).

In order to simplify the calculations, the efficiencies and heat losses determined at test conditions are adjusted to the actual generator average water temperature.

The corrected generator thermal loss at full load $P_{\text{gen,ls,Pn,corr}}$ is calculated by:

$$P_{\text{gen,ls,Pn,corr}} = \frac{(f_{\text{Hs/Hi}} - \eta_{\text{gen,Pn,corr}})}{\eta_{\text{gen,Pn,corr}}} \cdot P_{\text{n}} \qquad (16)$$

where

P_{n}	is the generator output at full load, in kW;
$f_{\text{Hs/Hi}}$	is the ratio of gross calorific value/net calorific value according to energy carrier, see Table A.9.

5.2.2.1 Generator thermal loss calculation at intermediate load

The efficiency at intermediate load $\eta_{\text{gen,Pint}}$ is measured at a reference generator average water temperature $\theta_{\text{gen,test,Pint}}$. This efficiency has to be adjusted to the actual generator average water temperature of the individual installation.

The temperature corrected efficiency at intermediate load $\eta_{\text{gen,Pint,corr}}$ is calculated by:

$$\eta_{\text{gen,Pint,corr}} = \eta_{\text{gen,Pint}} + f_{\text{corr,Pint}} \cdot (\theta_{\text{gen,test,Pint}} - \theta_{\text{HC,m}}) \qquad (17)$$

where

$\eta_{\text{gen,Pint}}$	is the generator efficiency at intermediate load. If the performance of the generator has been tested according to relevant standards (see Bibliography) or if the losses are calculated from measured values according to 5.2.1, it can be taken into account. If no values are available, default values shall be found in the relevant national annex or in Table A.1;
$f_{\text{corr,Pint}}$	is the correction factor taking into account variation of the efficiency as a function of the generator average water temperature. The value should be given in a national annex. In the absence of national values, default values are given in A.1.1.1. If the performance of the generator has been tested according to relevant standards (see Bibliography), it can be taken into account;
$\theta_{\text{gen,test,Pint}}$	is the generator average water temperature (or return temperature to the boiler for condensing boilers) at test conditions for intermediate load (see A.1.1.1);
$\theta_{\text{HC,m}}$	is the generator average water temperature (or return temperature to the generator for condensing boilers) as a function of the specific operating conditions (see input data).

The intermediate load depends on the generator type. Default values are given in Annex B.

The corrected generator thermal loss at intermediate load $P_{\text{gen,ls,Pint,corr}}$ is calculated by:

$$P_{\text{gen,ls,Pint,corr}} = \frac{(f_{\text{Hs/Hi}} - \eta_{\text{gen,Pint,corr}})}{\eta_{\text{gen,Pint,corr}}} \cdot P_{\text{int}} \qquad (18)$$

where

P_{int}	generator output at intermediate load, in kW;
$f_{\text{Hs/Hi}}$	conversion factor for delivered energy (see Table A.9).

5.2.2.2 Generator thermal loss calculation at 0 % load

The generator heat loss at 0 % load $P_{\mathrm{gen,ls,P0}}$ is determined for a test temperature difference according to relevant testing standards (see Bibliography). If the performance of the generator has been tested according to relevant standards (see Bibliography) or if the losses are measured depending on 5.2.1, it can be taken into account. If no manufacturer or national annex data are available, default values are given in A.1.1.2.

The temperature corrected generator thermal loss at 0 % load $P_{\mathrm{gen,ls,P0,corr}}$ is calculated by:

$$P_{\mathrm{gen,ls,P0,corr}} = \frac{P_{\mathrm{n}}}{\eta_{\mathrm{gen,Pn}}} \cdot f_{\mathrm{gen,ls,P0}} \cdot f_{\mathrm{Hs/Hi}} \cdot \left(\frac{\theta_{\mathrm{HC,m}} - \theta_{\mathrm{i,brm}}}{\Delta\theta_{\mathrm{gen,test,P0}}} \right)^{1,25} \qquad (19)$$

where

$P_{\mathrm{gen,ls,P0}}$	is the stand-by heat loss at 0 % load at test temperature difference $\Delta\theta_{\mathrm{gen,test,P0}}$;
$\eta_{\mathrm{gen,Pn}}$	is the generator efficiency at full load; for condensing boiler is $\eta_{\mathrm{gen,Pn,60}}$;
$f_{\mathrm{Hs/Hi}}$	is the conversion factor for delivered energy (see A.2);
$\theta_{\mathrm{HC,m}}$	is the generator average water temperature (or return temperature to the generator for condensing boilers) as a function of the specific operating conditions (see input data);
$\theta_{\mathrm{i,brm}}$	is the indoor temperature of the boiler room. Default values are given in A.1.3.3;
$\Delta\theta_{\mathrm{gen,test,P0}}$	is the difference between generator mean water temperature and room temperature at test conditions. Default values of mean water temperature of the generator at test conditions are given in A.1.1.1.

5.2.2.3 Boiler thermal loss at specific load ratio $\beta_{\mathrm{H,gen}}$ and power output P_{Px}

The actual load ratio $\beta_{\mathrm{H,gen}}$ of each boiler is calculated according to input data.

If $0 \leq \beta_{\mathrm{H,gen}} \leq \beta_{\mathrm{Pint}}$ the generator thermal loss $P_{\mathrm{gen,ls,Px}}$ is calculated by:

$$P_{\mathrm{gen,ls,Px}} = \frac{\beta_{\mathrm{H,gen}}}{\beta_{\mathrm{Pint}}} \cdot \left(P_{\mathrm{gen,ls,Pint,corr}} - P_{\mathrm{gen,ls,P0,corr}}\right) + P_{\mathrm{gen,ls,P0,corr}} \qquad (20)$$

If $\beta_{\mathrm{Pint}} < \beta_{\mathrm{H,gen}} \leq 1$ the generator thermal loss $P_{\mathrm{gnr,ls,Px}}$ is calculated by:

$$P_{\mathrm{gen,ls,Px}} = \frac{\beta_{\mathrm{H,gen}} - \beta_{\mathrm{Pint}}}{\beta_{\mathrm{Pn}} - \beta_{\mathrm{Pint}}} \cdot \left(P_{\mathrm{gen,ls,Pn,corr}} - P_{\mathrm{gen,ls,Pint,corr}}\right) + P_{\mathrm{gen,ls,Pint,corr}} \qquad (21)$$

The total boiler thermal loss $Q_{\mathrm{gen,ls}}$ during the considered time of operation of the boiler for heating is calculated by:

$$Q_{\mathrm{gen,ls}} = P_{\mathrm{gen,ls,Px}} \cdot \left(t_{\mathrm{H}} - t_{\mathrm{W}}\right) \qquad (22)$$

where

t_{H}	are the heating hours (see input data), in h/mth;
t_{W}	is the running time for hot water production – when connected (see Table 3), in h/mth.

5.2.2.4 Total generation thermal losses

The total generation sub-system thermal losses are the sum of the boiler thermal losses:

$$Q_{\mathrm{H,gen,ls}} = \sum Q_{\mathrm{gen,ls}} \tag{23}$$

5.2.3 Total auxiliary energy

The average auxiliary power for each boiler $P_{\mathrm{aux,Px}}$ is calculated by linear interpolation, according to the boiler load β_{gen} (calculated according to input data), between:

- $P_{\mathrm{aux,Pn}}$ auxiliary power of the boiler at full load ($\beta_{\mathrm{H,gen}} = 1$),
- $P_{\mathrm{aux,Pint}}$ auxiliary power of the boiler at intermediate load ($\beta_{\mathrm{H,gen}} = \beta_{\mathrm{Pint}}$),
- $P_{\mathrm{aux,P0}}$ auxiliary power of the boiler at stand-by ($\beta_{\mathrm{H,gen}} = 0$).

If no declared or measured data are available, default values are given in A.1.2.

If $0 \le \beta_{\mathrm{H,gen}} \le \beta_{\mathrm{Pint}}$ then $P_{\mathrm{aux,Px}}$ is given by:

$$P_{\mathrm{aux,Px}} = \frac{\beta_{\mathrm{H,gen}}}{\beta_{\mathrm{Pint}}} \cdot \left(P_{\mathrm{aux,Pint}} - P_{\mathrm{aux,P0}}\right) + P_{\mathrm{aux,P0}} \tag{24}$$

If $\beta_{\mathrm{Pint}} < \beta_{\mathrm{H,gen}} \le 1$ then $P_{\mathrm{aux,Px}}$ is given by:

$$P_{\mathrm{aux,Px}} = \frac{\beta_{\mathrm{H,gen}} - \beta_{\mathrm{Pint}}}{1 - \beta_{\mathrm{Pint}}} \cdot \left(P_{\mathrm{aux,Pn}} - P_{\mathrm{aux,Pint}}\right) + P_{\mathrm{aux,Pint}} \tag{25}$$

The total auxiliary energy for a boiler is given by:

$$W_{\mathrm{gen}} = P_{\mathrm{aux,Px}} \cdot \left(t_{\mathrm{H}} - t_{\mathrm{W}}\right) + P_{\mathrm{aux,P0}} \cdot \left(24 \cdot d_{\mathrm{mth}} - t_{\mathrm{H}}\right) \tag{26}$$

where

$P_{\mathrm{aux,P0}}$	is the stand-by auxiliary power;
t_{H}	is the running time (in the calculation interval) (see input data), in h/mth;
t_{W}	is the running time for hot water production – when connected (see Table 3), in h/mth;
d_{mth}	is the number of days per month (see Table 3).

The generation sub-system auxiliary energy $W_{\mathrm{H,gen}}$ is given by:

$$W_{\mathrm{H,gen}} = \sum W_{\mathrm{gen}} \tag{27}$$

5.2.4 Recoverable generation system thermal losses

5.2.4.1 Auxiliary energy

For the recoverable auxiliary energy, a distinction is made between:

- recoverable auxiliary energy transmitted to the heating medium (e.g. water). It is assumed that the auxiliary energy transmitted to the energy vector is totally recovered;
- recoverable auxiliary energy transmitted to the heated space.

The recovered auxiliary energy transmitted to the heating medium $Q_{\text{gen,aux,rvd}}$ is calculated by:

$$Q_{\text{gen,aux,rvd}} = W_{\text{gen}} \cdot f_{\text{rvd,aux}} \tag{28}$$

where

$f_{\text{rvd,aux}}$	is the part of the auxiliary energy transmitted to the distribution sub-system. The value should be given in a national annex. In the absence of national values, a default value is given in A.1.3.1. If the performance of the generator has been declared by the manufacturer, it can be taken into account.

Recovered auxiliary energy already taken into account in efficiency data shall not be calculated for recovery again. It has to be calculated for auxiliary energy need only.

NOTE Measured efficiency according to relevant standards usually includes the effect of heat recovered from auxiliary energy for oil heating, combustion air fan, control devices, primary pump (i.e. heat recovered from auxiliaries is measured with the useful output).

The recoverable auxiliary energy transmitted to the heated space $Q_{\text{gen,aux,rbl}}$ is calculated by:

$$Q_{\text{gen,aux,rbl}} = W_{\text{gen}} \cdot (1 - f_{\text{brm}}) \cdot f_{\text{rbl,aux}} \tag{29}$$

where

$f_{\text{rbl,aux}}$	is the part of the auxiliary energy not transmitted to the distribution sub-system. The value should be given in a national annex. In the absence of national values, a default value is given in A.1.3.1. If the performance of the generator has been certified, it can be taken into account;
f_{brm}	is the temperature reduction factor depending on location of the generator. The value of f_{brm} should be given in a national annex. In the absence of national values, a default value is given in A.1.3.3.

5.2.4.2 Generator thermal losses through the jacket (generator envelope)

Only the thermal losses through the jacket (generator envelope) are considered as recoverable and depend on the burner type. The thermal losses through the generator envelope are expressed as a fraction of the total stand-by heat losses.

The recoverable thermal losses through the jacket (generator envelope) $Q_{\mathrm{gen,ls,env,rbl}}$ are calculated by:

$$Q_{\mathrm{gen,ls,env,rbl}} = P_{\mathrm{gen,ls,P0,corr}} \cdot (1 - f_{\mathrm{brm}}) \cdot f_{\mathrm{env}} \cdot (t_{\mathrm{H}} - t_{\mathrm{W}}) \tag{30}$$

where

f_{env} is the thermal losses through the generator and the jacket (generator envelope) expressed as a fraction of the total stand-by heat losses. The value of f_{env} should be given in a national annex. In the absence of national values, default values are given in A.1.3.2. If the performance of the generator has been tested, it can be taken into account;

f_{brm} is the temperature reduction factor depending on location of the generator. The value of f_{brm} should be given in a national annex. In the absence of national values, a default value is given in A.1.3.3;

$t_{\mathrm{H,}}$ is the analytical running time (during a day), in h/mth;

t_{W} is the daily running time for hot water production – when connected, in h/mth.

5.2.4.3 Total recoverable generation system thermal losses

The total recovered auxiliary energy $Q_{\mathrm{H,gen,aux,rvd}}$ is calculated by:

$$Q_{\mathrm{H,gen,aux,rvd}} = \sum Q_{\mathrm{gen,aux,rvd}} \tag{31}$$

The total recoverable generation system thermal losses $Q_{\mathrm{H,gen,ls,rbl}}$ are calculated by:

$$Q_{\mathrm{H,gen,ls,rbl}} = \sum Q_{\mathrm{gen,ls,env,rbl}} + \sum Q_{\mathrm{gen,aux,rbl}} \tag{32}$$

5.2.5 Fuel input

Fuel heat input $E_{\mathrm{H,gen,in}}$ is calculated according to Formula 1.

Annex A
(informative)

Additional formulas and default values for parametering the boiler efficiency method

A.1 Information on the method

A.1.1 Generator efficiencies and stand-by losses

A.1.1.1 Default values for generator efficiency at full load and intermediate load as a function of the generator power output

The generator efficiency at full load and intermediate load as a function of the generator power output is given by:

$$\eta_{\mathrm{gen,Pn}} = \frac{c_1 + c_2 \cdot \log P_\mathrm{n}}{100} \tag{A.1}$$

For condensing boilers the generator efficiency at full load is to elaborate between 60°C and 30°C return temperature:

$$\eta_{\mathrm{gen,Pn,60}} = \frac{c_1 + c_2 \cdot \log P_\mathrm{n}}{100} \tag{A.2}$$

$$\eta_{\mathrm{gen,Pn,30}} = \frac{c_1 + c_2 \cdot \log P_\mathrm{n}}{100} \tag{A.3}$$

The generator efficiency at intermediate load as a function of the generator power output is given by:

$$\eta_{\mathrm{gen,Pint}} = \frac{c_3 + c_4 \cdot \log P_\mathrm{n}}{100} \tag{A.4}$$

where

P_n	is the nominal power output, in kW limited to a maximum value of 400 kW. If the nominal power output of the generator is higher than 400 kW, then the value of 400 kW is adopted in Formulae A.1, and A.2;
c_1, c_2, c_3, c_4	are the coefficients given in Table A.1.

Table A.1 — Parameters for calculation of generator efficiency and temperature limitation

Boiler type	Build year	Factor c_1	Factor c_2	Factor c_3	Factor c_4	$\theta_{\text{gen,test,Pn}}$ °C	$\theta_{\text{gen,test,Pint}}$ °C
Standard boilers:							
Multi-fuel boiler	before 1978	77,0	2,0	70,0	3,0	70	50
	1978 to 1987	79,0	2,0	74,0	3,0	70	50
Atmospheric solid fuel boiler (fossil and biomass fuel)	before 1978	78,0	2,0	72,0	3,0	70	50
	1978 to 1994	80,0	2,0	75,0	3,0	70	50
	after 1994	81,0	2,0	77,0	3,0	70	50
Atmospheric gas boiler	before 1978	79,5	2,0	76,0	3,0	70	50
	1978 to 1994	82,5	2,0	78,0	3,0	70	50
	after 1994	85,0	2,0	81,5	3,0	70	50
Fan-assisted boiler (fossil and biomass fuel)	before 1978	80,0	2,0	75,0	3,0	70	50
	1978 to 1986	82,0	2,0	77,5	3,0	70	50
	1987 to 1994	84,0	2,0	80,0	3,0	70	50
	after 1994	85,0	2,0	81,5	3,0	70	50
Burner replacement (only fan-assisted boilers)	before 1978	82,5	2,0	78,0	3,0	70	50
	1978 to 1994	84,0	2,0	80,0	3,0	70	50
Low temperature boilers:							
Atmospheric gas boiler	1978 to 1994	85,5	1,5	86,0	1,5	70	40
	after 1994	88,5	1,5	89,0	1,5	70	40
Circulation water heater (11 kW, 18 kW and 24 kW)	before 1987	84,0	1,5	82,0	1,5	70	40
	1987 to 1994	86,0	1,5	82,0	1,5	70	40
Fan-assisted boiler	before 1987	84,0	1,5	82,0	1,5	70	40
	1987 to 1994	86,0	1,5	86,0	1,5	70	40
	after 1994	88,5	1,5	89,0	1,5	70	40
Burner replacement (only fan-assisted boilers)	before 1987	86,0	1,5	85,0	1,5	70	40
	1987 to 1994	86,0	1,5	86,0	1,5	70	40
Condensing boiler (oil/gas)							
Condensing boiler	before 1987	89,0	1,0	95,0	1,0	60[c]	30[b]
	1987 to 1994	91,0	1,0	97,5	1,0	60[c]	30[b]
		92,0	1,0			30[c]	
	after 1994	92,0	1,0	98,0	1,0	60[c]	30[b]
		93,0	1,0			30[c]	
Condensing boiler, improved[a] from 1999	oil/gas	94,0	1,0	103	1,0	60[c]	30[b]
	oil	102,0	0,3			30[c]	
	gas	102,0	1,0			30[c]	

[a] If standard values for “condensing boilers improved” are used for the calculation, the product value for the boiler installed must exhibit the above given efficiency.

[b] For condensing boilers according to directive 92/42/EEC[28], testing applies at a return path temperature of 30 °C.

[c] For condensing boilers, testing applies at a return path temperature of 60 °C respectively 30 °C.

Table A.2 — Parameters for calculation of boiler efficiency and temperature limitation based on EN 303–5[10]

Boiler type	c_1	c_2	c_3	c_4	$\theta_{\mathrm{gen,test,Pn}}$ °C	$\theta_{\mathrm{gen,test,Pint}}$ °C
Class 1	47	6	48	6	70	50
Class 2	57	6	58	6	70	50
Class 3	67	6	68	6	70	50

A.1.1.2 Stand-by heat losses

Default value for the stand-by heat losses $f_{\mathrm{gen,ls.P0}}$ as a function of the generator power output is calculated by:

$$f_{\mathrm{gen,ls,P0}} = \frac{c_5 \cdot (P_\mathrm{n})^{c_6}}{100} \qquad \text{(A.5)}$$

where

P_n is the nominal power output, in kW;

c_5, c_6 are the parameters given in Table A.3.

Table A.3 — Parameters for calculation of stand-by heat losses

Boiler type	Build year	Factor c_5	Factor c_6	$\theta_{\mathrm{gen,test,P0}}$ °C
Standard boilers:				
Multi-fuel boilers	before 1987	12,5	−0,28	70
Atmospheric solid fuel boiler (fossil and biomass fuel)	before 1978	12,5	−0,28	70
	1978 to 1994	10,5	−0,28	70
	after 1994	8,0	−0,28	70
atmospheric gas boilers	before 1978	8,0	−0,27	70
	1978 to 1994	7,0	−0,3	70
	after 1994	8,5	−0,4	70
Fan-assisted boilers (fossil and biomass fuel)	before 1978	9,0	−0,28	70
	1978 to 1994	7,5	−0,31	70
	after 1994	8,5	−0,4	70
Biomass boilers	after 1994	14	−0,28	70
Low temperature boilers:				
Atmospheric gas boilers	before 1994	6,0	−0,32	70
	after 1994	6,1	−0,4	70
Circulation water heaters (combination boilers 11 kW, 18 kW and 24 kW)	before 1994	2,2	0	 70
Combination boilers KSp[b]	after 1994	2,2	0	70

[a] DL: Boiler with integrated domestic water heating working on the instantaneous principle with heat exchanger (V < 2 l).

[b] KSp: Boiler with integrated domestic water heating working on the instantaneous principle with small storage tank (2 < V < 10 l).

Table A.3 *(continued)*

Boiler type	**Build year**	**Factor c_5**	**Factor c_6**	$\theta_{\mathrm{gen,test,P0}}$ °C
Combination boilers DL[a]	after 1994	1,2	0	70
Fan-assisted boilers (oil/gas)	before 1994	7,0	−0,37	70
	after 1994	4,25	−0,4	70
Condensing boilers (oil/gas):				
Condensing boilers (oil/gas)	before 1994	7,0	−0,37	70
	after 1994	4,0	−0,4	70
Combination boilers KSp[b] (11 kW, 18 kW and 24 kW)	after 1994	2,2	0	70
Combination boilers DL[a] (11 kW, 18 kW and 24 kW)	after 1994	1,2	0	70

[a] DL: Boiler with integrated domestic water heating working on the instantaneous principle with heat exchanger ($V < 2$ l).

[b] KSp: Boiler with integrated domestic water heating working on the instantaneous principle with small storage tank ($2 < V < 10$ l).

A.1.1.3 Correction factor taking into account variation of efficiency depending on generator average water temperature

A.1.1.3.1 Default values

See Tables A.4 and A.5.

Table A.4 — Default values for full load correction factor $f_{\mathrm{corr,Pn}}$

Generator type	**Boiler average water temperature at boiler test conditions for full load** $\theta_{\mathrm{gen,test,Pn}}$	**Correction factor** $f_{\mathrm{corr,Pn}}$
Solid fuel boiler (fossil and biomass fuel)		
Standard boiler	70 °C	0,0 %/°C
Oil/gas boiler		
Standard boiler	70 °C	0,0 %/°C
Low temperature boiler	70 °C	0,04 %/°C

Table A.5 — Intermediate load correction factor $f_{\text{corr,Pint}}$

Generator type	Generator average water temperature at boiler test conditions for intermediate load $\theta_{\text{gen,test, Pint}}$	Correction factor $f_{\text{corr,Pint}}$
Solid fuel boiler (fossil and biomass fuel)		
Standard boiler	70 °C	0,04 %/°C
Oil/gas boiler		
Standard boiler	50 °C	0,04 %/°C
Low temperature boiler	40 °C	0,04 %/°C
Gas condensing boiler	30 °C [a]	0,20 %/°C
Oil condensing boiler	30 °C [a]	0,10 %/°C

[a] Return temperature.

For a condensing boiler, testing is not made with a defined generator average water temperature (average of the supply and return temperature), but with a return temperature of 30 °C. The efficiency corresponding to this return temperature can be applied for the generator average water temperature of 35 °C.

A.1.1.3.2 Calculated values

Correction factor $f_{\text{corr,Pn}}$ may be calculated using efficiency data from additional tests performed at a lower average water temperature, using the following formula:

$$f_{\text{corr,Pn}} = \frac{\eta_{\text{Pn}} - \eta_{\text{Pn,add}}}{\theta_{\text{gen,test,Pn,add}} - \theta_{\text{gen,test,Pn}}} \qquad \text{(A.6)}$$

where

η_{Pn} is the full load efficiency at standard test conditions with average water temperature $\theta_{\text{gen,test,Pn}}$;

$\eta_{\text{Pn,add}}$ is the full load efficiency with mean water temperature $\theta_{\text{gen,test,Pn,add}}$.

Correction factor $f_{\text{corr,Pint}}$ may be calculated using efficiency data from additional tests performed at a higher average water temperature, using the following formula:

$$f_{\text{corr,Pint}} = \frac{\eta_{\text{Pint}} - \eta_{\text{Pint,add}}}{\theta_{\text{gen,test,Pint,add}} - \theta_{\text{gen,test,Pint}}} \qquad \text{(A.7)}$$

where

η_{Pint} is the intermediate load efficiency at standard test conditions with average water temperature $\theta_{\text{gen,test,Pint}}$;

$\eta_{\text{Pint,add}}$ is the intermediate load efficiency with average water temperature $\theta_{\text{gen,test,Pint,add}}$.

A.1.2 Auxiliary energy

Default value for the power consumption of auxiliary equipment is calculated by:

$$P_{\mathrm{aux,Px}} = \frac{c_7 + c_8 \cdot (P_\mathrm{n})^\mathrm{n}}{1000} \tag{A.8}$$

where

P_n is the nominal power output, in kW;

c_7, c_8, n are the parameters given in Table A.6.

Table A.6 — Parameters for calculation of power consumption of auxiliary equipment

Boiler type	**Load**	**c_7** W	**c_8** W	**n**
Since 1994				
Heating boiler with forced draught burner[a] (fossil and biomass fuel)	P_n	0	45	0,48
	P_int	0	15	0,48
	P_0	15	0	0
Atmospheric gas boiler and solid fuel boiler (fossil and biomass fuel) up to 250 kW	P_n	40	0,35	1
	P_int	20	0,1	1
	P_0	15	0	0
Atmospheric gas boiler with more than 250 kW	P_n	80	0,7	1
	P_int	40	0,2	1
	P_0	15	0	0
Automatically-fed pellet central boiler[a], system with buffer tank	P_n	40	2	1
	P_int	40	1,8	1
	P_0	15	0	0
Automatically-fed wood chips central boiler[a], system with buffer tank	P_n	60	2,6	1
	P_int	70	2,2	1
	P_0	15	0	0
All other boilers				
Standard boiler				
Multi fuel boiler	P_n	0	45	0,48
	P_int	0	15	0,48
	P_0	20[b]	0	0
Solid fuel boiler (fossil and biomass fuel)	P_n	15[b]	0	0
	P_int	15[b]	0	0
	P_0	15[b]	0	0
Atmospheric gas boiler	P_n	40	0,148	1
	P_int	40	0,148	1
	P_0	15[b]	0	0

Table A.6 *(continued)*

Boiler type	Load	c_7 W	c_8 W	n
Heating boiler with forced draught burner (oil/gas)	P_n	0	45	0,48
	P_{int}	0	15	0,48
	P_0	15[b]	0	0
Low temperature boiler				
Atmospheric gas boiler	P_n	40	0,148	1
	P_{int}	40	0,148	1
	P_0	15[b]	0	0
Circulation water heaters	P_n	0	45	0,48
	P_{int}	0	15	0,48
	P_0	15[b]	0	0
Heating boiler with forced draught burner (oil/gas)	P_n	0	45	0,48
	P_{int}	0	15	0,48
	P_0	15[b]	0	0
Condensing boiler (oil/gas)				
condensing boiler (oil/gas)	P_n	0	45	0,48
	P_{int}	0	15	0,48
	P_0	15[b]	0	0

[a] If there is a forced draught ventilator assisting the burner than the values $P_{aux,Pn}$; $P_{aux,Pint}$ increase by 40 %.

[b] If an electronic controller is used, otherwise $P_{aux,P0} = 0$.

A.1.3 Recoverable generation thermal losses

A.1.3.1 Auxiliary energy

Default value of the part of the auxiliary energy transmitted to the distribution sub-system $f_{rvd,aux}$ is 0,75.

The part of the auxiliary energy transmitted to the heated space $f_{rbl,aux}$ is calculated by:

$$f_{rbl,aux} = 1 - f_{rvd,aux} \tag{A.9}$$

A.1.3.2 Generator envelope

The part of stand-by heat losses attributed to heat losses through the generator envelope is given by f_{env}. Default values of f_{env} are given in Table A.7.

Table A.7 — Part of stand-by heat losses attributed to losses through the generator envelope

Burner type	f_{env}
Atmospheric boiler	0,50
Fan assisted boiler	0,75

A.1.3.3 Default data according to boiler location

Table A.8 — Temperature reduction factor and default installation room temperature

Generator location	Temperature reduction factor, f_{brm} —	Installation room temperature, $\theta_{\mathrm{i,brm}}$ °C
Outdoors (for room independent boiler)	1	θ_{e}
In the boiler room	0,3	13
Under roof	0,2	5
Inside heated space	0,0	20

A.2 Conversion of the energy content of energy carriers

Factors for converting the energy content of energy carriers are specified in Table A.9.

Table A.9 — Conversion factors, as a function of energy carriers

Energy carrier		Ratio of gross calorific value $H_{\mathrm{s}}/H_{\mathrm{i}}$ (Conversion factor for delivered energy) $f_{\mathrm{Hs/Hi}}$
Fuels	Fuel oil	1,06
	Natural gas	1,11
	Liquid petroleum gas	1,09
	Anthracite coal	1,04
	Lignite coal	1,07
	Wood	1,08
Area/district heating by CHP[a]	Fossil fuels	1,00
	Renewable fuels	1,00
Area/district heating power plants	Fossil fuels	1,00
	Renewable fuels	1,00
Electricity	Electrical power source mix	1,00

[a] These values are typical for average area heating/district heating systems with a 70 % contribution by CHP plants.

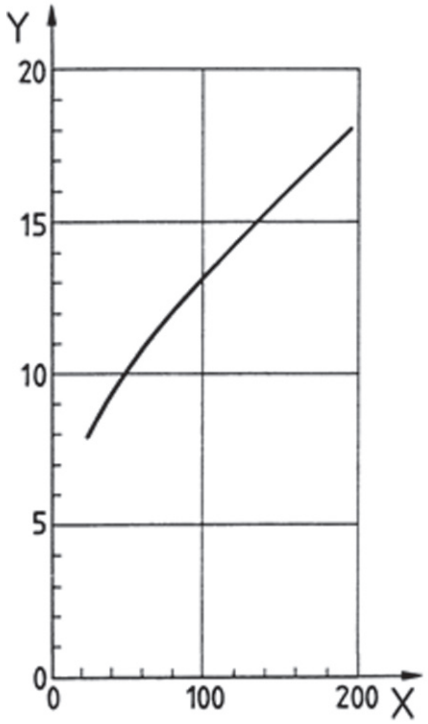
A.3 Deviation from default values

The above values need not to be used if the real net and gross calorific values of fuels are known. The factor $H_{\mathrm{s}}/H_{\mathrm{i}}$ is then the ratio of gross calorific value to net calorific value.

A.4 Fuel constants for flue gas measurement depending on Siegert constants

Table A.10 — Fuel constants for flue gas measurement depending on Siegert constants

	Natural gas	LPG	Light oil EL	Heavy fuel oil	Town gas
c_{10}	0,66	0,63	0,68	0,68	0,63
c_{11}	0,009	0,008	0,007	0,007	0,011



Key

X θ_{env} in °C

Y α in Wh/(m^2 K)

Figure A.1 — Heat transfer coefficient α for radiation and convection at horizontal and vertical area at ambient temperature θ_{brm} = 20 °C depending on the average envelope temperature θ_{env}

A.5 Default values for calculation of thermal losses through the chimney with the burner off

See Table A.11.

Table A.11 — Default value of $f_{ch,off}$

Description	$f_{ch,off}$ %
Liquid fuel or gas fired boiler with the fan before the combustion chamber and automatic closure of air intake with burner off:	
Premixed burners	0,2 0,2
Wall mounted, gas fired boiler with fan and wall flue gas exhaust	0,4
Liquid fuel or gas fired boiler with the fan before the combustion chamber and no closure of air intake with burner off:	
Chimney height ≤ 10 m	1,0
Chimney height > 10 m	1,2

A.6 Additional default data and calculation for condensing boilers

Flue gas temperature (at boiler outlet connection to flue gas), if not measured, is calculated by:

$$\theta_{fg} = \theta_{gen,RT} + \Delta\theta_{wfg} \quad (A.10)$$

where

$\theta_{gen,RT}$ is the boiler return water temperature, calculated according to Annex A.

The return temperature for part load measurement is 30 °C. The temperature difference between boiler return water temperature and flue gas temperature at part load is normally 5 K.

Actual amount of dry flue gas $V_{fg,dry}$ in Nm^3/Nm^3 or Nm^3/kg is calculated by:

$$V_{fg,dry} = V_{fg,st,dry} \cdot \frac{20{,}94}{20{,}94 - X_{O2,fg,dry}} \quad (A.11)$$

Actual amount of dry combustion air $V_{air,dry}$ in Nm^3/Nm^3 or Nm^3/kg is calculated by:

$$V_{air,dry} = V_{air,st,dry} + V_{fg,dry} - V_{fg,st,dry} \quad (A.12)$$

NOTE $V_{fg,dry} - V_{fg,st,dry}$ is excess air.

Combustion air temperature θ_{brm} is assumed either equal to installation room temperature for type B appliances or to external air temperature for type C appliances.

Saturation humidity of air $m_{H2O,air,sat}$ and flue gas $m_{H2O,fg,sat}$ shall be calculated according to θ_{brm} (combustion air temperature) and θ_{fg} (flue gas temperature), respectively, and expressed as kg of humidity per Nm^3 of dry air or dry flue gas. Data can be found in Table A.12. Linear or polynomial interpolation shall be used for intermediate temperatures.

Table A.12 — Saturation humidity as a function of temperature

Temperature (θ_{air} or θ_{fg})	°C	0	10	20	30	40	50	60	70
Saturation humidity $m_{H2O,air,sat}$ or $m_{H2O,fg,sat}$	kg/Nm^3_{dry}	0,004 93	0,009 86	0,019 12	0,035 21	0,063 31	0,111 2	0,197 5	0,359 6
NOTE Saturation humidity is expressed as kg of water vapour per Nm^3 of dry gas (either air or flue gas).									

Total humidity of combustion air $m_{\text{H2O,air}}$ in kg/Nm^3 or kg/kg is calculated by:

$$m_{\text{H2O,air}} = m_{\text{H2O,air,sat}} \cdot V_{\text{air,dry}} \cdot \frac{x_{\text{air}}}{100} \tag{A.13}$$

where

x_{air} is the combustion air relative humidity. Default value is given in Table A.14.

Total humidity of flue gas $m_{\text{H2O,fg}}$ in kg/Nm^3 or kg/kg is calculated by:

$$m_{\text{H2O,fg}} = m_{\text{H2O,fg,sat}} \cdot V_{\text{fg,dry}} \cdot \frac{x_{\text{fg}}}{100} \tag{A.14}$$

where

x_{fg} is the flue gas relative humidity. Default value is given Table A.14.

The amount of condensing water $m_{\text{H2O,cond}}$ in kg/Nm^3 or kg/kg is calculated by:

$$m_{\text{H2O,cond}} = m_{\text{H2O,st}} + m_{\text{H2O,air}} - m_{\text{H2O,fg}} \tag{A.15}$$

If $m_{\text{H2O,cond}}$ is negative, there is no condensation. Then $m_{\text{H2O,cond}} = 0$ and $f_{\text{cond}} = 0$.

The specific latent heat of condensation $h_{\text{cond,fg}}$ in kJ/kg is calculated by:

$$h_{\text{cond,fg}} = 2\,500{,}6\ \text{kJ/kg} - \theta_{\text{fg}} \times 2{,}435\ \text{kJ/kg}\cdot{}^\circ\text{C} \tag{A.16}$$

or

$$h_{\text{cond,fg}} = 694{,}61\ \text{Wh/kg} - \theta_{\text{fg}} \times 0{,}676\,4\ \text{Wh/kg}\cdot{}^\circ\text{C} \tag{A.17}$$

Use Formula A.16 or A.17 according to the choice of units for energy and time.

The specific condensation heat Q_{cond} in kJ/kg is calculated with:

$$Q_{\text{cond}} = m_{\text{H2O,cond}} \cdot h_{\text{cond.fg}} \tag{A.18}$$

The calculation is based on gross calorific values to get positive values, so the recovered latent heat of condensation P_{cond} is calculated by:

$$P_{\text{cond}} = \frac{Q_{\text{cond}}}{H_{\text{s}}} \cdot P_{\text{gen,del}} \tag{A.19}$$

Table A.13 — Default fuel data for condensation heat recovery calculation

Property	Symbol	Unit	Fuel			
			Natural gas (Groningen)	**Propane**	**Butane**	**Light oil EL**
Unit mass of fuel			1 Nm^3	1 Nm^3	1 Nm^3	1 kg

Table A.13 *(continued)*

Property	Symbol	Unit	Fuel			
			Natural gas (Groningen)	Propane	Butane	Light oil EL
Gross calorific value	H_s	kJ/kg or kJ/Nm^3	35 169 kJ/Nm^3	101 804 kJ/Nm^3	131 985 kJ/Nm^3	45 336 kJ/kg
Net calorific value	H_i	kJ/kg or kJ/Nm^3	31 652 kJ/Nm^3	93 557 kJ/Nm^3	121 603 kJ/Nm^3	42 770 kJ/kg
Stoichiometric dry air	$V_\text{air,st,dry}$	Nm^3/kg or Nm^3/Nm	8,4 Nm^3/Nm^3	23,8 Nm^3/Nm^3	30,94 Nm^3/Nm^3	11,23 Nm^3/kg
Stoichiometric dry flue gas	$V_\text{fg,st,dry}$	Nm^3/kg or Nm^3/Nm	7,7 Nm^3/Nm^3	21,8 Nm^3/Nm^3	28,44 Nm^3/Nm^3	10,49 Nm^3/kg
Stoichiometric water production	$m_\text{H2O,st}$	kg/kg or kg/Nm^3	1,405 kg/Nm^3	3,3 kg/Nm^3	4,03 kg/Nm^3	1,18 kg/kg

Table A.14 — Default values for the calculation of Q_cond

Description	Symbol	Unit	Case	Value
Combustion air relative humidity	x_air	%	All cases	50
Flue gas relative humidity	x_fg	%	All cases	100
Flue gas oxygen contents at maximum combustion power	$X_\text{O2,fg,dry}$	—	All cases	6

Annex B
(informative)

General part default values and information

B.1 Control factor

See Table B.1.

Table B.1 — Default values for control factor $f_{\mathrm{ctr,ls}}$ in Formula 2

Description	$f_{\mathrm{ctr,ls}}$
All control types	1,0

Other values may be specified in a national annex, provided that emission control losses have not been taken into account in the emission part.

NOTE The effect of heat emission control is taken into account in the emission and control part. The effect of the control of generation is taken into account through losses and efficiency corrections according to the operating temperature of the generator.

Table B.2 is an example of such table to be given in a national annex.

Table B.2 — Sample default national table for control factor in Formula 2

Boiler type	Control type	$f_{\mathrm{ctr,ls}}$
Floor standing boiler	Outdoor temperature controlled	1,00
Wall hanged boiler	Outdoor temperature controlled	1,03
	Room temperature controlled	1,06

B.2 Intermediate load

Intermediate load P_{int} is given by:

$$P_{\mathrm{int}} = P_{\mathrm{n}} \cdot \beta_{\mathrm{Pint}} \qquad \text{(B.1)}$$

For gas and oil fuelled generators, the default value of β_{Pint} is 0,3.

Annex C
(normative)

Maximum heating power in the building zone

C.1 General considerations

The value of the maximum heating power installed in the building zone is needed in order to calculate the utilization of the system components and, on the basis of this, the corresponding energy need using the methods described in ISO 13790.

The maximum heated power required for a building zone is calculated by an approximate balance calculation of the quasi-steady-state heat flows due to transmission and ventilation heat sinks for the climatic conditions of the heating season for which the system was designed. Heat source must be neglected in these approximations. Where no ventilation systems are installed, the value is determined as described in C.2.

If a ventilation system is installed, additional reheating of the supply air from the ventilation system must be taken into consideration when calculating the utilization of the individual system components. This is discussed in C.4.

Conditioning of outdoor air to achieve indoor air conditions in ventilation systems is not included in the calculations for the maximum heating power. The power required for this process must be calculated separately for HVAC systems.

NOTE The maximum heating power calculated by the method described here cannot be used to substitute design calculation of system components in accordance with the applicable technology standards.

C.2 Calculation of the maximum heating power $P_{\mathrm{n,max}}$ for a design-rating day (without ventilation system)

$$P_{\mathrm{n,max}} = P_{\mathrm{sink,max}} = P_{\mathrm{tr,max}} + P_{\mathrm{ve,max}} \tag{C.1}$$

where

$$P_{\mathrm{tr,max}} = \sum H_{\mathrm{tr}} \cdot (\theta_{\mathrm{H,int,min}} - \theta_{\mathrm{e,min}}) \tag{C.2}$$

$$P_{\mathrm{ve,max}} = \sum H_{\mathrm{ve}} \cdot (\theta_{\mathrm{H,int,min}} - \theta_{\mathrm{e,min}}) \tag{C.3}$$

and

H_{tr}	is the heat transfer coefficient of transmission;
H_{ve}	is the heat transfer coefficient of ventilation;
$\theta_{\mathrm{H,int,min}}$	is the design room, zone temperature for heating operation;
$\theta_{\mathrm{e,min}}$	is the design external air temperature.

C.3 Design rating conditions

The following boundary conditions must be taken into consideration:

- climatic conditions ($\theta_{\mathrm{e,min}}$) on the day are taken as a design reference for heating operations;
- internal heat gains and solar heat gains are assumed to be zero;
- reduced heating at night times is not taken into consideration;
- the air volume flow values (infiltration and window airing) applying to normal usage times are applied;
- heat and cold gains due to heat generation and refrigeration, storage and distribution process are not taken into consideration.

C.4 Maximum heating power required, taking into consideration a ventilation system

To take a ventilation system into consideration when determining the maximum heating power required in the building zone, the calculations must account for cooling due to the supply air induced by the ventilation system. In this case, the calculation must include the volume flow of the ventilation system for the winter design conditions and corresponding to the type of usage and/or the requirements of the system, as well as the supply-air temperature at design rating conditions. The ventilation system must be taken into consideration when determining values for infiltration and air change due to window airing.

The necessary heating power, including the power required for reheating supply air is thus calculated as follows:

$$P_{\mathrm{H,max,res}} = P_{\mathrm{sink,max}} = P_{\mathrm{tr,max}} + P_{\mathrm{ve,max}} + P_{\mathrm{ve,mech,min}} \tag{C.4}$$

with

$$P_{\mathrm{tr,max}} = \sum H_{\mathrm{tr}} \cdot (\theta_{\mathrm{H,int,min}} - \theta_{\mathrm{e,min}}) \tag{C.5}$$

$$P_{\mathrm{ve,max}} = \sum H_{\mathrm{ve}} \cdot (\theta_{\mathrm{H,int,min}} - \theta_{\mathrm{e,min}}) \tag{C.6}$$

$$P_{\mathrm{ve,mech,min}} = \dot{V}_{\mathrm{mech,min}} \cdot c_{\mathrm{p,air}} \cdot \rho_{\mathrm{air}} \cdot (\theta_{\mathrm{H,int,min}} - \theta_{\mathrm{ve,mech}}) \quad \text{in cases where} \quad \theta_{\mathrm{H,int,min}} > \theta_{\mathrm{ve,mech}} \tag{C.7}$$

where

H_{tr}	is the heat transfer coefficient of transmission;
H_{ve}	is the heat transfer coefficient of ventilation;
$\dot{V}_{\mathrm{mech,min}}$	is the minimum volume flow of the ventilation system under design conditions for heating operation without special requirements;
$c_{\mathrm{p,air}}$	is the specific heat capacity of air;
ρ_{air}	is the density of air;
$c_{\mathrm{p,air}} \cdot \rho_{\mathrm{air}}$	is assigned a value of 0,34 Wh/(m^3 K);
$\theta_{\mathrm{H,int,min}}$	is the design room, zone temperature for heating operation;

$\theta_{e,min}$	is the design external air temperature;
$\theta_{ve,mech}$	is the supply-air temperature of the ventilation system under design conditions for heating operation (without special requirements and taking into consideration the design temperature $\theta_{e,min}$).

If no ventilation system is installed $P_{H,max,res} = P_{H,max}$.

Annex D
(informative)

Calculation examples for modulating condensing boiler

D.1 Input data

See Table D.1.

Table D.1 — Boiler data

Description	Symbol	Value
Boiler type		Gas condensing boiler 2005
Nominal power (heat output)	P_n	70 kW
Efficiency test results produced in accordance with standard tests	$\eta_{gen,Pn,60}$	95,8 % (full-load net efficiency) $\theta_{gen,test,Pn}$ = 60 °C
	$\eta_{gen,Pn,30}$	95,8 % (full-load net efficiency) $\theta_{gen,test,Pn}$ = 30 °C
	$\eta_{gen,Pint}$	104,8 % (30% part-load net efficiency) $\theta_{gen,test,Pint}$ = 30 °C
Auxiliary electric power at full load	$P_{aux,Pn}$	364 W
Auxiliary electric power at intermediate load	$P_{aux,Pint}$	115 W
Auxiliary electric power at zero load	$P_{aux,P0}$	15 W
Fuel used.		Natural gas
Burner type		Modulating, fan assisted
Boiler location		Boiler room
Type of control		Depending on outside temperature
Generation circuit typology		Direct connection of boiler
Operation time of the generator	t_H	2 592 000 s = 720 h[a]
Generator heat output	$Q_{H,gen,out}$	80,9 GJ = 22 472 kWh
Generation average temperature	$\theta_{HC,m}$	48,9 °C
Generation return temperature	$\theta_{HC,RT}$	37,7 °C
generation average power	input data	$P_{gen,out} = \frac{80{,}9\ \text{GJ}}{2\ 592\ 000\ \text{s}} = 31{,}2\ \text{kW}$
load factor	input data	$\beta_{H,gen} = \frac{31{,}2\ \text{kW}}{70\ \text{kW}} = 0{,}446$ (single boiler, only heating load)
load factor at full load	input data	β_{Pn} = 1,0 (single boiler, only heating load)
load factor at intermediate load	input data	β_{Pint} = 0,3 (single boiler, only heating load)

[a] Example estimated as 30 days, continuous operation.

D.2 Calculation procedure

See Table D.2.

Table D.2 — Calculation procedure

Procedure step	References	Calculation details and results
Calculation of corrected boiler efficiency at full load	5.2.2 Table A.3 Formula 17a	$\eta_{\text{gen,Pn,corr}} = 95{,}85\,\% - \frac{95{,}85\,\% - 103{,}85\,\%}{60\,°\text{C} - 30\,°\text{C}} \cdot (60°\text{C} - 37{,}7\,°\text{C})$ $\theta_{\text{gen,test,Pn}}$ = 60 °C (Table A.3, gas condensing boiler) $\eta_{\text{gnr,Pn,corr}}$ = 101,8 %
Calculation of corrected generator thermal losses at full load	5.2.2 Formula 18	$P_{\text{gen,ls,Pn,corr}} = \frac{(111\ \% - 101{,}8\ \%)}{101{,}8\ \%} \times 70\ \text{kW}\ = 6332\ \text{W}$
Calculation of corrected boiler efficiency at intermediate load	5.2.2.1 Formula 19 Table A.4	$f_{\text{corr,Pint}}$ = 0,20 %/°C (Table A.4, gas condensing boiler) $\theta_{\text{gen,test,Pint}}$ = 30 °C (Table A.4, gas condensing boiler) $\eta_{\text{gen,Pint,corr}} = 104{,}8\,\% + 0{,}20\ \%/°\text{C} \times (30\,°\text{C} - 37{,}7\,°\text{C})$ = 103,3%
Calculation of corrected generator thermal losses at intermediate load	5.2.2.1 Formula 20	$P_{\text{gen,ls,Pint,corr}} = \frac{(111\,\% - 103{,}3\,\%)}{103{,}3\,\%} \times 21\,\text{kW}\ = 1564\ \text{W}$
Calculation of stand-by heat loss of the boiler	A.1.3.2 Table A.2 Formula A.3	c_5 = 4,0 (Table A.2, gas condensing boiler, after 1994) c_6 = −0,4 (Table A.2, gas condensing boiler, after 1994) $f_{\text{gen,ls,P0}} = \frac{4{,}0 \cdot (70\,\text{kW})^{-0{,}4}}{100}\ = 0{,}007\,31$
Calculation of corrected thermal losses at 0% load	5.2.2.2 Formula 21	$P_{\text{gen,ls,P0,corr}} = \frac{70\ \text{kW}}{95{,}8\,\%} \cdot 0{,}007\,31 \cdot 111\,\% \cdot \left(\frac{48{,}9\,°\text{C} - 13\ °\text{C}}{50\ \text{K}}\right)^{1{,}25}$ = 392 W
Calculation of corrected thermal losses at actual load	5.2.2.3 Formula 23	Formula 23 because $P_{\text{Px}} > P_{\text{Pint}}$ $P_{\text{gen,ls,Px}} = \frac{31{,}2\ \text{kW} - 21\ \text{kW}}{70\ \text{kW} - 21\ \text{kW}} \times (6\,332\ \text{W} - 1\,564\ \text{W}) + 1\,564\ \text{W}$ = 2 558 W
Calculation of total boiler thermal loss	5.2.2.3 Formula 24	$Q_{\text{gen,ls}}$ = 2,558 kW × 720 h = 1842 kWh = 6630 MJ
Calculation of total boiler thermal loss	5.2.2.4 Formula 25	$Q_{\text{H,gen,ls}} = \sum Q_{\text{gen,ls}}\ = 1\,842\ \text{kWh} = 6\,630\ \text{MJ}$
Calculation of auxiliary power at actual load	5.2.3 Formula 27	Formula (27) because $\beta_{\text{gnr}} > \beta_{\text{int}}$ $P_{\text{aux,Px}} = \frac{0{,}446 - 0{,}30}{1 - 0{,}30} \times (346\,\text{W} - 115\,\text{W}) + 115\,\text{W}\ = 163\ \text{W}$
Calculation of generator total auxiliary energy demand	5.2.3 Formula 28	W_{gen} = 163 W × 720 h + 15 W × (720 h − 720 h) = 117,6 kWh
Calculation of generation total auxiliary energy demand	5.2.3 Formula 29	$W_{\text{H,gen}} = \sum W_{\text{gen}}\ = 117{,}6\ \text{kWh} = 423{,}3\ \text{MJ}$

Table D.2 *(continued)*

Procedure step	References	Calculation details and results
Calculation of generator recovered auxiliary energy	5.2.4.1	No recovered auxiliary energy is explicitly taken into account because it is already included in test data $Q_{\text{gen,aux,rvd}} = 0$
Calculation of generator recoverable auxiliary energy (to the heated space)	A.1.3.1 Formula A.9 Table A.7 5.2.4.1 Formula 31	$f_{\text{rbl,aux}} = 1 - 0{,}75 = 0{,}25$ $f_{\text{brm}} = 0{,}3$ $Q_{\text{gen,aux,rbl,}} = 117{,}6\ \text{kWh} \times (1 - 0{,}3) \times 0{,}25 = 20{,}6\ \text{kWh} = 74{,}1\ \text{MJ}$
Calculation of generator recoverable heat losses	5.2.4.2 Formula 32	$Q_{\text{gen,ls,env,rbl}} = 392\ \text{W} \times (1 - 0{,}3) \times 0{,}75 \times 720\ \text{h} = 148{,}1\ \text{kWh} = 533{,}1\ \text{MJ}$
Calculation of total generation recovered auxiliary energy	5.2.4.3 Formula 28	No recovered auxiliary energy is explicitly taken into account because it is already included in test data, hence $Q_{\text{H,gen,aux,rvd}} = 0$
Calculation of total generation recoverable heat losses	5.2.4.3 Formula 29	$Q_{\text{H,gen,ls,rbl}} = 148{,}1\ \text{kWh} + 20{,}6\ \text{kWh} = 168{,}7\ \text{kWh} = 607{,}2\ \text{MJ}$
Calculation of total generation heat input	4.5 and 5.2.5 Formula 1	$E_{\text{H,gen,in}} = 22\,472\ \text{kWh} - 0\ \text{kWh} + 1842\ \text{kWh} - 0\ \text{kWh}$ $= 24\,314\ \text{kWh} = 87\,529\ \text{MJ}$

D.3 Output data

See Table D.3.

Table D.3 — Output data

Description	Symbol	Value
Fuel heat requirement	$E_{\text{H,gen,in}}$	24 314 kWh = 87 529 MJ
Total generation heat loss	$Q_{\text{H,gen,ls}}$	1 842 kWh = 6 630 MJ
Auxiliary consumption	$W_{\text{H,gen,}}$	118 kWh = 423 MJ
Recoverable heat loss	$Q_{\text{H,gen,ls,rbl}}$	169 kWh = 607 MJ

D.4 Conversion of gross values to net values

If losses have to be calculated according to net calorific value, then the following procedure in Table D.4 applies.

Table D.4 — Gross to net conversion procedure

Procedure step	References	Calculation details and results
Calculation of the latent heat	Table A.12	Default values for natural gas: — H_s = 35,17 MJ/Nm^3 — H_i = 31,65 MJ/Nm^3 — $Q_{lat} = 87\,529\ \text{MJ} \times \frac{35{,}17\ \text{MJ/Nm}^3 - 31{,}65\ \text{MJ/Nm}^3}{35{,}17\ \text{MJ/Nm}^3}$ = 8 760 MJ = 2 433 kWh
Correction of fuel input		$E_{H,gen,in,net}$ = 87 529 MJ –8 760 MJ = 78 769 MJ = 21 880 kWh

Annex E
(informative)

Generation sub-systems and gross calorific values

E.1 Multiple boilers or generation sub-systems

The primary scope of this International Standard is to calculate losses, fuel requirement and auxiliary energy requirements for an individual boiler.

If there are multiple generation sub-systems, the input data allows for a modular approach to take into account cases where:

- a heating system is split up in zones with several distribution sub-systems;
- several heat generation sub-systems are available.

EXAMPLE 1 A separate circuit may be used for domestic hot water production.

EXAMPLE 2 A boiler may be used as a back-up for a solar and/or cogeneration sub-system(s).

In these cases, the total heat requirement of the connected distribution sub-systems $\Sigma_i Q_{X,dis,in,i}$ shall equal the total heat output of the generation sub-systems $\Sigma_j Q_{X,gen,out,j}$:

$$\sum_j Q_{X,gen,out,j} = \sum_i Q_{X,dis,in,i} \tag{E.1}$$

NOTE X is used as an index in Formula 3 to mean space heating, domestic hot water heating or other building services requiring heat from a generation sub-system.

If there are several generation sub-systems, the total heat demand of the distribution sub-system(s) shall be distributed among the available generation sub-systems. The calculation described in E.3 shall be performed independently for each heat generation device j, on the basis of $Q_{H,gen,out,j}$.

Criteria for distribution of the total heat demand among the available generation sub-systems may be based on physical, efficiency or economic considerations.

EXAMPLE 3 Solar or heat pump sub-system maximum heat output.

EXAMPLE 4 Heat pumps or cogeneration optimum (either economic or energetic) performance range.

Appropriate criteria for specific types of generation sub-systems can be found in the relevant parts of the EN 15316-4-X series of standards.

Procedures to split the load among multiple combustion generators (boilers) are given for basic cases in E.3.

EXAMPLE 5 Given $\Sigma Q_{H,dis,in}$, the maximum output of a solar generation system $Q_{H,sol,out}$ should be calculated first, and subsequently the heat output that can be provided by a cogeneration system is added $Q_{chp,gen,out}$. The rest ($Q_{H,gen,out,boil} = \Sigma Q_{H,dis,in} - Q_{H,sol,out} - Q_{chp,gen,out}$, see Figure E.1) is attributed to boilers and may be further split among multiple boilers according to E.3.

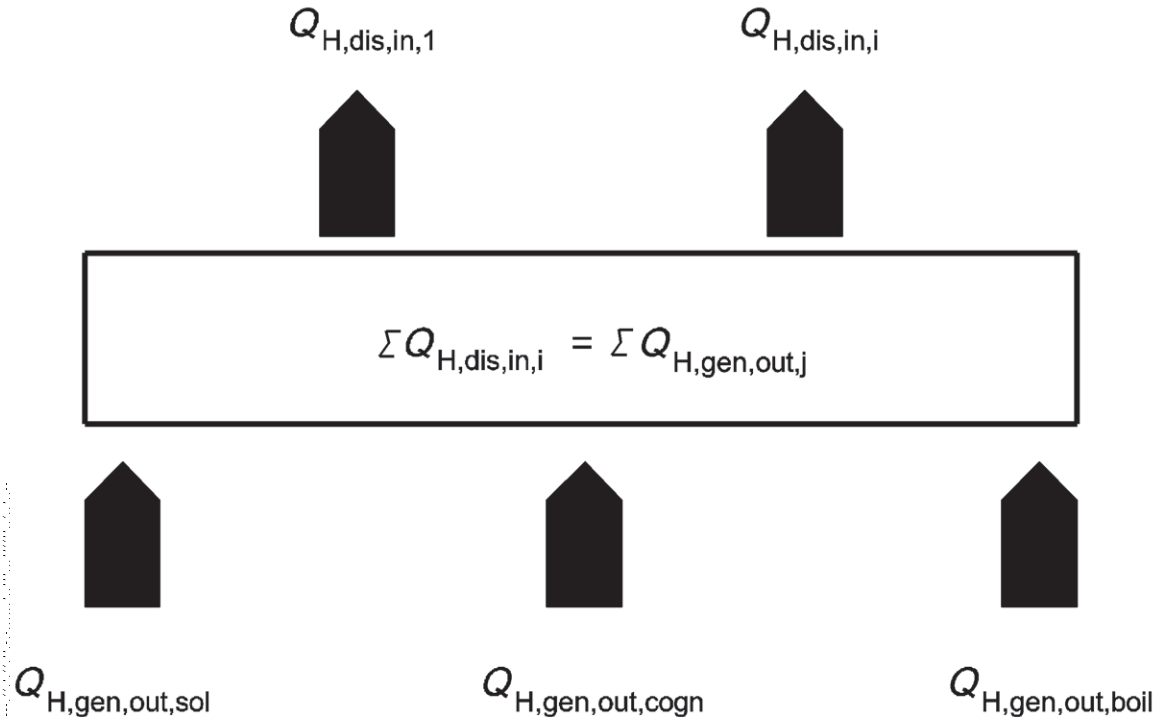


Figure E.1 — Example of load splitting among generation sub-systems

E.2 Using net or gross calorific values

Calculations described in Annex E may be performed according to net or gross calorific values. All parameters and data shall be consistent with this option.

If the calculation of the generation sub-system is performed according to data based on fuel net calorific values H_i, total losses $Q_{H,gen.ls,net}$, non-recoverable thermal losses $Q_{H,gen,ls,th,nrbl,net}$ and generation sub-system energyware, $E_{H,gen,in,net}$ (i.e. fuel input for combustion systems) based on net calorific values may be converted to values $Q_{H,gen,ls,grs}$, $Q_{H,gen,ls,th,nrbl,grs}$ and $E_{H,gen,in,grs}$ based on gross calorific values H_S by addition of the latent heat of condensation Q_{lat} according to the following:

$$Q_{lat} = E_{H,gen,in,net} \cdot \frac{H_s - H_i}{H_i} \tag{E.2}$$

$$E_{H,gen,in,grs} = E_{H,gen,in,net} + Q_{lat} \tag{E.3}$$

$$Q_{H,gen,ls,grs} = Q_{H,gen,ls,net} + Q_{lat} \tag{E.4}$$

$$Q_{H,gen,ls,th,nrbl,grs} = Q_{H,gen,ls,th,nrbl,net} + Q_{lat} \tag{E.5}$$

E.3 Load of each boiler

E.3.1 Generation sub-system average power

Generation sub-system average power $\Phi_{\mathrm{H,gen,out}}$ is given by:

$$\Phi_{\mathrm{H,gen,out}} = \frac{Q_{\mathrm{H,gen,out}}}{t_{\mathrm{gen}}} \tag{E.6}$$

where

t_{gen} is the total time of generator(s) operation.

E.3.2 Single boiler generation sub-system

If there is only one generator installed, the load factor β_{gnr} is given by:

$$\beta_{\mathrm{gnr}} = \frac{\Phi_{\mathrm{H,gen,out}}}{\Phi_{\mathrm{Pn}}} \tag{E.7}$$

where

Φ_{Pn} is the nominal power output of the generator.

E.3.3 Multiple boilers generation sub-system

E.3.3.1 General

If there are several boilers installed, distribution of the load among boilers depends on control. Two types of control are distinguished:

- without priority;
- with priority.

E.3.3.2 Multiple generators without priority

All generators are running at the same time and therefore the load factor β_{gnr} is the same for all boilers and is given by:

$$\beta_{\mathrm{gnr}} = \frac{\Phi_{\mathrm{H,gen,out}}}{\sum_{\mathrm{i}} \Phi_{\mathrm{Pn,i}}} \tag{E.8}$$

where

$\Phi_{\mathrm{Pn,i}}$ is the nominal power output of generator i at full load.

E.3.3.3 Multiple generators with priority

The generators of higher priority are running first. A given generator in the priority list is running only if the generators of higher priority are running at full load ($\beta_{\mathrm{gnr,i}} = 1$).

If all boilers have the same power output Φ_{Pn}, the number of running generators $N_{\mathrm{gnr,on}}$ is given by:

$$N_{\mathrm{gnr,on}} = \mathrm{int}\left(\frac{\Phi_{\mathrm{H,gen,out}}}{\Phi_{\mathrm{Pn}}}\right) \tag{E.9}$$

Otherwise running boilers have to be determined so that $0 < \beta_{\mathrm{gnr,j}} < 1$ (see Formula E.8).

The load factor $\beta_{\mathrm{gnr,j}}$ for the intermittent running generator is calculated by:

$$\beta_{\mathrm{gnr,j}} = \frac{\Phi_{\mathrm{H,gen,out}} - \sum_{\mathrm{i=1}}^{\mathrm{N_{gnr,on}}} \Phi_{\mathrm{Pn,i}}}{\Phi_{\mathrm{Pn,j}}} \tag{E.10}$$

where

$\Phi_{\mathrm{Pn,i}}$ is the nominal power output of generator i running at full load;

$\Phi_{\mathrm{Pn,j}}$ is the nominal power output of intermittent running generator.

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