Doc. CEN/TC 228 N532

CEN/TC 228

Date: 2006-08

CEN/TC 228 WI 023

CEN/TC 228

Secretariat: DS

Heating systems in buildings — Method for calculation of system energy requirements and system efficiencies — Part 4-1: Space heating generation systems, combustion systems

Einführendes Element — Haupt-Element — Ergänzendes Element

Élément introductif — Élément central — Élément complémentaire

ICS:

Descriptors:

Document type: European Standard
Document subtype:
Document stage: Formal Vote
Document language: E

C:\Mine dokumenter\TC 228\WG 4\WI 00228023\TC version\N532_prEN 15316-4-1_WI00228023_2006-08.doc STD Version 2.1c

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Foreword

This document (prEN 15316-4-1:2005) has been prepared by Technical Committee CEN/TC 228 “Heating systems in buildings”, the secretariat of which is held by DS.

The subjects covered by CEN/TC 228 are the following:

- design of heating systems (water based, electrical etc.);
- installation of heating systems;
- commissioning of heating systems;
- instructions for operation, maintenance and use of heating systems;
- methods for calculation of the design heat loss and heat loads;
- methods for calculation of the energy performance of heating systems.

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

All these standards are systems standards, i.e. they are 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 other European or International Standards, a.o. 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.

The guidelines describe ways to meet the requirements, but other ways to fulfil the functional requirements might be used if fulfilment can be proved.

Heating systems differ among the member countries due to climate, traditions and national regulations. In some cases requirements are given as classes so national or individual needs may be accommodated.

In cases where the standards contradict with national regulations, the latter should be followed.

Introduction

This standard presents methods for calculation of the additional energy requirements of a heat generation system in order to meet the distribution and/or storage sub-system demand. 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;

— optimisation 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.

The user shall refer to other European Standards or to national documents for input data and detailed calculation procedures not provided by this standard.

1 Scope

This standard is part of a series of standards on the method for calculation of heating system energy requirements and heating system efficiencies.

This standard defines:

— required inputs;

— calculation method;

— resulting outputs

for space heating generation by combustion sub-systems using liquid and gaseous fuels, including control.

This standard can also be used for generation for domestic hot water production. The case of generation which products heat only for domestic hot water is treated in EN 15316-3-3.

2 Normative references

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

EN 13790, *Thermal performance of buildings - Calculation of energy use for space heating and cooling*

prEN 15316-1, *Heating systems in building - Method for calculation of system energy requirements and system efficiencies – Part 1: General*

prEN 15316-2-1, *Heating systems in building - Method for calculation of system energy requirements and system efficiencies – Part 2-1: Space heating emission systems*

prEN 15316-2-3, *Heating systems in building - Method for calculation of system energy requirements and system efficiencies – Part 2-3: Space heating distribution systems*

prEN 15316-3-3, *Heating systems in building - Method for calculation of system energy requirements and system efficiencies – Part 3-3: Domestic hot water systems, generation*

EN ISO 7345, *Thermal insulation - Physical quantities and definitions (ISO 7345:1987)*

EN 297, *Boilers for gaseous fuels - boilers of Types B_{11} and B_{11Bs} with atmospheric burners with a rated heat part load smaller than or equal to 70 kW Heizkessel für gasförmige Brennstoffe — Heizkessel der Typen B_{11} und B_{11Bs} mit atmosphärischen Brennern mit einer Nennwärmebelastung kleiner oder gleich 70 kW[*

EN 303-5, *Solid fuel boilers, manually and automatically fired, rated heat load up to 300 kW- terms, requirements, testing and identification [Heizkessel — Teil 5: [Boilers — Part 5:] Heizkessel für feste Brennstoffe, hand- und automatisch beschickte Feuerungen, Nennwärmeleistung bis 300 kW — Begriffe, Anforderungen, Prüfung und Kennzeichnung]*

EN 304, *Boilers — Testing regulations for boilers with oil atomisation burners [Heizkessel — Prüfregeln für Heizkessel mit Ölzerstäubungsbrennern]*

EN 656, *Boilers for gaseous fuels — Type B boilers with a rated heat load greater than 70 kW, but equal to or less than 300 kW [Heizkessel für gasförmige Brennstoffe — Heizkessel der Typs B mit einer Nennwärmebelastung größer als 70 kW, aber gleich oder kleiner als 300 kW]*

EN 15034 ??

EN 15035 ??

prEN 15456 *Heating boilers – Electrical power consumption for heat generators – System boundaries - Measurements*

3 Terms and definitions

3.1 Definitions

For the purposes of this document, the definitions given in EN ISO 7345:1995 and the following terms and definitions apply:

3.1.1
auxiliary energy
energy, other than fuel, required for the operation of any equipment (the burner, the primary pump, …) whose operation is dependent only on the heat generation sub-system operation, not on the distribution

3.1.2
boiler
a gas or liquid fuelled appliance designed to provide hot water for space heating. It may (but need not) be designed to provide domestic hot water as well.

3.1.3
calculation period
time period considered for the calculation of the heat losses of the heating system

3.1.4
combustion power
product of the fuel flow rate and the net calorific power of the fuel

3.1.5
condensing boiler
a boiler designed to make use of the latent heat released by condensation of water vapour in the combustion flue products. The boiler must allow the condensate to leave the heat exchanger in liquid form by way of a condensate drain.

NOTE: Boilers not so designed, or without the means to remove the condensate in liquid form are called ‘non-condensing’

3.1.6
energy requirements for heating
energy to be delivered to the heating system to satisfy the heat demand of the building

3.1.7
heat demand, building
heat to be delivered to the heated space to maintain the internal set-point temperature of the heated space

3.1.8
heated space
room or enclosure heated to a given set-point temperature

3.1.9
heating system heat losses, generation
heat loss due to losses through the chimney and through the generator envelope

3.1.10
heating system heat losses, total
total of the heat losses from the heating system, including recoverable heat losses

3.1.11
low temperature boiler
a non-condensing boiler designed as a low temperature boiler and tested as a low temperature boiler as prescribed by the Council Directive 92/42/EEC about Boiler Efficiency

3.1.127
modes of operation
various modes in which the heating system can operate (set-point mode, cut-off mode, reduced mode, set-back mode, boost mode)

3.1.13
modulating boiler
a boiler with the capability to vary the fuel burning rate whilst maintaining continuous burner firing

3.1.14
net heat requirements
heat requirements reduced by the recovered system heat losses

3.1.15
oil condensing boiler
A boiler designed to make use of the latent heat released by condensation of water vapour in the combustion flue products of a liquid fuel (see EN 15034 or EN 15035)

3.1.16
on/off boiler
a boiler without the capability to vary the fuel burning rate whilst maintaining continuous burner firing. This includes boilers with alternative burning rates set once only at the time of installation, referred to as range rating

3.1.17
primary energy
energy taking into account the considered transformation losses of the entire energy chain

3.1.18
recoverable heat loss
part of the heat loss, from the space heating and domestic hot water system, which may be recovered to lower the heat demand for space heating

3.1.19
recovered heat loss
part of the recoverable heat loss which contributes to meet the heat demand of the space

3.2 Symbols and units

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

Table 1: Symbols and units

Symbol	Name of quantity	Unit
b	temperature reduction factor	-
c	specific condensate production	kg/kg or kg/Nm³
CH	latent condensation heat of water	MJ/kg or MJ/Nm³
e	system performance coeff. (expenditure factor)	-
E	primary energy	J
f	conversion factor	-
FC	heat generator part load ratio, load factor	-
G,H	parameters	-
k	part of recoverable auxiliary energy	-
LH	lower combustion heat of fuel	MJ/kg or MJ/Nm³
M	burner modulation ratio	-
N	number of running generators	-
P	specific heat losses	%
p	part of electrical power transmitted to the air	-
Q	quantity of heat, energy	J
r	recoverable heat factor	-
R	condensation heat recovery factor	%
t	time, period of time	s
T	thermodynamic temperature	K
W	electrical auxiliary energy	J
β	Load factor	-
Φ	thermal or electrical power	W
θ	Celsius temperature	°C
η	Efficiency	-

Table 2: Indices

a	air	*g*	generation		
af	*after generator*	gs	gains	*p*	primary
avg	*average*	*gn*	*generator*		
aux	auxiliary	*h*	heating energy	*Pint*	*power at intermediate load*
br	before generator			*P0*	*power at zero load*
c	control	*i*	internal	*Pn*	*power at nominal load*
ch	*chimney*	in	input to system	*Px*	*power at x load*
ci	calculation period	*int*	*intermediate*		
cn	*combustion*			r	return
cor	*corrected*	*j*	*indices*	ref	reference
d	distribution	*l*	loss	*rd*	recovered
dhw	domestic hot water	max	maximum	*rl*	*recoverable*
		min	minimal	*s*	storage
e	external	n	nominal	*t*	total
el	electrical energy	*nh*	*non recoverable*	*test*	*test conditions*
env	envelope	nr	non recovered losses	*w*	heating system water
em	emission				
		off	off	*x*	indices
f	*final*	*on*	on	*z*	indices
fl	fluid (water)	out	output from system		

Note 1: The indices specifying the symbols in this standard shall be put in the following order:

— the first index represents the use (h = space heating, w = domestic hot water);

— the second index represents the sub-system (gn = generation, di = distribution, etc.);

— the third index represents the type (ls= losses, gs = gains, in = input, etc.);

— other indices can be used for more details (rd = recovered, rb = recoverable, int = internal, etc.).

Note 2: The indices are separated by a comma.

TO BE DONE: CHECK ALLL SYMBOLS AND INDICES

4 Principle of the method

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

4.1.1 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:

— heat losses to the chimney (or flue gas exhaust) during total time of generator operation (running and stand-by);

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

— auxiliary energy.

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

— type of heat generator(s);

— location of heat generator(s);

— part load ratio;

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

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

4.1.2 Calculation structure (input and output data)

The calculation method of this standard shall be based on the following input data from other parts of the EN 15316-X-X standards series:

— heat demand of the heating system heat distribution sub-system(s) $\Sigma Q_{h,d,in}$ calculated according to EN15316-2-3;

— heat demand of the domestic hot water distribution sub-system $\Sigma Q_{w,d,,in}$. calculated according to EN 15316-3-2, where appropriate.

The performance of the generation sub-system may be characterised by additional input data to take into account:

— type and characteristics of the generation sub-system;

— generator settings;

— type of the generation control system;

— location of the generator;

— operating conditions;

— heat requirement.

Based on these data, the following output data shall be calculated in the generation sub-system module:

— fuel heat requirement $Q_{g,in}$;

— generation total heat loss (flue gas and generator envelope) $Q_{g,l,t}$;

— auxiliary energy consumption W_g ;

— recoverable generation heat losses $Q_{g,l,rl}$.

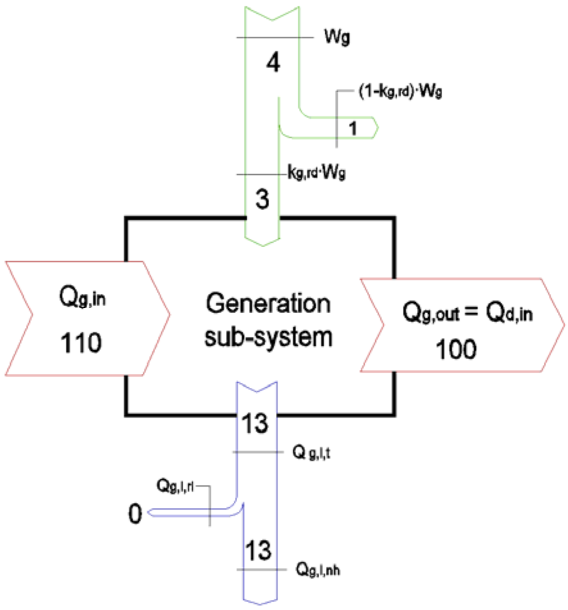

Figure 1: Generation sub-system inputs, outputs and energy balance

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

NOTE: Values shown are sample percentage

where:

W_g total auxiliary energy required by the generation sub-system (pumps, burner fan, etc.).

$k_{g,rd}$ part of auxiliary energy recovered by the generation sub-system (i.e. burner fan) (-)

$Q_{g,out}$ heat supplied to the distribution sub-systems (space heating and domestic hot water)

$Q_{g,in}$ heat requirement of the generation sub-system (fuel input)

$Q_{g,l,t}$ total losses of the generation sub-system (through the chimney, generator envelope, etc.)

$Q_{g,l,rl}$ recoverable losses of the generation sub-system for space heating (i.e. boiler installed inside the heated space) or for the generation sub-system (i.e. preheating of combustion air by flue gas)

$Q_{g,l,nh}$ unrecoverable losses of the generation sub-system

4.2 Generation sub-system basic energy balance

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

$$Q_{g,in} = k_{ctrl} \cdot Q_{g,out} - k_{g,rd} \cdot W_g + Q_{g,l,t} \quad [J] \qquad (1)$$

where symbols have the meaning defined in § 4.1.2 and :

$k_{g,rd}$ part of auxiliary energy recovered by the generation sub-system (i.e. burner fan) (-)

k_{ctrl} factor taking into account emission control losses. Default value of k_{ctrl} depending on the boiler control method **(IS THIS IN LINE WITH DECIDED STRATEGY?)** are given in table D1. Other values may be specified in a national annex, provided that emission control losses has not been already taken into account in the emission part (EN 15316-2-1) or in the distribution part (EN 15316-2-3).

NOTE: $Q_{g,l,t}$ takes into account flue gas and generator envelope losses, part of which may be recoverable according to location. See § 4.4, 5.3.5 and 5.4.6

4.3 Auxiliary energy W_g

Auxiliary energy is the energy, other than fuel, required for operation of the burner, the primary pump and any equipment whose operation is related to operation of the heat generation sub-system. Auxiliary energy is counted in the generation part as long as no transport energy from the auxiliary equipment is transferred to the distribution sub-system (example: zero–pressure distribution array). Such auxiliary equipment can be (but need not be) an integral part of the generator.

Auxiliary energy, normally in the form of electrical energy, may partially be recovered as heat for space heating or for the generation sub-system.

Examples of recoverable auxiliary energy:

— electrical energy transmitted as heat to the water of the primary circuit;

— part of the electrical energy for the burner fan.

Example of non-recoverable auxiliary energy:

— electrical energy for electric panel auxiliary circuits, if the generator is installed outside the heated space.

4.4 Recoverable, recovered and unrecoverable heat losses

Not all of the calculated system heat losses are lost. Some of the losses are recoverable and part of the recoverable system heat losses are actually recovered.

Example of recoverable heat losses are:

— heat losses through the envelope of a generator installed within the heated space.

Example of non-recoverable heat losses are:

— heat losses through the envelope of a generator installed outside the heated space;

— heat losses through the chimney installed outside the heated space.

According to EN 15315, recovery of heat losses to the heated space can be accounted for either:

- as a reduction of total losses within the specific part (simplified method)
- or taking into account globally recoverable losses as gains (holistic method)

This standard allows both approaches.

Generation losses recovered by the generation sub-system are directly taken into account in the generation performance (e.g. combustion air preheating by flue gas losses).

4.5 Calculation periods

The objective of the calculation is to determine the annual primary energy demand of the heating generation sub-system. This may be done in one of the following two different ways:

— by using annual data for the system operation period and perform the calculations using yearly average values;

— by dividing the year into a number of calculation periods (e.g. months, weeks, operation periods as defined in EN ISO 13790) and perform the calculations for each period using period-dependent values and adding up the results for all the periods over the year.

NOTE: Generation efficiency is strongly dependent on the load factor and this relation is not linear. To achieve a good precision, the calculation periods should not be longer than 1 month.

4.6 Multiple boilers or generation sub-systems

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

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

- a heating system may be split up in zones with several distribution sub-systems.
- several heat generation sub-systems may be 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 distribution sub-systems $\Sigma_i Q_{d,in,i}$ shall equal the total heat output of the generation sub-systems $\Sigma_i Q_{g,out,j}$.:

$$\sum_j Q_{g,out,j} = \sum_i Q_{d,in,i} \tag{2}$$

If there are several generation sub-system, the total heat demand of the distribution sub-system(s) shall be distributed among the available generation sub-systems. The calculation described in the paragraphs 5.2, 5.3, 5.4 and/or 5.5 shall be performed independently for each boiler j, on the basis of $Q_{g,out,j}$.

Criteria to distribute the total distribution requirements may be based on physical, efficiency or economic reasons.

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 this standard series (see EN 15316-4-XX).

Procedures to split the load among multiple combustion generators are given for basic cases in paragraphs 5.3.3 and 5.4.9 of this standard.

EXAMPLE 5: Given $Q_{d,in}$, the maximum output of a solar system $Q_{g,out,sol}$ should be calculated first, then the heat output that can be provided by a cogeneration is added $Q_{g,out,cgn}$.
The rest ($Q_{h,gn,out,boil} = \Sigma Q_{h,di,in} - Q_{h,gn,out,sol} - Q_{h,gn,out,cg}$, see figure 2) is attributed to boilers and may be further split among multiple boilers according to paragraphs 5.3.3 and 5.4.9.

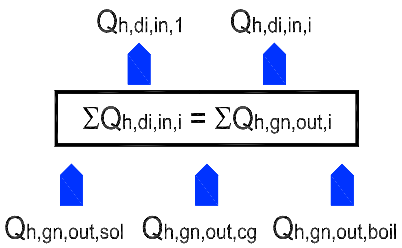

Figure 2 – Example of load splitting among generation sub-systems

4.7 Using net or gross calorific values

Calculations described in chapter 5 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 Hi, total losses $Q_{g,l,t}$ and generation sub-system heat needs $Q_{g,in}$ (i.e fuel for combustion systems) may be converted to values $Q^*_{g,l,t}$ and $Q^*_{g,in}$ based on gross calorific values H_s by addition of the condensation latent heat Q_{lat}: according to the following formulas:

$$Q_{lat} = Q_{g,in} \cdot \frac{H_s - H_i}{H_i}$$ [lkWh] (3)

$$Q^*_{g,in} = Q_{g,in} + Q_{lat} = Q_{g,in} \frac{H_s}{H_i}$$ [lkWh] (4)

$$Q^*_{g,l,t} = Q_{g,l.t} + Q_{lat}$$ [lkWh] (5)

4.8 Boundaries between distribution and generation sub-system

Boundaries between generation sub-system and distribution sub-system should be defined according to the following principles.

If the generation-subsystem includes the generator only (i.e. there is no pump within the generator), the boundary with the distribution sub-system is represented by the hydraulic connection of the boiler, as shown in figure 3.

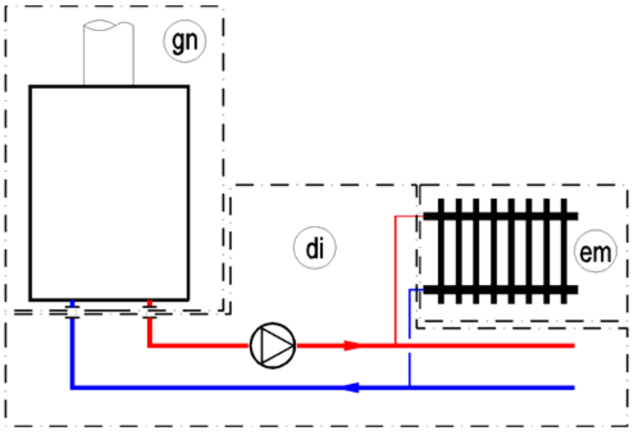

Figure 3 – Sample boundaries

Key to figure: gn = generation, di = distribution, em = emission

A pump physically within the boiler is however considered part of the distribution sub-system if it contributes to the flow of heating medium to the emitters. An example is shown in figure 4.

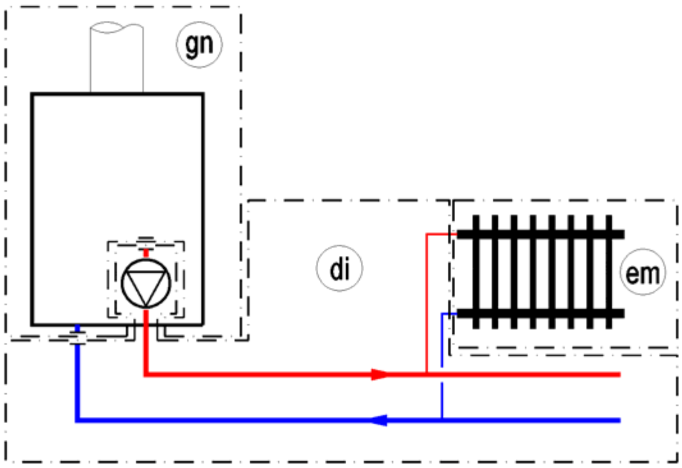

Figure 4 – Sample boundaries

Key to figure: gn = generation, di = distribution, em = emission

Only pumps dedicated to generator requirements may be considered within the generation sub-system. An example is shown in figure 5

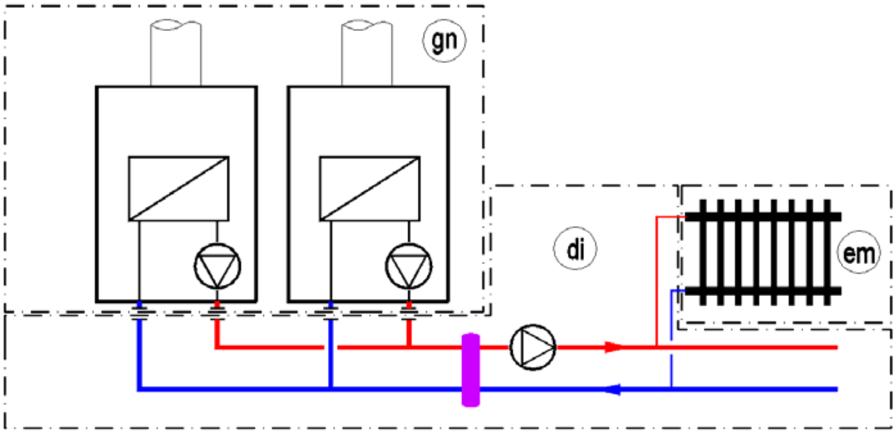

Figure 5 – Sample boundaries

Key to figure: gn = generation, di = distribution, em = emission

5 Generation sub-system calculation

5.1 Available methodologies

In this standard, three performance calculation methods for the heat generation sub-system are described corresponding to different use (simplified or detailed estimation, on site measurements, etc.). The calculation methods differ with respect to:

- required input data;
- operating conditions taken into account;
- calculation period applied.

For the first method (see 5.2), the considered calculation period is the heating season. The performance calculation is based on the data related to the Council Directive 92/42/EEC about Boiler Efficiency. The operation conditions taken into account (climate, distribution sub-system connected to the generator, etc.) are approximated by typology of the considered region and are not case specific. If this method is to be applied, an appropriate national annex with the relevant values shall be available.

The second method (see 5.3) is also based on the data related to the Council Directive 92/42/EEC about Boiler Efficiency, but supplementary data are needed in order to take into account the specific operation conditions of the individual installation. The considered calculation period can be the heating season but may also be a shorter period (month, week, or the operation periods according to EN ISO 13790). The method is not limited and can be used with the default values given in informative annex B.

The third method (see 5.4) distinguishes in a more explicit way the losses of a generator which occurs during boiler cycling (i.e. combustion losses). Some of the parameters can be measured on site. This method is well adapted for existing buildings and to take into account condensation heat recovery according to operating conditions.

The calculation method to be applied is chosen as a function of the available data and the objectives of the user.

Further details on each method are given in the respective parametering annexes (annexes A, B and C)

5.2 Seasonal boiler performance method based on system typology (typology method)

5.2.1 **Principle of the method**

This method assumes, that:

— climatic conditions;

— operation modes;

— typical occupancy patterns of the relevant building sector

have been considered and are incorporated in a procedure to convert standard test results of boiler efficiency (as used for the Council Directive 92/42/EEC about Boiler Efficiency) into a seasonal efficiency for the relevant building sector.

The stages within the seasonal efficiency calculation procedure are:

(i) adapt test results for uniformity, taking account of boiler type, fuel and specific conditions for testing imposed by the Council Directive 92/42/EEC about Boiler Efficiency and the relevant standards;

(ii) adjust for annual performance in installed conditions, taking account of regional climate, operation modes and occupancy patterns typical of the relevant building sector;

(iii) perform the calculations and determine fuel heat requirement, total generation heat loss (as an absolute value), recoverable generation heat loss, auxiliary consumption, recoverable auxiliary consumption).

The procedure allows for national characteristics of the relevant building sector.

5.2.2 **Calculation procedure**

5.2.2.1 Selection of appropriate seasonal efficiency procedure

A seasonal efficiency calculation procedure is selected from the appropriate national annex on the basis of the following information:

— region (climate) in which the building is situated;

— building sector (housing, commercial, industrial ,etc).

The procedure shall include limitation in use, relevant boundary conditions and reference to validation data.

The procedure shall be defined in a national annex. If there is no appropriate national annex, this method cannot be used.

Annex A (informative) is an example of a seasonal efficiency calculation procedure, known as SEDB_UK, and it represents conditions in the housing sector of the UK.

5.2.2.2 Input information required for the seasonal efficiency procedure

This paragraph may be replaced by: "*The calculation structure of the procedure defined in the national annex shall comply with requirements set in paragraph 4.1.2*"

Input information for the procedure shall comprise:

— heat demand of the heating system heat distribution sub-system(s) $\Sigma Q_{h,d,in}$ calculated according to EN15316-2-3;

— heat demand of the domestic hot water distribution sub-system $\Sigma Q_{w,d,,in}$. calculated according to EN 15316-3-2, where appropriate.

Input information for the procedure may comprise:

— full-load and 30% part-load efficiency test results produced in accordance with standard tests as required for the Council Directive 92/42/EEC about Boiler Efficiency, and independently certified;

— boiler type (condensing or not, combination or not, hot water store included or not, etc);

— fuel used (natural gas, LPG, oil, etc);

— boiler power output (maximum and minimum if a range);

— ignition method (permanent pilot flame or not);

— burner type (modulating, multistage or on/off);

— internal store included in efficiency tests (yes/no);

— store characteristics (volume, insulation thickness).

5.2.2.3 Output information obtained from the seasonal efficiency procedure

Output information from the procedure shall comprise:

$Q_{g,in}$ fuel heat requirement;

$Q_{g,l,t}$ total generation heat loss (NOT NECESSARY FOR FURTHER CALCULATIONS)

W_g auxiliary consumption;

$Q_{g,l,rl}$ recoverable losses for space heating.

5.3 Case specific boiler efficiency method

5.3.1 Principle of the method

This method is related to the Council Directive 92/42/EEC about Boiler Efficiency and is based on the following principle:

a) data are collected for three basic load factors or power outputs:

- efficiency at 100 % load, $\eta_{gn,Pn}$;
- efficiency at intermediate load, $\eta_{gn,Pint}$;
- losses at 0 % load, $\Phi_{gn,l,P0}$.

b) efficiency and losses data are corrected according to boiler operating conditions (temperature);

c) losses power at 100% $\Phi_{gn,l,Pn}$ and at intermediate load $\Phi_{gn,l,Pint}$ are calculated according to corrected efficiencies;

d) calculation of losses power for the actual power output, is made by linear or polynomial interpolation between losses powers for the three basic power outputs.

NOTE: All powers and the load factor β_{gn} are referred to generation sub-system output.

e) auxiliary energy is calculated taking into account the actual power output of the boiler;

f) recoverable generator envelope heat losses are calculated according to a tabulated fraction of stand-by losses and boiler location

g) recoverable auxiliary energy is added to recoverable generator losses to give total recoverable energy

5.3.2 Input data to the method

5.3.2.1 Boiler data

The boiler is characterised by the following values:

Φ_{Pn} generator output at full load

$\eta_{gn,Pn}$ generator efficiency at full load

$\theta_{gn,test,Pn}$ generator average water temperature at test conditions for full load

$f_{cor,Pn}$ correction factor of full-load efficiency

Φ_{Pint} generator output at intermediate load

$\eta_{gn,Pint}$ generator efficiency at intermediate load

$\theta_{gn,test,Pint,}$ generator average water temperature at test conditions for intermediate load

$f_{cor,Pint}$ correction factor of intermediate load efficiency

$\Phi_{gn,l,PO}$ stand-by heat loss at test temperature difference $\Delta\theta_{i,test}$

$\Delta\theta_{gn,test}$ Difference between mean boiler temperature and test room temperature in test conditions

$\Phi_{aux,gn,Pn}$ power consumption of auxiliary devices at full load

$\Phi_{aux,gn,Pint}$ power consumption of auxiliary devices at intermediate load

$\Phi_{aux,gn,P0}$ stand-by power consumption of auxiliary devices

$\theta_{gn,min}$ minimum operating boiler temperature

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

- product data from the manufacturer, if the boiler has been tested according to EN 297, EN 303-5, EN 304, EN 656, EN 15034, EN 15035, prEN 15456 (auxiliary power data);
- default data from the relevant national annex;
- default data from annexes B or D

It shall be recorded if the efficiency value includes or not auxiliary energy recovery.

5.3.2.2 Actual operating conditions

Actual operating conditions are characterised by the following values:

$Q_{g,out}$ net heat output to the heat distribution sub-system(s);

$\theta_{gn,w,av}$ average water temperature in the boiler;

$\theta_{gn,w,r}$ return water temperature to the boiler (for condensing boilers);

$\theta_{i,gn}$ boiler room temperature;

b_g temperature reduction factor depending on the location of the generator.

5.3.3 **Load of each boiler**

5.3.3.1 Generation sub-system average power

Generation sub-system average power Φ_{gn} is given by:

$$\Phi_{gn} = \frac{Q_{g,out}}{t_{gn}} \qquad [W] \qquad (6)$$

where

t_{gn} total time of generator(s) operation [s]

5.3.3.2 Single boiler generation sub-system

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

$$\beta_{gn} = \frac{\Phi_{gn}}{\Phi_{Pn}} \qquad [-] \qquad (7)$$

where:

Φ_{Pn} nominal power output of the generator (kW)

5.3.3.3 Multiple boilers generation sub-system

THIS PARAGRAPH MIGHT BE RECOVERED AS A GENERAL PART AND ADDED BELOW 4.6

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

- without priority

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

  $$\beta_{gn} = \frac{\Phi_{gn}}{\sum \Phi_{Pn,g1} + \Phi_{Pn,g2} + \ldots} \qquad [\%] \qquad (8)$$

  where:

  $\Phi_{Pn,g1}$, $\Phi_{Pn,g2,}$ nominal power of the individual generators (kW)

- 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 ($\beta_{gn,i}$ = 1).

  If all boilers have the same power output, the number of running generators n_{gn} is given by

  $$n_{gn} = \text{int}\left(\frac{\Phi_{gn}}{\Phi_{Pn}}\right) \qquad [-] \qquad (9)$$

  Otherwise running boilers have to be determined so that $0 < \beta_{gn,j} < 1$ (see equation 10)

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

$$\beta_{gn,j} = \frac{\Phi_{gn} - \sum_i \Phi_{Pn,i}}{\Phi_{Pn,j}} \quad [-] \qquad (10)$$

where:

$\Phi_{Pn,j}$	nominal power of generators running at full load	(kW)
$\Phi_{Pn,j}$	nominal power of intermittent running generator	(kW)

5.3.4 **Generators with double service (space heating and domestic hot water production)**

During the heating season, the heat generator can produce energy for the space heating installation and the domestic hot water (double service).

Calculation of the heat losses related to the domestic hot water generation is specified in the domestic hot water part of this standard, prEN 15316-3-3. But the domestic hot water generation also influences the heating part of the generator in respect of:

— running temperature of the generator;

— running time;

— load.

The running temperature of the generator may be modified if domestic hot water production is required. The dynamic effects of this temperature modification (heating up, cooling down) are neglected in this part of the standard. The losses related to the temperature changes needed for hot water production are taken into account in the domestic hot water part of this standard.

The needs for domestic hot water production may extend the heating up period, if the generator is already running at nominal power. The impacts on the time periods (heating up, normal mode, etc.) defined in EN ISO 13790 are neglected.

The domestic hot water production increases the load of the generator. This effect is taken into account by increasing the average generator power output during the considered period by:

$$\Phi_{Px} = \Phi_{Px,h} + \Phi_{Px,dhw} \quad [W] \qquad (11)$$

where:

$$\Phi_{Px,dhw} = \frac{Q_{dhw}}{t_{gn}} \quad [W] \qquad (12)$$

In general, the considered calculation period is the same for domestic hot water production and for space heating.

However, if the domestic hot water is produced only during specific operation modes (e.g. only during normal mode or if a priority control is fitted), the calculation may be perfomed independently for the two operation modes:

- once taking into account tgn,h (operation time for heating) and ΦPx,h (calculated with tgn,h) and operating conditions for heating service
- once taking into account tgn,dhw (operation time for domestic hot water production) and ΦPx,dhw (calculated with tgn,dhw) and operating conditions for domestic hot water production.

Losses, auxiliary energy, fuel input are summed at the end of the calculation.

5.3.5 GENERATOR HEAT LOSSES

5.3.5.1 Generator heat loss calculation at 100 % load

For oil and gas fired boilers, the efficiency at full load is measured at a reference generator average water temperature $\theta_{gn,test,Pn}$. This efficiency has to be adjusted to the actual generator average water temperature of the individual installation.

The temperature corrected efficiency $\eta_{gn,Pn,cor}$ is calculated by:

$$\eta_{gn,Pn,cor} = \eta_{gn,Pn} + f_{cor,Pn} \cdot (\theta_{gn,test,Pn} - \theta_{gn,w}) + \Delta\eta \ [\%] \qquad (13)$$

where:

$\eta_{gn,Pn}$ generator efficiency at full load [%]
If the performance of the generator has been tested according to relevant EN standards (see § 5.3.2.1), it can be taken into account. If no values are available, default values are given in C.3.1 or in the relevant national annex.

$f_{cor,Pn}$ 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 C.3.3. If the performance of the generator has been tested according to relevant EN standards (see § 5.3.2.1), it can be taken into account.

$\theta_{gn,test,Pn}$ generator average water temperature [°C]
at test conditions for full load (see C.3.3 or XXX)

$\theta_{gn,w}$ average water temperature in the boiler (or return temperature to the boiler for condensing boilers) [°C]
as a function of the specific operating conditions (see 5.3.5)

Priority order for data is already specified in § 5.3.2.1. and could be removed to shorten the text.

In order to simplify the calculations, the efficiencies and heat losses determined at test conditions are adjusted to the actual generator average water temperature. It is allowed, as it is physically correct, to adjust the performance at each load to the actual generator average water temperature of each load.

The corrected generator heat loss at 100 % load $\Phi_{gn,l,Pn,cor}$ is calculated by:

$$\Phi_{gn,l,Pn,cor} = \frac{(100 - \eta_{gn,Pn,cor})}{\eta_{gn,Pn,cor}} \cdot \Phi_{Pn} \cdot 1.000 \qquad [W] \qquad (14)$$

where:

Φ_{Pn} generator output at full load [kW]

5.3.5.2 Generator heat loss calculation at intermediate load

The impact on efficiency from variation of the generator average water temperature is calculated by:

$$\eta_{gn,Pint,cor} = \eta_{gn,Pint} + f_{cor,Pint} \cdot (\theta_{gn,test,Pint} - \theta_{gn,w}) \ [\%] \qquad (15)$$

where:

$\eta_{gn,Pint}$ generator efficiency at intermediate load [%]
If the performance of the generator has been tested according to relevant EN standards (see 5.3.2), it can be taken into account. If no values are available, default values are given in C.3.1 or in the relevant national annex.

$f_{cor,Pint}$ 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 C.3.3. If the performance of the generator has been tested according to relevant EN standards (see 5.3.2), it can be taken into account.

$\theta_{gn,test,Pint,}$ generator average water temperature [°C]
at test conditions for intermediate load (see C.3.3)

$\theta_{gn,w}$ average water temperature in the boiler (or return temperature to the boiler for condensing boilers) [°C]
as a function of the specific operating conditions (see 5.3.5)

Priority order for data is already specified in § 5.3.2.1. and could be removed to shorten the text.

The intermediate load depends on the generator type. Default values are given in annex D, § D.2.

The corrected generator heat loss at intermediate load $\Phi_{gn,l,Pint,cor}$ is calculated by:

$$\Phi_{gn,l,P\text{int},cor} = \frac{(100 - \eta_{gn,P\text{int},cor})}{\eta_{gn,P\text{int},cor}} \cdot \Phi_{P\text{int}} \cdot 1.000 \quad \text{[W]} \qquad (16)$$

where

Φ_{Pint} generator output at intermediate load [kW]

5.3.5.3 Generator heat loss calculation at 0 % load

The generator heat loss at 0 % load $\Phi_{gn,l,P0}$ is, determined for a test temperature difference according to relevant testing standards (i.e. EN297/A2, EN483/A2, EN 303, EN 13 836 and EN 15 043), If the performance of the generator has been **tested according to** relevant EN standards (see § 5.3.2.1), it can be taken into account.
If no manufacturer or national annex data are available, default values are given in B.3.2.

The corrected generator heat loss at 0% load $\Phi_{gn,l,P0,cor}$ is calculated by:

$$\Phi_{gn,l,P0,cor} = \Phi_{gn,l,PO} \cdot \left(\frac{\theta_{gn,w} - \theta_{i,gn}}{\Delta\theta_{test}} \right)^{1,25} \quad \text{[W]} \qquad (17)$$

where:

$\Phi_{gn,l,PO}$ stand-by heat loss at test temperature difference $\Delta\theta_{i,test}$ [W]

$\theta_{i,gn}$ indoor temperature of the boiler room [°C]
Default values are given in Table B.7

$\Delta\theta_{,test}$ Difference between mean boiler temperature and test room temperature in test conditions [°C]
Default values are given in Table B.2.

5.3.5.4 Boiler heat loss at specific load ratio $\beta_{gn,i}$ and power output Φ_{Px}

The specific load ratio $\beta_{gn,i}$ of each boiler is calculated according to 5.3.6.

The actual power output Φ_{Px} of the boiler is given by

$$\Phi_{Px} = \Phi_{Pn} \cdot \beta_{gn,i} \qquad \text{[W]} \qquad (18)$$

If $\beta_{gn,i}$ is between 0 (power output $\Phi_{P0} = 0$) and β_{int} (intermediate load, power output Φ_{Pint}), the generator heat loss $\Phi_{gn,l,Px}$ is calculated by:

$$\Phi_{gn,l,Px} = \frac{\Phi_{Px}}{\Phi_{P\text{int}}} \cdot (\Phi_{gn,l,P\text{int},cor} - \Phi_{gn,l,P0,cor}) + \Phi_{gn,l,P0,cor} \qquad \text{[W]} \qquad (19)$$

If $\beta_{gn,i}$ is between β_{int} (intermediate load, power output Φ_{Pint}) and 1 (power output Φ_{Pn}), the generator heat loss $\Phi_{gn,l,Px}$ is calculated by:

$$\Phi_{gn,l,Px} = \frac{\Phi_{Px} - \Phi_{P\text{int}}}{\Phi_{Pn} - \Phi_{P\text{int}}} \cdot (\Phi_{gn,l,Pn,cor} - \Phi_{gn,l,P\text{int},cor}) + \Phi_{gn,l,P\text{int},cor} \qquad \text{[W]} \qquad (20)$$

$\Phi_{gn,l,Px}$ may also be calculated by 2nd order polynomial interpolation. A formula for such interpolation is given in informative annex B, paragraph B2, equation B1.

The total boiler heat loss $Q_{gn,l,t,i}$ during the considered period is calculated by:

$$Q_{gn,l,t} = \Phi_{gn,l,Px} \cdot t_{gn} \qquad \text{[J]} \qquad (21)$$

If there are several boilers, total generation sub-system losses are the sum of boiler total losses.

5.3.6 Total auxiliary energy

The total auxiliary energy for a boiler is given by:

$$W_g = \Phi_{aux,Px} \cdot t_{gn} + \Phi_{aux,SB} \cdot (t_{ci} - t_{gn}) \qquad \text{[J]} \qquad (22)$$

where

$\Phi_{aux,SB}$ auxiliary power when the generation system is inactive.
If the generator is electrically isolated when inactive, $\Phi_{aux,SB} = 0$
Otherwise $\Phi_{aux,SB} = \Phi_{aux,P0}$

t_{ci} is the calculation interval

t_{gn} is the operation time of the generator within the calculation interval

The average auxiliary power for each boiler $\Phi_{aux,Px}$ is calculated by linear interpolation, according to the boiler load β_{gn}, between:

$\Phi_{aux,Pn}$ auxiliary power of the boiler at full load ($\beta_{gn}=1$).

$\Phi_{aux,Pint}$ auxiliary power of the boiler at intermediate load ($\beta_{gn} = \beta_{int}$).

$\Phi_{aux,P0}$ auxiliary power of the boiler in stand-by (β_{gn}=0).

measured according to prEN 15456.

If $0 \leq \beta_{gn} \leq \beta_{int}$ then $\Phi_{aux,Px}$ is given by

$$\Phi_{aux,Px} = \Phi_{aux,P0} + \frac{\beta_{gn}}{\beta_{int}} \cdot \left(\Phi_{aux,Pint} - \Phi_{aux,P0}\right) \quad [J] \quad (23)$$

If $\beta_{int} < \beta_{gn} \leq 1$ then $\Phi_{aux,Px}$ is given by:

$$\Phi_{aux,Px} = \Phi_{aux,Pint} + \frac{\beta_{gn} - \beta_{int}}{1 - \beta_{int}} \cdot \left(\Phi_{aux,Pn} - \Phi_{aux,Pint}\right) \quad [J] \quad (24)$$

5.3.7 Recoverable generation heat losses

5.3.7.1 Auxiliary energy

Auxiliary energy **<u>already taken into account in efficiency data</u>** shall not be calculated for recovery again (example: oil heating, combustion air fan, primary pump).

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 recoverable auxiliary energy transmitted to the heated space is calculated by:

$$W_{g,rl} = W_g \cdot (1 - b_g) \cdot p_{aux,g} \quad [J] \quad (25)$$

where

$p_{aux,g}$ part of the nominal electrical power 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 B.5.1. If the performance of the generator has been certified, it can be taken into account.

b_g temperature reduction factor depending on location of the generator [-]
The value of b should be given in a national annex. In the absence of national values, a default value is given in B.3.3, table B.7.

5.3.7.2 Generator heat loss (generator envelope)

Only the heat losses through the generator envelope are considered as recoverable and depend on the burner type. For oil and gas fired boilers, the heat losses through the generator envelope are expressed as a fraction of the total stand-by heat losses.

The recoverable heat losses through the generator envelope $Q_{gn,env,rl}$ are calculated by:

$$Q_{gn,env,rl} = \Phi_{gn,l,P0,cor} \cdot (1 - b_g) \cdot p_{gn,env} \cdot t_{gn} \quad [J] \quad (26)$$

where:

$p_{gn,env}$ heat losses through the generator envelope [-]
expressed as a fraction of the total stand-by heat losses. The value of $p_{gn,env}$ should be given in a national annex. In the absence of national values, default values are given in B.3.2, table B.6. If the performance of the generator has been tested, it can be taken into account.

t_{gn} boiler operating time [s]

5.3.7.3 Total recoverable generation heat losses

The total recoverable generation heat losses $Q_{g,l,rl}$ are calculated by:

$$Q_{g,l,rl} = Q_{gn,env,rl} + W_{g,rl} \quad \text{[J]} \qquad (27)$$

5.3.8 Operating temperature of the generator

The operating temperature of the generator depends on:

— type of control (taken into account by a correction factor);

— technical limit of the generator (taken into account by the temperature limitation);

— temperature of the distribution sub-system connected to the generator.

The effect of control on the boiler is assumed to be a varying average temperature of the heat emitters. Therefore three types of boiler control are taken into account:

— constant water temperature;

— variable water temperature depending on the inside temperature;

— variable water temperature depending on the outside temperature.

The operating temperature of the generator is calculated by:

$$\theta_{gn,w} = \max(\theta_{gn,\min}, \theta_{em}) \quad \text{[°C]} \qquad (28)$$

where:

$\theta_{gn,min}$ minimum operating boiler temperature for each generator [°C]
If the installation is equipped with several generators, the running temperature limitation used for calculation is the highest value of the temperature limitations of the generators running at the same time. The values should be given in a national annex. In the absence of national values, default values are given in B.1.1

θ_{em} temperature for heat distribution during the considered period [°C]
This temperature is calculated according to **annex H**. If different heat distribution sub-systems are connected to the generator, the highest temperature among the heat distribution sub-systems is used for calculation.

TO BE DONE: CHECK IF IT IS CORRECTLY CALCULATED IN THE DISTRIBUTION PART

ADD IN THE PARAMETER LIST

5.4 Boiler cycling method

5.4.1 Principle of the method

This calculation method is based on the following principles.

The operation time is divided in two parts:

- burner on operation t_{ON};
- burner off operation (stand-by) t_{OFF}

The total time of operation of the generator is $t_{gn} = t_{ON} + t_{OFF}$.

Heat losses are taken into account separately for these two periods of time.

During burner on operation, the following heat losses are taken into account:

- heat of flue gas with burner on: $Q_{ch,on}$.
- heat losses through the generator envelope: $Q_{gn,env}$

During burner off operation, the following heat losses are taken into account:

- heat of air flow to the chimney: $Q_{ch,off}$
- heat losses through the generator envelope: $Q_{gn,env}$

Auxiliary energy is considered separately for appliances before and after the heat generator:

- W_{br} is the auxiliary energy required by components and devices that are before the combustion chamber following the energy path (typically burner fan, see **figure 6**)

NOTE typically these components and devices are running only when the burner is on, i.e. during t_{ON}

- W_{af} is the auxiliary energy required by components and devices that are before the combustion chamber following the energy path (typically primary pump, see **figure 6**)

NOTE typically these components and devices are running during the entire operation period of the heat generator, i.e. during $t_{gn} = t_{ON} + t_{OFF}$

k_{af} and k_{br} express the fractions of the auxiliary energy for these appliances recovered to the heating medium (typically the efficiency of the primary pumps and the burner fan). Therefore:

- $Q_{br} = k_{br} \cdot W_{br}$ is the auxiliary energy recovered from appliances before the heat generator;
- $Q_{af} = k_{af} \cdot W_{af}$ is the auxiliary energy recovered from appliances after the heat generator.

Auxiliary energy transformed into heat and emitted to the heated space may be considered separately and is added to the recoverable heat losses.

The basic energy balance of the generation sub-system is:

$$Q_{g,out} = Q_{cn} + Q_{br} + Q_{af} - Q_{ch,on} - Q_{ch,off} - Q_{gn,env} \quad [J] \qquad (29)$$

NOTE: This is the same as equation 1 $Q_{g,in} = k_{ctrl} \cdot Q_{g,out} - k_{g,rd} \cdot W_g + Q_{g,l,t}$ where:

$$Q_{g,l,t} = Q_{ch,on} + Q_{ch,off} + Q_{gn,env} \quad [J] \quad (30)$$

$$Q_{g,in} = Q_{cn} \quad [J] \quad (31)$$

$$k_{g,rd} \cdot W_g = Q_{br} + Q_{af} \quad [J] \quad (32)$$

A schematic diagram of the energy balance of the generation sub-system is shown in Figure 2.

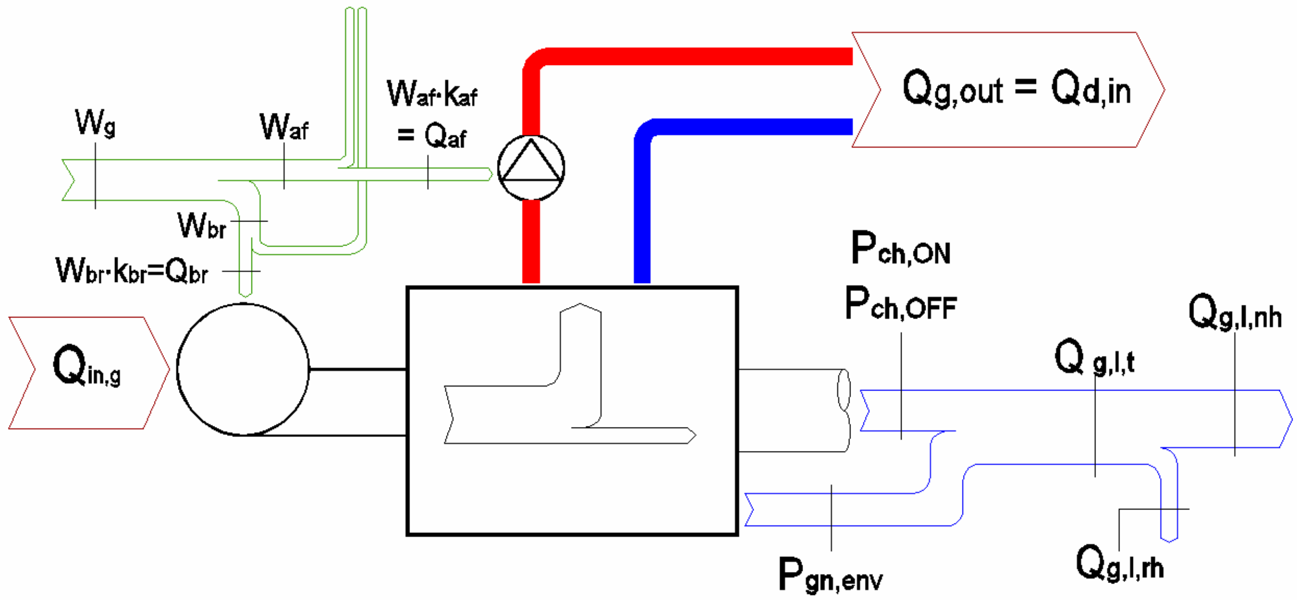

Figure 6: Schematic energy balance of generation sub-system

Heat losses at test conditions are expressed as a percentage ($P'_{ch,on}$, $P'_{ch,off}$ and $P'_{gn,env}$) of a reference power at test conditions.

The heat generator is characterised by the following values:

Φ_{cn} combustion power of the generator, which is the reference power for $P'_{ch,on}$ (either design or actual value)

Φ_{ref} reference power for the heat loss factors $P'_{ch,off}$ and $P'_{gn,env}$ (usually $\Phi_{ref} = \Phi_{cn}$)

$P'_{ch,on}$, $P'_{ch,off}$, $P'_{gn,env}$ heat loss factors at test conditions

Φ_{br} electrical power consumption of auxiliary appliances (before the generator)

k_{br} recovery factor of Φ_{br}

Φ_{af} electrical power consumption of auxiliary appliances (after the generator)

k_{af} recovery factor of Φ_{af}

$\theta_{gn,test}$ average boiler water temperature at test conditions for $P_{ch,on}$

$\theta_{ch,test}$ flue gas temperature at test conditions for $P_{ch,on}$

$\theta_{i,test}$ temperature of test room for $P_{gn,env}$ and $P_{ch,off}$

$\Delta\theta_{gn,env,ref} = \theta_{gn,test} - \theta_{i,test}$ at test conditions for $P_{gn,env}$ and $P_{ch,off}$

Exponents n, m and p for the correction of heat loss factors

For multistage or modulating boilers, the following additional data is required:

$\Phi_{cn,min}$ minimum combustion power of the generator

$P'_{ch,on,min}$ heat loss factor $P_{ch,on}$ at minimum combustion power $\Phi_{cn,min}$

$\Phi_{br,min}$ electrical power consumption of auxiliary appliances (before the generator) at minimum combustion power $\Phi_{cn,min}$

For condensing boilers, the following additional data is required:

$\Delta\theta_{wfl}$ temperature difference between boiler return water temperature and flue gas temperature.

$O_{2\ fl,dry}$ flue gas oxygen contents.

For condensing multistage or modulating boilers, the following additional data is required:

$\Delta\theta_{wfl,min}$ temperature difference between boiler return water temperature and flue gas temperature at minimum combustion power.

$O_{2\ fl,dry,min}$ flue gas oxygen contents at minimum combustion power.

Actual operation conditions are characterised by the following values:

$Q_{g,out}$ net heat output to the heat distribution sub-system(s)

$\theta_{gn,w,av}$ average water temperature in the boiler

$\theta_{gn,w,r}$ return water temperature to the boiler (for condensing boilers)

$\theta_{i,gn}$ boiler room temperature

$k_{gn,env}$ reduction factor taking into account recovery of heat losses through the generator envelope depending on location of the generator

FC load factor

NOTE: All powers and the load factor FC are referred to generator input (combustion power).

5.4.2 Load factor

The load factor FC is the ratio between the time with the burner on and the total time of generator operation (running and stand-by):

$$FC = \frac{t_{ON}}{t_{gn}} = \frac{t_{ON}}{t_{ON} + t_{OFF}} \qquad [\%] \qquad (33)$$

where

t_{gn} total time of generator operation [s]

t_{ON} time with the burner on (fuel valve open, pre- and post-ventilation are not considered) [s]

t_{OFF} time with the burner off [s]

The load factor shall either be calculated according to the actual energy, $Q_{g,out}$, to be supplied by the generation sub-system or be measured (e.g. by time counters) on existing systems.

5.4.3 Specific heat losses

5.4.3.1 General

Specific heat losses of the generator are given at standard test conditions.

Test values shall be adjusted according to actual operation conditions. This applies both to standard test values and to field measurements.

Test conditions are identified by a quote.

5.4.3.2 Heat losses through the chimney with the burner on $P_{ch,on}$

The correction method for this losses factor takes into account the effects of:

- average water temperature in the boiler;
- load factor;
- burner settings (power and excess air changing the heat exchange efficiency).

Actual specific heat losses through the chimney with the burner on $P_{ch,on}$ are given by:

$$P_{ch,on} = \left[P'_{ch,on} + \left(\theta_{gn,w,av} - \theta_{gn,test}\right) \cdot f_{cor}\right] \cdot FC^{n} \quad [\%] \quad (34)$$

where:

$P'_{ch,on}$ heat losses through the chimney at test conditions [%]
(complement to 100 of the combustion efficiency)
$P'_{ch,on}$ is measured with the average water temperature $\theta_{gn,test}$.
Heat losses through the chimney shall be expressed as a percentage of the combustion power Φ_{cn}.
For the design of new systems, $P'_{ch,on}$ is the value declared by the manufacturer.
For existing systems, $P'_{ch,on}$ is given by a measure of combustion efficiency. Combustion efficiency measurement shall be realised according to national standards or recommendations. When combustion efficiency is measured, the corresponding average water temperature $\theta_{gn,test}$ and combustion power Φ_{cn} shall be measured as well.
If no data is available, default values are given in Table C.1.
The source of data shall be clearly stated in the calculation report.

$\theta_{gn,test}$ average water temperature in the boiler at test conditions [°C]
(average of flow and return temperature, usually flow temperature 80 °C, return temperature 60 °C).
For the design of new systems, $\theta_{gn,test}$ is the value declared by the manufacturer.
For existing systems, $\theta_{gn,test}$ is measured together with combustion efficiency.
If no data is available, default values are given in Table C.1.
The source of data shall be clearly stated in the calculation report.
For condensing boilers, return water temperature $\theta_{gn,test,r}$ shall be used in (34) instead of average water temperature $\theta_{gn,test}$

$\theta_{gn,w,av,}$ average water temperature in the boiler at actual conditions [°C]
(average of flow and return temperature).
For condensing boilers, return water temperature $\theta_{gn,w,r}$ shall be used in (34) instead of average water temperature $\theta_{gn,w,av,}$

f_{cor} correction factor for $P'_{ch,on}$ [-]
Default values for this factor is given in Table C.1.

n exponent for the load factor FC [-]
Default values for this exponent are given in Table C.2.
FC^n takes into account the reduction of losses with high intermittencies, due to a lower average temperature of the flue gas (higher efficiency at start). An increasing value of n corresponds to a higher value of $M_{ch,on}$, defined as heat capacity per kW of the heat exchange surface between flue gas and water.

NOTE 1: Equation (34) takes into account variation in combustion efficiency depending on average temperature of water in the generator by a linear approximation. The assumption is, that temperature difference between water and flue gas is approximately constant (i.e. a 20 °C increase of average water temperature causes a 20 °C increase of flue gas temperature). A 22 °C increase of flue gas temperature corresponds to 1% increase of losses through the chimney, hence the default value 0,045 for f_{cor}.
Equation 34 does not include the effect of any latent heat recovery. This is done separately. See § 5.4.8.

NOTE 2: Equation (34) does not take into account explicitly the effect of varying air/fuel ratio. The constant 0,045 is valid for standard excess air (3% O_2 in flue gas). For new systems, a correct setting is assumed. For existing systems, the air/fuel ratio contributes to $P'_{ch,on}$. If required, the constant 0,045 should be recalculated according to the actual air/fuel ratio.

NOTE 3: Equation (34) does not take into account explicitly the effect of varying combustion power Φ_{cn}. If the combustion power is significantly reduced, the procedure for existing systems shall be followed (i.e. $P_{ch,on}$ shall be measured).

5.4.3.3 Heat losses through the generator envelope $P_{gn,env}$

Actual specific heat losses through the generator envelope $P_{gn,env}$ are given by:

$$P_{gn,env} = P'_{gn,env} \cdot k_{gn,env} \cdot \frac{(\theta_{gn,w,av} - \theta_{i,gn})}{(\theta_{gn,test} - \theta_{i,test})} \cdot FC^m \quad [\%] \qquad (35)$$

where

$P'_{gn,env}$ heat losses through the generator envelope at test conditions [%]
$P'_{gn,env}$ is expressed as a percentage of the reference power Φ_{ref} (usually nominal combustion power of the generator). For the design of new systems, $P'_{gn,env}$ is the value declared by the manufacturer.
If no data is available, default values are given in C.2.2.
The source of data shall be clearly stated in the calculation report.

$k_{gn,env}$ reduction factor [-]
taking into account the location of the generator. $k_{gn,env}$ takes into account recovery of heat losses as a reduction of total losses. Default values are given in Table C.4.

$\theta_{i,test}$ temperature of the test room. Default values are given in table C1. [°C]

$\theta_{i,gn}$ actual temperature of the room where the generator is installed. [°C]
Default values are given in Table C4.

m exponent for the load factor FC. [-]
Default values for this exponent are given in Table C.5 depending on the parameter $M_{gn,env}$, defined as the ratio between the total weight of the boiler (metal + refractory materials + insulating materials) and the nominal combustion power Φ_{cn} of the boiler.

NOTE: The factor FC^m takes into account the reduction of heat losses through the generator envelope if the generator is allowed to cool down during stand-by. This reduction applies only to the specific control option, where the room thermostat stops directly the burner and the circulation pump (in series with the boiler thermostat, solution adopted on small systems only). In all other cases m=0 inhibits this correction.

It is assumed that heat losses through the envelope are related to the temperature difference between the average water temperature in the boiler and the temperature of the boiler surroundings. The relation is assumed to be linear (heat conduction through the boiler insulation).

$P'_{gn,env}$ can be determined as the difference between the combustion efficiency and the net efficiency of the generator at test conditions (continuous operation).

Recovery of heat losses through the generator envelope are taken into account as a reduction of total losses (by the reduction factor $k_{gn,env}$).

As an alternative, it is possible to determine the actual total generator envelope heat losses $P_{gn,env}$ from the total heat losses at test conditions $P'_{gn,env}$ by:

$$P_{gn,env} = P'_{gn,env} \cdot \frac{(\theta_{gn,w,av} - \theta_{i,gn})}{(\theta_{gn,test} - \theta_{i,test})} \cdot FC^{m} \qquad [\%] \qquad (36)$$

and determine the actual recoverable heat losses, $P_{gn,rl}$ by:

$$P_{gn,rl} = P_{gn,env} \cdot (1 - k_{g}) \qquad [\%] \qquad (37)$$

5.4.3.4 Heat losses through the chimney with the burner off $P_{ch,off}$

This heat loss takes into account the stack effect of the chimney, which causes a flow of cold air through the boiler.

A correction according to the average water temperature in the boiler and the boiler room temperature is required. A second correction is required when the room thermostat shuts down the circulation pump at the same time as the burner. With this control option, the actual average temperature of the water in the boiler decreases with the load factor. During each burner off period, the maximum energy which can be lost is the heat stored in the boiler (in the metallic parts and in the water). Therefore, the load factor is a function of the heat capacity of the boiler.

Actual specific heat losses through the chimney when the burner is off $P_{ch,off}$ are given by:

$$P_{ch,off} = P'_{ch,off} \cdot \frac{(\theta_{gn,w,av} - \theta_{i,gn})}{(\theta_{gn,test} - \theta_{i,test})} \cdot FC^{p} \qquad [\%] \qquad (38)$$

where

$P'_{ch,off}$ heat losses through the chimney when the burner is off at test conditions [%]
$P'_{ch,off}$ is expressed as a percentage of the reference power Φ_{ref} (usually nominal combustion power of the generator). For the design of new systems, $P'_{ch,off}$ is the value declared by the manufacturer. For existing systems, $P'_{ch,off}$ can be calculated by measuring the flow rate and the temperature at the boiler flue gas outlet.
If no data is available, default values are given in Table C.6.
The source of data shall be clearly stated in the calculation report.

p exponent for the load factor FC. [-]
Default values for this exponent are given in Table C.7 depending on the parameter $M_{ch,off}$, defined as the ratio between the total weight of the boiler (metal + refractory materials + insulating materials) and the nominal combustion power Φ_{cn} of the boiler.

NOTE: The factor FC^{p} takes into account the reduction of heat losses through the chimney with the burner off if the generator is allowed to cool down during stand-by. This reduction applies only to the specific control option, where the room thermostat stops directly the burner and the circulation pump (in series with the boiler thermostat, solution adopted on small systems only). In all other cases p=0 inhibits this correction.

5.4.4 Total heat losses

Heat losses through the chimney with the burner on:

$$Q_{ch,on} = \frac{P_{ch,on}}{100} \cdot \Phi_{cn} \cdot t_{ON} \quad \text{[J]} \quad (39)$$

Heat losses through the chimney with the burner off:

$$Q_{ch,off} = \frac{P_{ch,off}}{100} \cdot \Phi_{ref} \cdot t_{OFF} \quad \text{[J]} \quad (40)$$

Heat losses through the generator envelope:

$$Q_{gn,env} = \frac{P_{gn,env}}{100} \cdot \Phi_{ref} \cdot (t_{OFF} + t_{ON}) \text{[J]} \quad (41)$$

5.4.5 Auxiliary energy

For each auxiliary device of the generator, the following data shall be determined:

— Electrical power consumption $\Phi_{W,i}$. Values can be:

  — declared by the manufacturer;

  — measured;

  — or default values given in Table C.8

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

— Running time $t_{on,i}$, as a function of load factor FC where appropriate (i.e. burner auxiliaries)
Example: burner fan: t_{on} = FC · t_{gn}

— Part of the electrical energy converted to heat and recovered to the system before the combustion chamber $k_{br,I}$ (auxiliary energy recovery factor). The default value for k_{br} is given in Table C.9.

EXAMPLE 1 Examples of such auxiliaries are combustion air fan, fuel pump, fuel heaters.

— Part of the electrical energy converted to heat and recovered to the system after the generator $k_{af,I}$ (auxiliary energy recovery factor). The default value for k_{af} is given in Table C.9.

EXAMPLE 2 Examples of such auxiliaries are primary pumps.

Variable electrical power consumption should be approximated by an equivalent constant average electrical power consumption.

The total auxiliary energy required by the generation sub-system is given by:

$$W_g = \sum_i \Phi_{W,i} \cdot t_{on,i} \quad \text{[J]} \quad (42)$$

The auxiliary energy converted to heat and recovered to the system before the generator is given by (assuming $t_{on,i}$ = t_{ON}):

$$Q_{br} = \sum_i \Phi_{br,i} \cdot t_{on,i} \cdot k_{br,i} = \Phi_{br} \cdot k_{br} \cdot t_{ON} \qquad [J] \qquad (43)$$

The auxiliary energy converted to heat and recovered to the system after the generator is given by (assuming $t_{on,i} = t_{gn}$):

$$Q_{af} = \sum_i \Phi_{af,i} \cdot t_{on,i} \cdot k_{af,i} = \Phi_{af} \cdot k_{af} \cdot t_{gn} \qquad [J] \qquad (44)$$

5.4.6 Calculation procedure for single stage generators

1. Determine the total heat output $Q_{g,out}$ of the generation sub-system, which is equal to $Q_{d,in}$, total heat to be supplied to the distribution sub-system in the calculation period.
   For multiple interconnected distribution and/or generation sub-systems, refer to § 4.6 and 5.4.9 and then proceed with the present procedure using $Q_{g,out,i}$ for each generation sub-system.

2. Determine the total time t_{gn} of operation of the generator (= t_{ON} + t_{OFF}).

3. Set the load factor FC=1
   The calculation requires iterations with the load factor FC approaching the final value.
   If the value of FC is known (measured on an existing system), perform step 4 and 5, skip step 6 and 7 and proceed to step 8 (no iteration required).

4. Determine the values of $P_{ch,on,}$ $P_{ch,off}$ and $P_{gn,env}$ according to 5.4.3 for the current load factor FC.

5. Determine the values of W_g, Q_{br} and Q_{af} according to 5.4.4 and 5.4.5 for the current load factor FC.

6. Calculate a new load factor FC by:

$$FC = \frac{\dfrac{100 \cdot \left(Q_{g,out} - Q_{af}\right)}{t_{gn} \cdot \Phi_{ref}} + P_{ch,off} + P_{gn,env}}{100 \cdot \dfrac{\Phi_{cn} + k_{br} \cdot \Phi_{br}}{\Phi_{ref}} - \dfrac{\Phi_{cn}}{\Phi_{ref}} P_{ch,on} + P_{ch,off}} \qquad [-] \qquad (45)$$

7. Repeat steps 4, 5 and 6 until FC converges. Typically one iteration is enough.
   More iterations may be required if FC approaches 0.

8. Calculate the energy to be supplied by the fuel by:

$$Q_{g,in} = \Phi_{cn} \cdot t_{gn} \cdot FC \qquad [J] \qquad (46)$$

9. Calculate the total heat losses by:

$$Q_{g,l,t} = Q_{g,in} - Q_{g,out} + Q_{br} + Q_{af} \qquad [J] \qquad (47)$$

10. There are no recoverable heat losses, since recovery has been taken into account as a reduction of heat losses through the generator envelope:

$$Q_{g,l,rl} = 0 \qquad [J] \qquad (48)$$

5.4.7 Multistage and modulating generators

5.4.7.1 General

A multistage or modulating generator is characterised by 3 possible states:

— burner off

— burner on at minimum power

— burner on at maximum power.

It is assumed that only two situations are possible:

— the generator is operating intermittently as a single stage generator at minimum power;

— the generator is operating at a constant average power between minimum and maximum power.

5.4.7.2 Additional data required

The following additional data are required to characterise a multistage or modulating generator:

$\Phi_{cn,min}$	minimum combustion power of the generator
$P'_{ch,on,min}$	heat loss factor $P_{ch,on}$ at minimum combustion power $\Phi_{cn,min}$, as a percentage of $\Phi_{cn,min}$
$\Phi_{br,min}$	electrical power consumption of burner auxiliaries at minimum combustion power

If data from the manufacturer or default values from a national annex are not available, default values are given in tables C10, C11 and C12.

It is assumed that nominal values correspond to maximum power output, therefore:

$\Phi_{cn,max} = \Phi_{cn}$	maximum combustion power of the generator	[W]
$P'_{ch,on,max} = P'_{ch,on}$	heat loss factor $P_{ch,on}$ at maximum combustion power $\Phi_{cn,max}$	[%]

5.4.7.3 Calculation procedure for multistage or modulating generators

The procedure begins following the method described in 5.4.6 for single stage generators, using:

- $\Phi_{cn,min}$ instead of Φ_{cn}
- $P'_{ch,on,min}$ instead of $P'_{ch,on}$
- $\Phi_{br,min}$ instead of Φ_{br}

If the load factor FC converges to a value which is not greater than 1, the procedure for single stage generators is followed up to the end.

If the load factor FC converges to a value greater than 1, then $t_{on}=t_{gn}$ and the average combustion power $\Phi_{cn,avg}$ is calculated as follows:

1. Determine the total heat output $Q_{g,out}$ of the generation sub-system, which is equal to $Q_{d,in}$, total heat to be supplied to the distribution sub-system in the calculation period.
   For multiple interconnected distribution and/or generation sub-systems, refer to § 4.6 and 5.4.9 and then proceed with the present procedure using $Q_{g,out,i}$ for each generation sub-system.

2. Calculate $P_{gn,env}$ according to equation (35) and load factor FC=1
3. Calculate $P_{ch,on,min}$ and $P_{ch,on,max}$ according to equation(34) and load factor FC = 1
4. Calculate Q_{af} according to equation (44)
5. Set $\Phi_{cn,avg} = \Phi_{cn,min}$
6. Calculate $P_{ch,on,avg}$ by:

$$P_{ch,on,avg} = P_{ch,on,\min} + \left(P_{ch,on,\max} - P_{ch,on,\min}\right) \cdot \frac{\Phi_{cn,avg} - \Phi_{cn,\min}}{\Phi_{cn,\max} - \Phi_{cn,\min}} \quad [\%] \quad (49)$$

7. Calculate $\Phi_{br,avg}$ by:

$$\Phi_{br,avg} = \Phi_{br,\min} + \left(\Phi_{br,\max} - \Phi_{br,\min}\right) \cdot \frac{\Phi_{cn,avg} - \Phi_{cn,\min}}{\Phi_{cn,\max} - \Phi_{cn,\min}} \quad [W] \quad (50)$$

8. Calculate a new $\Phi_{cn,avg}$ by:

$$\Phi_{cn,avg} = \frac{\dfrac{Q_{g,out} - Q_{af}}{t_{gn}} + \dfrac{P_{gn,env}}{100} \Phi_{ref} - k_{br} \cdot \Phi_{br,avg}}{1 - \dfrac{P_{ch,on,avg}}{100}} \quad [W] \quad (51)$$

9. Repeat steps 6, 7 and 8 until $\Phi_{cn,avg}$ converges. Typically one iteration is enough.
10. Calculate the energy to be supplied by the fuel by:

$$Q_{g,in} = \Phi_{cn,avg} \cdot t_{gn} \quad [J] \quad (52)$$

11. Calculate auxiliary energy by:

$$W_g = t_{gn} \cdot \left(\Phi_{br,avg} + \Phi_{af}\right) \quad [J] \quad (53)$$

12. Calculate recovered auxiliary energy by:

$$W_{g,rd} = t_{gn} \cdot \left(\Phi_{br,avg} \cdot k_{br} + \Phi_{af} \cdot k_{af}\right) \quad [J] \quad (54)$$

13. Calculate total heat losses by:

$$Q_{g,l,t} = Q_{g,in} - Q_{g,out} + \Phi_{br,avg} \cdot k_{br} \cdot t_{gn} + \Phi_{af} \cdot k_{af} \cdot t_{gn} \quad [J] \quad (55)$$

14. There are no recoverable heat losses, since recovery has been taken into account as a reduction of heat losses through the generator envelope:

$$Q_{g,l,rl} = 0 \quad [J] \quad (56)$$

5.4.8 **Condensing boilers**

5.4.8.1 Principle of the method

The effect of condensation latent heat recovery is taken into account as a reduction of $P_{ch,on}$ (losses through the chimney with burner on).

Latent heat recovery is calculated taking into account flue gas temperature and excess air.

The connection between return water temperature and flue gas temperature is given by the Δθ between flue gas and return water, which characterises the boiler.

For multistage boilers, Δθ and excess air at minimum and maximum combustion power are taken into account separately.

For modulating boilers, it is assumed that Δθ and oxygen contents (excess air) vary linearly between maximum and minimum combustion power.

5.4.8.2 Boiler data

To characterise a single stage (on-off) condensing boiler, the following additional data is required:

- $\Delta\theta_{wfl}$ [°C]] temperature difference between boiler return water temperature and flue gas temperature. Value should be given by the appliance manufacturer.
  If this data is not available, it can be either measured on existing system or taken from tables in a national annex or from default table C14
- $O_{2\ fl,dry}$ [%] is the flue gas oxygen contents.
  Value shall be given by the appliance manufacturer.
  If this data is not available, it can be either measured on existing system or taken from tables in a national annex or from default table C14

For multistage or modulating burners, the following additional data is required:

- $\Delta\theta_{wfl,min}$ [°C] temperature difference between boiler return water temperature and flue gas temperature at minimum combustion power.
  $\Delta\theta_{wfl,min}$ shall be given by the appliance manufacturer.
  If this data is not available, it can be either measured on existing system or taken from tables in a national annex or from default values in table C14
- $O_{2\ fl,dry,min}$ [%] flue gas oxygen contents at minimum combustion power $O_{2\ fl,dry}$
  Value shall be given by the appliance manufacturer.
  If this data is not available, it can be either measured on existing system or taken from tables in a national annex or from default values in table C14
- *$\Delta\theta_{wfl,max}$ [°C]* *temperature difference between boiler return water temperature and flue gas temperature at maximum combustion power instead of $\Delta\theta_{wfl}$.*
  $\Delta\theta_{wfl,max}$ shall be given by the appliance manufacturer.
  If this data is not available, it can be either measured on existing system or taken from tables in a national annex or from default values in table C14
- *$O_{2\ fl,dry,max}$ [%]* *flue gas oxygen contents at maximum combustion power instead of $O_{2\ fl,dry}$*
  Value shall be given by the appliance manufacturer.
  If this data is not available, it can be either measured on existing system or taken from tables in a national annex or from default values in table C14

NOTE: $\Delta\theta_{wfl,max}$ and $O_{2\ fl,dry,max}$ are the same values as $\Delta\theta_{wfl}$ and $O_{2\ fl,dry}$ for single stage boilers.

5.4.8.3 Data on fuel

The following data on fuel is required for condensation heat recovery R calculation:

H_s	Gross calorific value	[kJ/kg] or [kJ/Nm³]
H_i	Net calorific value	[kJ/kg] or [kJ/Nm³]
$V_{air,st}$	Stoichiometric dry air	[Nm³/kg] or [Nm³/Nm³]

$V_{fl,st,dry}$	Stoichiometric dry flue gas	[Nm³/kg] or [Nm³/Nm³]
$M_{H2O,st}$	Stoichiometric water production	[kg/kg] or [kg/Nm³]

Data should be given in a national annex. If no national annex is available, default data is given in Table C.13.

5.4.8.4 Single stage (on-off) boilers

Condensing, single stage, boiler fuel energy, auxiliary energy and heat losses shall be calculated with the same procedure as in 5.4.6 where $P_{ch,on}$ in equation 45 is replaced by $P^*_{ch,on}$ given by:

$$P^*_{ch,on} = P_{ch,on,max} - R \qquad [\%] \qquad (57)$$

where

- R [%] recovered latent heat at nominal power, as a percentage of Φ_{cn}, calculated according to paragraph 5.4.8.7

5.4.8.5 Multi stage (stepping) boilers

The procedure set-out in paragraph 5.4.7 shall be followed, where $P_{ch,on,max}$, and $P_{ch,on,min}$ in equation 49 are replaced with $P^*_{ch,on,max}$ and $P^*_{ch,on,min}$ given by:

$$P^*_{ch,on,max} = P_{ch,on,max} - R_{max} \qquad [\%] \qquad (58)$$

$$P^*_{ch,on,min} = P_{ch,on,min} - R_{min} \qquad [\%] \qquad (59)$$

where

- R_{min} [%] recovered latent heat at minimum combustion power, as a percentage of Φ_{min}.
- R_{max} [%] recovered latent heat at maximum combustion power, as a percentage of Φ_{max}.

R_{min} is calculated according to 5.4.8.7 using:

- $O_{2\ fl,dry,min}$ instead of $O_{2\ fl,dry}$
- $\Delta\theta_{wfl,min}$ instead of $\Delta\theta_{wfl}$

R_{max} is calculated according to 5.4.8.7 using:

- $O_{2\ fl,dry,max}$ instead of $O_{2\ fl,dry}$
- $\Delta\theta_{wfl,max}$ instead of $\Delta\theta_{wfl}$

5.4.8.6 Modulating boilers

The procedure set out in paragraph 5.4.7 shall be followed, where $P_{ch,min}$ is replaced with with $P^*_{ch,min}$ given by:

$$P^*_{ch,on,min} = P_{ch,on,min} - R_{min} \qquad [\%] \qquad (60)$$

and $P_{ch,on,avg}$ in equation (51) is replaced with $P^*_{ch,on,avg}$ given by:

$$P^*_{ch,on,avg} = P_{ch,on,avg} - R_{avg} \qquad [\%] \qquad (61)$$

where

- R_{min} [%] recovered latent heat at minimum combustion power, as a percentage of Φ_{min}.
- R_{avg} [%] recovered latent heat at average combustion power, as a percentage of Φ_{avg}.

R_{min} is calculated according to 5.4.8.7 using:

- $O_{2\ fl,dry,min}$ instead of $O_{2\ fl,dry}$
- $\Delta\theta_{wfl,min}$ instead of $\Delta\theta_{wfl}$

R_{avg} is calculated according to 5.4.8.7 using:

- $O_{2\ fl,dry,avg}$ instead of $O_{2\ fl,dry}$
- $\Delta\theta_{wfl,avg}$ instead of $\Delta\theta_{wfl}$

$\Delta\theta_{wfl,avg}$ is calculated (linear interpolation of $\Delta\theta_{wfl}$ according to combustion power) as:

$$\Delta\theta_{wfl,avg} = \Delta\theta_{wfl,\min} + \left(\Delta\theta_{wfl} - \Delta\theta_{wfl,\min}\right)\cdot\frac{\Phi_{cn,avg} - \Phi_{cn,\min}}{\Phi_{cn,\max} - \Phi_{cn,\min}}$$ [%] (62)

$O_{2\ fl,dry,avg}$ is calculated from (linear interpolation of $O_{2\ fl,dry}$ according to combustion power):

$$O2_{wfl,avg} = \Delta\theta_{wfl,\min} + \left(\Delta\theta_{wfl} - \Delta\theta_{wfl,\min}\right)\cdot\frac{\Phi_{cn,avg} - \Phi_{cn,\min}}{\Phi_{cn,\max} - \Phi_{cn,\min}}$$ [%] (63)

5.4.8.7 Calculation procedure of R

NOTE: $P^*_{ch,on,}$ may be negative when values are based on fuel net calorific value.
Total losses will be always positive when referred to gross calorific values according to paragraph 4.7.

Flue gas temperature (at boiler outlet connection to flue gas) is calculated with:

$$\theta_{fl} = \theta_{gn,w,r} + \Delta\theta_{wfl}$$ [°C] (64)

where:

- $\theta_{gn,w,r}$ [°C] boiler return water temperature, calculated according to annex H

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

Actual amount of dry flue gas $V_{fl,dry}$ is calculated with:

$$V_{fl,dry} = V_{fl,st,dry}\cdot\frac{20{,}94}{20{,}94 - O_{2\ fl,dry}}$$ [Nm³/Nm³] or [Nm³/kg] (65)

where

If the CO2 value is available, then to corresponding O2 value is obtained with:

Actual amount of dry combustion air $V_{air,dry}$ is calculated with:

$$V_{air,dry} = V_{air,dry} + V_{fl,dry} - V_{fl,st,dry} \qquad [Nm^3/Nm^3] \text{ or } [Nm^3/kg] \qquad (66)$$

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

Saturation humidity of air $M_{H2O,air,sat}$ and flue gas $M_{H2O,fl,sat}$ shall be calculated according to θ_{air} (combustion air temperature) and θ_{fl} (flue gas temperature) respectively and expressed as kg of humidity per Nm³ of dry air or flue gas. Data can be found in the following Table 3. Linear or polynomial interpolation shall be used for intermediate temperatures.

Table 3 – Saturation humidity as a function of temperature

Temperature (θ_{air} or θ_{fl})	°C	0	10	20	30	40	50	60	70
Saturation humidity $M_{H2O,air,sat}$ or $M_{H2O,fl,sat}$	kg/Nm³$_{dry}$	.00493	.00986	.01912	.03521	.06331	.1112	.1975	.3596
NOTE: Saturation humidity expressed as kg of water vapour per Nm³ of dry gas (either air or flue gas)									

Total humidity of combustion air $M_{H2O,air}$ is calculated with:

$$M_{H2O,air} = M_{H2O,air,sat} \cdot V_{air,dry} \cdot \frac{HUM_{air}}{100} \qquad [kg/Nm^3] \text{ or } [kg/kg] \qquad (67)$$

where

- HUM_{air} [%] combustion air relative humidity.
  Default value is given in annex C___

Total humidity of flue gas $M_{H2O,fl}$ is calculated with:

$$M_{H2O,fl} = M_{H2O,fl,sat} \cdot V_{fl,dry} \cdot \frac{HUM_{fl}}{100} \qquad [kg/Nm^3] \text{ or } [kg/kg] \qquad (68)$$

where

- HUM_{fl} [%] flue gas relative humidity.
  Default value is given in annex C___

The amount of condensing water $M_{H2O,cond}$ is calculated with:

$$M_{H2O,cond} = M_{H2O,st} + M_{H2O,air} - M_{H2O,fl} \qquad [kg/Nm^3] \text{ or } [kg/kg] \qquad (69)$$

If $M_{H2O,cond}$ is negative, there is no condensation. Then $M_{H2O,cond} = 0$ and $\Delta\eta_{cn,cond} = 0$.

The condensation specific latent heat $H_{cond,fl}$ is calculated with:

$$H_{cond,fl} = 2500600 - \theta_{fl} \cdot 2435 \qquad [J/kg] \ (70)$$

The condensation heat Q_{cond} is calculated with:

$$Q_{cond} = M_{H2O,cond} \cdot H_{cond.fl}$$ [J/Nm³] or [J/kg] (71)

The recovered latent heat R is calculated with:

$$R = \frac{100 \cdot Q_{cond}}{H_i}$$ [%] (72)

5.4.9 Systems with multiple generators

5.4.9.1 General

In general, sub-systems with multiple generators can be calculated as separated generation sub-systems in parallel. Criteria similar to those given in § 5.3.3 can be used to split $Q_{g,out}$ amongst available generators.

5.4.9.2 Modular systems

A modular system consists of N_{tot} identical modules or generators, each characterized by a maximum and a minimum combustion power $\Phi_{cn,i,max}$ and $\Phi_{cn,i,min}$, assembled as a single unit or connected to the same mains.

The combustion power of the entire system is calculated by:

$$\Phi_{cn} = \Phi_{cn,i,max} \cdot N_{tot}$$ ([W] (73)

5.4.9.3 Modular systems with hydraulic shutdown of stand-by modules

If there is an automatic control system applied, which shuts down and insulates stand-by generators and/or modules from the distribution network, the following procedure shall be followed.

The number N of running generators and/or modules is calculated as:

$$N = \text{int}\left(N_{tot} \cdot FC^* + 1\right)$$ [%] (74)

where load factor FC* is calculated for a single stage generator of combustion power Φ_{cn}.

The actual performance of the modulating generator is calculated following the procedure for multistage generators and assuming:

$\Phi_{cn,max} = \Phi_{cn,i,max} \cdot N$

$\Phi_{cn,min} = \Phi_{cn,i,min}$

5.4.9.4 Modular systems without hydraulic shutdown of stand-by modules

If there is no control system applied, which shuts down and insulates stand-by generators and/or modules from the distribution network, the following procedure shall be followed.

The actual performance of the modulating generator is calculated following the procedure for multistage generators and assuming:

$\Phi_{cn,max} = \Phi_{cn,i,max} \cdot N_{tot}$

$\Phi_{cn,min} = \Phi_{cn,i,min} \cdot N_{tot}$

5.5 Large indoor space heating

5.5.1 Dark radiator (Type C), decentralised hot air generator (Type C)

The heat generation loss for dark radiator and decentralised hot air generator is given by:

$$Q_{g,l,t} = f \cdot Q_{g,out} \quad \text{in kWh per month} \qquad (75)$$

The losses factors are provided in table D.3. Heat recovery is already accounted for as reduction of losses

Here the assumption is made that these heat generators are installed in the working space such that they are independent of room air, and are connected to concentric air/exhaust gas pipework.

5.5.2 Bright radiator (Type A)

5.5.2.1 General

The heating facility generally comprises a number of bright radiators. The heat generation loss for bright radiator facilities is given by:

$$Q_{g,l,t} = V_{Abluft,spez} \cdot c_{p,Abluft} \cdot (\vartheta_{Abluft} - \vartheta_{Außen}) \cdot t_{h,rL} \qquad (76)$$

where

$V_{Abluft,spez}$ is the specific combustion air demand = 10 m³/(h · kW heat load);

$c_{p,Abluft}$ is the specific heat capacity = 0.361 Wh/(m³ · K);

ϑ_{Abluft} is the exhaust air temperature = 18 °C;

ϑ_e is the average monthly external air temperature, in °C;

$t_{h,rL}$ is the monthly analytical running time (, in h.

Here the assumption is made that these heat generators are installed in the working space and that they are fitted with an indirect exhaust air duct in accordance with EN 13410.

5.5.2.2 Auxiliary energy for bright radiators

Auxiliary energy for wall or ceiling ventilators, with reference to the heat demand of the large indoor space, heated with a bright radiator facility

$$W_g = 0.0006 \cdot Q_{h,b} \qquad (77)$$

in kWh per month

Where

$Q_{h,b}$ heat demand (in the month), in kWh

PARAGRAPH 5.5 TO BE CHECKED

Bibliografy

- Auxiliary energy measurements on boilers En 15456 (Breidenbach or Schilling should provide information)
- Council Directive 92/42/EEC of 21 May 1992 about the efficiency requirements of the new gas or oil boilers

Annex A
(informative)

Sample seasonal boiler performance method based on system typology (typology method) -

A.1 Scope

This annex is an example of a national annex defining a typology method. The example is based on the Seasonal efficiency calculation procedure (SEDB_UK) intended for use in the housing sector of the UK.

If there is no such appropriate national annex, this method (system typology) cannot be used.

A.2 Limitations in use of this method

This procedure is used to determine the seasonal effficiency of gas and oil boilers installed in the UK housing sector. It is named SEDB_UK (Seasonal Efficiency of Domestic Boilers in the UK)

This method of calculation is applicable only to boilers for which the full load efficiency and the 30% part load efficiency values, obtained by the methods deemed to satisfy Council Directive 92/42/EEC about Boiler Efficiency, are available.

These are net efficiency values (higher efficiency values, referenced to the lower heat value of fuels).

It is essential that both test results are available and that the tests are appropriate to the type of boiler as defined in Council Directive 92/42/EEC about Boiler Efficiency, otherwise the calculation cannot proceed.

If SEDB_UK values are declared, they should be accompanied by the wording given in A5, which is necessary to avoid confusion with efficiency values calculated by other methods.

A.3 Boiler typologies definition

For the purpose of this method, the following boiler typologies are defined.

regular boiler
a boiler which does not have the capability to provide domestic hot water directly (i.e. not a combination boiler). It may nevertheless provide domestic hot water indirectly via a separate hot water storage cylinder

combination boiler
a boiler with the capability to provide domestic hot water directly, in some cases containing an internal hot water store

instantaneous combination boiler
a combination boiler without an internal hot water store, or with an internal hot water store of capacity less than 15 litres

storage combination boiler
a combination boiler with an internal hot water store of capacity at least 15 litres but less than 70 litres, or a

combination boiler with an internal hot water store of capacity at least 70 litres, in which the feed to the space heating circuit is not taken directly from the store. If the store is at least 70 litres and the feed to the space heating circuit is taken directly from the store, refer to definition of combined primary storage unit (CPSU)

combined primary storage unit (CPSU)
a single appliance designed to provide both space heating and domestic hot water, in which there is a burner that heats a thermal store which contains mainly primary water which is in common with the space heating circuit. Capacity of the hot water store is at least 70 litres and the feed to the space heating circuit is taken directly from the store

on/off boiler
a boiler without the capability to vary the fuel burning rate whilst maintaining continuous burner firing. This includes boilers with alternative burning rates set once only at the time of installation, referred to as range rating

modulating boiler
a boiler with the capability to vary the fuel burning rate whilst maintaining continuous burner firing

condensing boiler
a boiler designed to make use of the latent heat released by condensation of water vapour in the combustion flue products. The boiler must allow the condensate to leave the heat exchanger in liquid form by way of a condensate drain. Boilers not so designed, or without the means to remove the condensate in liquid form are called 'non-condensing'

A.4 Procedure

In the procedure, the data are first converted to gross efficiency (lower efficiency values, referenced to the higher heat value of fuels) under test conditions, and then converted to a seasonal efficiency, which applies under typical conditions of use in a dwelling, allowing for standing losses.

In this annex, efficiencies are expressed in percent. Intermediate calculations should be done to at least four decimal places of a percentage, and the final result should be rounded off to one decimal place.

The steps are as follows:

1 Determine fuel for boiler type.
The fuel for boiler type must be one of natural gas, LPG (butane or propane), or oil (kerosene or gas oil).

2 Obtain test data.
Retrieve the full-load net efficiency and 30% part-load net efficiency test results. Tests must have been carried out using the same fuel as the fuel for boiler type.

3 Reduce to maximum net efficiency values.
Table A.1 gives the maximum values of net efficiency depending on the type of boiler. Reduce any higher net efficiency test values to the appropriate value given in Table A.1.

Table A.1: Maximum net efficiency values (%)

Condensing boilers		Non-condensing boilers	
Full load	30% part load	Full load	30% part load

101,0	107,0	92,0	91,0

4 Convert the full load efficiency and the 30% part load efficiency from net values to gross values. Use the following equation with the appropriate factor from Table A.2.

$$\eta_{Px,gross} = f \times \eta_{Px,net} \quad \text{(A1)}$$

Table A.2: Efficiency conversion factors

Fuel	Net-to-gross conversion factor, *f*
Natural gas	0,901
LPG (propane or butane)	0,921
Oil (kerosene or gas oil)	0,937

5 Categorise the boiler.

(a) Select the appropriate category for the boiler according to the definitions (see A.4).

(b) For a gas or LPG boiler, determine whether or not it has a permanent pilot light:

if it has a permanent pilot light, set p = 1

if not, set p = 0.

(c) For a storage combination boiler (either on/off or modulating), determine from the test report whether or not the losses from the store are included in the test values reported (this depends on whether or not the store was connected to the boiler during the tests):

if the store loss is included, set b = 1

if not, set b = 0.

(d) For a condensing combined primary storage unit (CPSU, either on/off or modulating),

set b = 1.

(e) For a storage combination boiler or a CPSU, obtain the store volume, V, in litres from the specification of the device and the stand-by loss factor, L, using the following equation:

if th < 10 mm: L = 0,0945 – 0,0055 x th

if th ≥ 10 mm: L = 0,394 / th

where th is the thickness of the insulation of the store in mm.

6 Calculate seasonal efficiency

(a) Use the boiler category and other characteristics as defined in 3.1 (non-condensing or condensing; gas or LPG or oil; on/off or modulating) to look up the appropriate SEDB_UK equation number in Table A.3 and select the appropriate equation from Table A.4 or Table A.5, as applicable. If no equation number is given in Table A.3, the calculation cannot proceed.

(b) Substitute the gross full load efficiency and part load efficiency (found in step 4) and p, b, V and L (found in step 5) in the equation found in step 6a. Round off the result to one decimal place, i.e. to the nearest 0.1%. Note the result for the purpose of the declaration in A.3.

(c) Convert the gross seasonal efficiency back to net seasonal efficiency as required by prEN 15316:

$$\eta_{Px,net} = 1/f \times \eta_{Px,gross} \quad \text{(A2)}$$

Table A.3: Boiler category table

SEDB_UK EQUATION NUMBERS FOR DIFFERENT BOILER TYPES	non-condensing				low-temperature	condensing			
	Gas or LPG		Oil			Gas or LPG		Oil	
	on/off	modulating	on/off	modulating		on/off	modulating	on/off	modulating
regular boiler	101	102	201	X	X	101	102	201	X
instantaneous combi boiler	103	104	202	X	X	103	104	202	X
storage combi boiler	105	106	203	X	X	105	106	203	X
combined primary storage unit	107	107	X	X	X	105	106	X	X

Table A.4 : Seasonal efficiency, η, for natural gas boilers and LPG boilers

Gas or LPG boiler type	Eq. no.	Equation
On/off regular	101	$\eta = 0{,}5 \times (\eta_{full} + \eta_{part}) - 2{,}5 - 4 \times p$
Modulating regular	102	$\eta = 0{,}5 \times (\eta_{full} + \eta_{part}) - 2{,}0 - 4 \times p$
On/off instantaneous combination	103	$\eta = 0{,}5 \times (\eta_{full} + \eta_{part}) - 2{,}8 - 4 \times p$
Modulating instantaneous combination	104	$\eta = 0{,}5 \times (\eta_{full} + \eta_{part}) - 2{,}1 - 4 \times p$
On/off storage combination On/off combined primary storage unit (condensing only)	105	$\eta = 0{,}5 \times (\eta_{full} + \eta_{part}) - 2{,}8 + (0{,}209 \times b \times L \times V) - 4 \times p$
Modulating storage combination Modulating combined primary storage unit (condensing only)	106	$\eta = 0{,}5 \times (\eta_{full} + \eta_{part}) - 1{,}7 + (0{,}209 \times b \times L \times V) - 4 \times p$
On/ off combined primary storage unit (non-condensing only) Modulating combined primary storage unit (non-condensing only)	107	$\eta = 0{,}5 \times (\eta_{full} + \eta_{part}) - (0{,}539 \times L \times V) - 4 \times p$

Table A.5 : Seasonal efficiency, η, for oil boilers

Oil boiler type	Eq. No.	Equation
Regular	201	$\eta = 0{,}5 \times (\eta_{full} + \eta_{part})$
Instantaneous combination	202	$\eta = 0{,}5 \times (\eta_{full} + \eta_{part}) - 2{,}8$
Storage combination	203	$\eta = 0{,}5 \times (\eta_{full} + \eta_{part}) - 2{,}8 + (0{,}209 \times b \times L \times V)$

7 Calculate generation heat loss

The SEDB_UK method is based on a typological approach using correlations on efficiency values. Therefore it is necessary to express the seasonal performance of generation in absolute values in order to fit the general structure of prEN 15316.

The total generation heat loss $Q_{g,l,t}$ is calculated by:

$$Q_{g,l,t} = Q_{g,out} \cdot \frac{1 - \eta_{g,net}}{\eta_{g,net}} \qquad \text{(A3)}$$

8 Calculate fuel heat requirement
The fuel heat requirement $Q_{g,in}$ is calculated by:

$$Q_{g,in} = \frac{Q_{g,out}}{\eta_{g,net}} \quad \text{(A4)}$$

9 Calculate auxiliary consumption
The auxiliary consumption is calculated according to 5.3.6

10 Calculate total recoverable heat loss
No recoverable generation heat loss is taken into account

A.5 Declaring values of seasonal efficiency

1 Manufacturers wishing to declare the seasonal efficiency of their products as SEDB_UK values can do so provided that:

(a) they use the SEDB_UK calculation procedure given in A.2 above; and

(b) the necessary boiler test data are independently certified.

2 Where a manufacturer declares the SEDB_UK, it shall be expressed as:

“Seasonal Efficiency (SEDB_UK) = [x]%
The test data from which it has been calculated have been certified by
[insert name and/or identification of Notified Body].”

Data for several products may be presented in tabulated form, in which case the second paragraph of the declaration should be incorporated as a note to the table.

Annex B
(informative)

Additional formulas and default values for parametering the case specific boiler efficiency method

B.1 Information on the method

B.1.1 Basic assumptions and intended use

This method is intended for use with boilers where data declared according to Council Directive 92/42/CE are known.

This methodology assumes that losses power and auxiliary power are linearly dependant on boiler load in two ranges:

from 0 to intermediate power;

from intermediate power to nominal (maximum) load.

The intermediate load is assumed to be the same as defined by Council Directive 92/42/CE on boiler efficiencies, that is 30% of maximum load.

It is also assumed that efficiencies determined according to testing standards can be corrected using linear functions of actual boiler operating temperature or boiler installation room temperature.

B.1.2 Known approximations

The intermediate power should be the minimum power with burner on. The intermediate load of 30% is kept to ease use of data declared according to Council Directive 92/42/CE. Polynomial interpolation is used to reduce the influence of this approximation.

The assumption of the linear dependence of efficiencies according to boiler temperature is not true when condensation (which is inherently a non linear phenomenon) occurs. Variable values of f_{cor} according to boiler typology have been introduced to reduce the influence of this approximation.

Change in boiler efficiency at 30% and 100% load according to installation room temperature is neglected. Installation room temperature has an influence only on stand-by losses and therefore on performance in the range from 0 lto intermediate load.

B.2 Polynomial interpolation formulas

The following formulas may replace linear interpolation formulas (19) and (20):

$$\Phi_{gn,l,Px} = \Phi_{Px}^2 \frac{\Phi_{Pint}\left(\Phi_{gn,l,Pn,cor} - \Phi_{gn,l,P0,cor}\right) - \Phi_{Pn}\left(\Phi_{gn,l,Pint,cor} - \Phi_{gn,l,P0,cor}\right)}{\Phi_{Pn}\Phi_{Pint}\left(\Phi_{Pn} - \Phi_{Pint}\right)} \cdot$$
$$+ \Phi_{Px}\Phi_{Pn}^2 \frac{\left(\Phi_{gn,l,Pint,cor} - \Phi_{gn,l,P0,cor}\right) - \Phi_{Pint}^2\left(\Phi_{gn,l,Pn,cor} - \Phi_{gn,l,P0,cor}\right)}{\Phi_{Pn}\Phi_{Pint}\left(\Phi_{Pn} - \Phi_{Pint}\right)} \qquad \text{(B1)}$$
$$+ \Phi_{gn,l,P0,cor}$$

B.3 Generator efficiencies and stand-by losses

B.3.1 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 expressed as:

Full load

$$\eta_{gn,Pn} = A + B \cdot \log \Phi'_{Pn} \qquad [\%] \qquad \text{(B2)}$$

Intermediate load

$$\eta_{gn,Pint} = C + D \cdot \log \Phi'_{Pn} \qquad [\%] \qquad \text{(B3)}$$

for oil-condensing boilers
$$\eta_{gn,Pint} = \frac{(C + D \cdot \log \Phi'_{Pn})}{1.05} \qquad [\%] \qquad \text{(B4)}$$

where:

Φ'_{Pn} 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 equations B2 and B3 and B4.

A,B,C,D parameters given in Table B.1

Table B.1: Parameters for calculation of generator efficiency and temperature limitation

Boiler type	Build year	A	B	C	D	$\theta_{gn,min}$
Standard boiler, generic	After 1994	84	2	80	3	45 °C
Low temperature boiler, generic	After 1994					
Change-fuel boilers	before 1978	77.0	2.0	70.0	3.0	50 °C
	1978 to 1987	79.0	2.0	74.0	3.0	50 °C
Standard boilers:						
Atmospheric gas boilers	before 1978	79.5	2.0	76.0	3.0	50 °C
	1978 to 1994	82.5	2.0	78.0	3.0	50 °C
	after 1994	85.0	2.0	81.5	3.0	50 °C
Heating boiler with forced draught burner	before 1978	80.0	2.0	75.0	3.0	50 °C
	1978 to 1986	82.0	2.0	77.5	3.0	50 °C
	1987 to 1994	84.0	2.0	80.0	3.0	50 °C
	after 1994	85.0	2.0	81.5	3.0	50 °C
Burner replacement (only heating boiler with forced draught burner)	before 1978	82.5	2.0	78.0	3.0	50 °C
	1978 to 1994	84.0	2.0	80.0	3.0	50 °C
Low temperature boilers:						
Atmospheric gas boilers	1978 to 1994	85.5	1.5	86.0	1.5	35°C
	after 1994	88.5	1.5	89.0	1.5	35°C
Circulation water heater (11 kW 18 kW and 24 kW)	before 1987	86.0	0.0	84.0	0.0	35°C
	1987 to 1992	88.0	0.0	84.0	0.0	35°C
Heating boiler with forced draught burner	before 1987	84.0	1.5	82.0	1.5	35°C
	1987 to 1994	86.0	1.5	86.0	1.5	35°C
	after 1994	88.5	1.5	89.0	1.5	35°C
Burner replacement (only heating boiler with forced draught burner)	before 1987	86.0	1.5	85.0	1.5	35°C
	1987 to 1994	86.0	1.5	86.0	1.5	35°C
Condensing boilers:						
Condensing boilers	before 1987	89.0	1.0	95.0	1.0	20 °C
	1987 to 1994	91.0	1.0	97.5	1.0	20 °C
	after 1994	92.0	1.0	98.0	1.0	20 °C
Condensing boilers, improved[a]	from 1999	94.0	1.0	103	1.0	20 °C

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

B.3.2 Stand-by heat losses

Default value for the stand-by heat losses depending on the generator power output is calculated by:

$$\Phi_{gn,l,P0} = \Phi_{Pn} \cdot \left(E + F \cdot \log \Phi'_{Pn}\right) \quad \text{[W]} \qquad \text{(B5)}$$

where:

Φ_{Pn} nominal power output in kW

Φ'_{Pn} 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 equation B5

E,F parameters given in Table B.2

Table B.2: Parameters for calculation of stand-by heat losses

Boiler type	Build year	Factor E	Factor F	$\Delta\theta$,test °C
Change-fuel boilers	until 1987	12.5	–0.28	30
Standard boilers:				
Atmospheric gas boilers	before 1978	8.0	–0.27	30
	1978 to 1994	7.0	–0.3	30
	after 1994	8.5	–0.4	30
Heating boiler with forced draught burner (oil/gas)	before 1978	9.0	–0.28	30
	1978 to 1994	7.5	–0.31	30
	after 1994	8.5	–0.4	30
Low temperature boilers:				
atmospheric gas boilers	until 1994	6.0	–0.32	30
	after 1994	4.5	–0.4	30
Circulation water heaters (combination boilers 11 kW, 18 kW and 24 kW)	until 1994	2.2	0.0	30
Combination boilers KSp[b]	after 1994	2.2	0.0	30
Combination boilers DL[a]	after 1994	1.2	0.0	30
Heating boiler with forced draught burner (oil/gas)	until 1994	7.00	–0.37	30
	after 1994	4.25	–0.4	30
Condensing boilers:				
Condensing boilers (oil/gas)	until 1994	7.0	–0.37	30
	after 1994	4.0	–0.4	30
Combination boilers KSp (11 kW, 18 kW and 24 kW) (*)	after 1994	2.2	0.0	30
Combination boilers DL (11 kW, 18 kW and 24 kW) (**)	after 1994	1.2	0.0	30

(*)	KSp: Boiler with integrated domestic hot water heating working on the instantaneous principle with small storage tank ($2 < V < 10$ l).
(*)	DL: Boiler with integrated domestic hot water heating working on the instantaneous principle with heat exchanger (V < 2 l).

B.3.3 Correction factor taking into account variation of efficiency depending on generator average water temperature

B.3.3.1 Default values

Table B.3 : Default values for full load correction factor $f_{cor,Pn}$

Generator type	Boiler average water temperature at boiler test conditions for full load $\theta_{gn,test, Pn}$	Correction factor $f_{cor,Pn}$
Standard boiler	70 °C	0,04
Low temperature boiler	70 °C	0,04
Gas condensing boiler	70 °C (*)	0,20
Oil Condensing boiler	70 °C (*)	0,04
(*) Return temperature		

Table B.4: Intermediate load correction factor $f_{cor,Pint}$

Generator type	Generator average water temperature at boiler test conditions for intermediate load $\theta_{gn,test, Pint}$	Correction factor $f_{cor,Pint}$
Standard boiler	50 °C	0,05
Low temperature boiler	40 °C	0,05
Gas condensing boiler	30 °C (*)	0,20
Oil Condensing boiler	30 °C (*)	0,10
(*) Return temperature		

For a condensing boiler, testing is not made with a 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.

B.3.3.2 Calculated values

Correction factor $f_{cor,Pn}$ may be calculated using efficiency data from additional tests performed at a lower average water temperatures , using the following equation:

$$f_{con,Pn} = \frac{\eta_{Pn} - \eta_{Pn,add}}{\theta_{gn,test,Pn,add} - \theta_{gn,test,Pn}} \quad \text{[W]} \qquad \text{(B6)}$$

where

η_{Pn} full load efficiency in standard test conditions with average water temperature $\theta_{gn,test,Pn}$

$\eta_{Pn,add}$ full load efficiency with average water temperature $\theta_{gn,test,Pn,add}$

Correction factor $f_{cor,Pint}$ may be calculated using efficiency data from additional tests performed at a higher average water temperatures, using the following equation:

$$f_{con,P\,\mathrm{int}} = \frac{\eta_{P\,\mathrm{int}} - \eta_{P\,\mathrm{int},add}}{\theta_{gn,test,P\,\mathrm{int},add} - \theta_{gn,test,P\,\mathrm{int}}} \quad \text{[W]} \qquad \text{(B7)}$$

where

η_{Pint} intermediate load efficiency in standard test conditions with average water temperature $\theta_{gn,test,Pint}$

$\eta_{Pint,add}$ full load efficiency with average water temperature $\theta_{gn,test,Pint,add}$

B.4 Auxiliary consumption

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

$$\Phi_{aux,gn} = G + H \cdot \Phi_{Pn}^{n} \quad \text{[W]} \qquad \text{(B8)}$$

where:

Φ_{Pn} nominal power output in kW

G,H,n parameters given in Table B.5

Table B.5: Parameters for calculation of power consumption of auxiliary equipment

		Factor G	Factor H	Factor n
Boiler with forced draught burner	full load	0	45	0,48
	part load	0	15	0,48
	stand by	15	0	0
Boiler with atmospheric burner up to 250 kW	full load	40	0,35	1
	part load	20	0,1	1
	stand by	15	0	0
with atmospheric burner from 250 kW	full load	80	0,7	1
	part load	40	0,2	1
	stand by	15	0	0
Change-fuel boilers	full load	0	45	0,48
	part load	0	15	0,48
	stand by	0		
Standard boiler				
Atmospheric gas boilers	full load	40	0,148	1
	part load	40	0,148	1
	stand by	15	0	0

Heating boiler with forced draught burner (oil/gas)	full load	0	45	0,48
	part load	0	15	0,48
	stand by	15	0	0
Low temperature boilers				
Atmospheric gas boilers	full load	40	0,148	1
	part load	40	0,148	1
	stand by	15	0	0
Circulation water heaters	full load	0	45	0,48
	part load	0	15	0,48
	stand by	15	0	0
Heating boiler with forced draught burner (oil/gas)	full load	0	45	0,48
	part load	0	15	0,48
	stand by	15	0	0
Condensing boilers (oil/gas)	full load	0	45	0,48
	part load	0	15	0,48
	stand by	15	0	0

B.5 Recoverable generation heat losses

B.5.1 Auxiliary energy

The part of the nominal electrical power transmitted to the distribution sub-system $p_{aux,g}$ is calculated by:

$$p_{aux,g} = 1 - \eta_{hydraulic} \qquad [-] \qquad \text{(B9)}$$

Default value of the hydraulic efficiency $\eta_{hydraulic}$ is 0,75.

B.5.2 Generator envelope

The part of stand-by heat losses attributed to heat losses through the generator envelope is given by $p_{gn,env}$. Default values of $p_{gn,env}$ are given in Table B.6.

Table B.6: Part of stand-by heat losses attributed to losses through the generator envelope

Burner type	$p_{gn,env}$
Atmospheric burner	0,50
Fan assisted burner	0,75

B.5.3 Default data according to boiler location

Table B.7 Temperature reduction factor and default installation room temperature

Generator location	**Temperature reduction factor**	**Installation room temperature**

	b_g	°C
Outdoors	**1**	θ_{ext}
In the boiler room	0.3	13
underroof	0.2	5
Inside heated space	0.0	20

Annex C
(informative)

Default values for parametering the boiler cycling method

C.1 Information on the method

C.1.1 Basic assumptions and intended use

This method is intended

- for use with existing boilers where data declared according to Council Directive 92/42/CE are not known;
- to determine the effect of operating conditions on performances of condensing boilers.

This methodology is based on an physical analysis of losses and takes in to account two operating conditions:

- boiler with burner on;
- boiler with burner off (stand-by).

Latent heat recovery is calculated separately from sensible heat losses. Data for heating system operating conditions, boiler and fuel are kept separate.

This methodology is suitable for on-off, modulating, modular and condensing boilers, as well as for their combinations (like modulating, condensing boilers)

All data given in this annex are based on net calorific values H_i. If losses have to calculated with respect to gross calorific value H_s, this has to be done with the procedure defined in § 4.7.

C.1.2 Known approximations

Additional losses during ignition cycles (ventilation before ignition) are not taken into account.

Losses through the chimney with burner off are not easily measured. However this loss factor has a reduced impact in new boilers with air intake closure at stand-by.

C.2 Default specific losses

C.2.1 Default values of $\theta_{gn,test}$, $P'_{ch,on}$ and n

Table C.1: Default value of $\theta_{gn,test}$ and $P'_{ch,on}$

Description	$\theta_{gn,test}$ [°C]	$P'_{ch,on}$ [%]	$\theta_{i,test}$ [°C]	f_{cor}
Atmospheric boiler	70	12	20	0,045
Force draught gas boiler	70	10	20	0,045
Liquid fuel boiler	70	11	20	0,045

Description	$\theta_{gn,test}$ **[°C]**	**P'$_{ch,on}$** **[%]**	$\theta_{i,test}$ **[°C]**	f_{cor}
Condensing boiler	50 (*)	6	20	0,045
NOTE (*) Return temperature for condensing boilers				

Table C.2: Default value of exponent n

Description	$M_{ch,on}$ **[kg/kW]**	**n** **[-]**
Wall mounted boiler	< 1	0,05
Steel boiler	1 – 2	0,1
Cast iron boiler	> 2	0,15

where $M_{ch,on}$ is heat capacity per kW of the heat exchange surface between flue gas and water.

C.2.2 Default values of $P'_{gn,env}$, $k_{gn,env}$ and m

The default losses through the boiler envelope $P_{gn,env}$ are given by:

$$P_{gn,env} = A - B \cdot \log \Phi_{cn} \qquad [\%] \qquad (C1)$$

where

A, B parameters given in Table C.3

Φ_{cn} boiler nominal combustion power [kW]

Table C.3: Value of parameters A and B

Boiler insulation type	**A** **[-]**	**B** **[-]**
Well insulated, high efficiency new boiler	1,72	0,44
Well insulated and maintained	3,45	0,88
Old boiler with average insulation	6,90	1,76
Old boiler, poor insulation	8,36	2,2
No insulation	10,35	2,64

Table C.4: Default value of factor $k_{gn,env}$ and installation room temperature

Boiler type and location	$k_{gn,env}$ **[-]**	$\theta_{i,gn}$ **[°C]**

Boiler type and location	**$k_{gn,env}$** **[-]**	$\theta_{i,gn}$ **[°C]**
Boiler installed within the heated space	0,1	20
Atmospheric boiler installed within the heated space	0.2	20
Boiler installed within a boiler room	0.7	13
Under roof	0.8	5
Boiler installed outdoors	1	External temperature

Default values for $\theta_{i,test}$ is 20°C

Table C.5: Default value of exponent m

Description	**$M_{gn,env}$** **[kg/kW]**	**m** **[-]**
The primary pump is always running		0,0
The primary pump stops a few minutes after the burner turns off and both are controlled by the room thermostat:		
- wall mounted boiler	< 1	0,15
- steel boiler	1 – 3	0,10
- cast iron boiler	> 3	0,05
$M_{gn,env}$ is the ratio between the total weight of the boiler (metal + refractory materials + insulating materials) and the nominal combustion power Φ_{cn} of the boiler.		

C.2.3 Default values of $P'_{ch,off}$ and p

Table C.6: Default value of $P'_{ch,off}$

Description	**$P'_{ch,off}$** **[%]**
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
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

Description	$P'_{ch,off}$ [%]
Atmospheric gas fired boiler:	
Chimney height < 10 m	1,2
Chimney height > 10 m	1,6

Table C.7: Default value of exponent p

Description	$M_{ch,off}$ [kg/kW]	p [-]
The primary pump is always running		0,0
The primary pump stops a few minutes after the burner turns off and both are controlled by the room thermostat:		
- wall mounted boiler	< 1	0,15
- steel boiler	1 – 3	0,10
- cast iron boiler	> 3	0,05
$M_{ch,off}$ is the ratio between the total weight of the boiler (metal + refractory materials + insulating materials) and the nominal combustion power Φ_{cn} of the boiler.		

C.3 Default auxiliary power consumption

Table C.8: Default value of electrical power consumption of auxiliary devices

Description	Electrical power consumption [kW]
Atmospheric boilers	$\Phi_{br} = 20 + \Phi_{cn} \cdot 0{,}00035$
Burner fan and auxiliaries (gas)	$\Phi_{br} = \Phi_{cn} \cdot 0{,}002$
Burner fan and auxiliaries (light oil)	$\Phi_{br} = \Phi_{cn} \cdot 0{,}003$
Burner fan and auxiliaries (heavy oil)	$\Phi_{br} = \Phi_{cn} \cdot 0{,}004$
Primary pump	$\Phi_{af} = \Phi_{cn} \cdot 0{,}001$

where Φ_{cn} is the boiler nominal combustion power [kW].

Table C.9: Default value of auxiliary energy recovery factors

Description	Value [-]
k_{br}	0,8

k_{af}	0,8

C.4 Additional default data for multistage and modulating burners

The default minimum combustion power of the boiler is given by:

$$\Phi_{cn,min} = \Phi_{cn} \cdot M \quad [kW] \quad (C2)$$

where:

M parameter given in Table C.10

Φ_{cn} boiler nominal (maximum) combustion power [kW]

Table C.10: Parameter M for multistage and modulating burners

Description	**M** **[-]**
Gas boiler	0,3
Liquid fuel boiler	0,5

Table C.11: Default value of $\theta_{gn,test}$ and $P'_{ch,on,min}$

Description	$\theta_{gn,test}$ **[°C]**	$P'_{ch,on,min}$ **[%]**
Atmospheric boiler	70	11
Force draught gas boiler	70	9
Oil boiler	70	10
Condensing boiler	50	5

Table C.12: Default value of electrical power consumption of auxiliary devices at $\Phi_{cn,min}$

Description	$\Phi_{br,min}$ **[kW]**
Atmospheric boilers	$\Phi_{br,min} = 10 + \Phi_{cn,min} \cdot 0,00035$
Burner fan and auxiliaries (gas)	$\Phi_{br,min} = \Phi_{cn,min} \cdot 0,002$
Burner fan and auxiliaries (light oil)	$\Phi_{br,min} = \Phi_{cn.min} \cdot 0,003$
Burner fan and auxiliaries (heavy oil)	$\Phi_{br,min} = \Phi_{cn,min} \cdot 0,004$

where $\Phi_{cn,min}$ is the minimum combustion power of the boiler (kW).

C.5 Additional default data for condensing boilers

Table C13 – Default fuel data for condensation heat recovery calculation

Property	Symbol	Unit	Fuel			
			Natural gas (Groningen)	Propane	Butane	Light oil EL
Gross calorific value	H_s	kJ/kg or kJ/Nm³	35 169 [kJ/Nm³]	101 804 [kJ/Nm³]	131 985 [kJ/Nm³]	45 336 kJ/kg
Net calorific value	H_i	kJ/kg or kJ/Nm³	31 652 [kJ/Nm³]	93 557 [kJ/Nm³]	121.603 [kJ/Nm³]	42 770 kJ/kg
Stoichiometric dry air	$V_{air,st}$	Nm³/kg or Nm³/Nm	8.4 [Nm³/Nm³]	23.,8 [Nm³/Nm³]	30.94 [Nm³/Nm³]	11,23 Nm³/kg
Stoichiometric dry flue gas	$V_{fl,st,dry}$	Nm³/kg or Nm³/Nm	7.7 [Nm³/Nm³]	21.8 [Nm³/Nm³]	28.44 [Nm³/Nm³]	10,49 Nm³/kg
Stoichiometric water production	$M_{H2O,st}$	kg/kg or kg/Nm³	1.405 [kg/Nm³]	3.3 [kg/Nm³]	4.03 [kg/Nm³]	1,18 kg/kg

Table C14 - Default values for the calculation of R

Description	Symbol	Unit	Case	Value
combustion air relative humidity	HUM_{air}	%	All cases	50
flue gas relative humidity	HUM_{fl}	%	All cases	100
temperature difference between boiler return water temperature and flue gas temperature	$\Delta\theta_{wfl}$	°C	$\eta_{gn,Pn}$>102	20
			$\eta_{gn,Pn}$<102	60
temperature difference between boiler return water temperature and flue gas temperature at minimum power	$\Delta\theta_{wfl,min}$	°C	$\eta_{gn,Pmin}$>106	5
			$\eta_{gn,Pn}$<106	20
flue gas oxygen contents	$O_{2\ fl,dry}$	%	All cases	6
flue gas oxygen contents at minimum combustion power	$O_{2\ fl,dry,min}$	%	Modulation of both air and gas	6
			Only gas modulation	15

Annex D
General part default values and information

D.1 Control factor

Table D.1 Default values for control factor in equation [1]

Description	k_{ctrl}
All control types	1,0

Other values may be specified in a national annex, provided that emission control losses has not been taken into account in the emission part (EN 15316-2-1).

Note In this standard the effect of heat emission control is taken into account in the emission and control part (EN 15316-2-1). 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 D2 is an example of such table to be given in a national annex

Table D.2 Sample default national table for control factor in equation [1]

Description		k_{ctrl}
Floor standing boiler	Outdoor temperature controlled	1,00
Wall hanged boiler	Outdoor temperature controlled	1,03
	room temperature controlled	1,06

D.2 Intermediate load

Intermediate load Φ_{int} is given by

$$\Phi_{int} = \Phi_{Pn} \cdot \beta_{int} \quad \text{[kW]} \qquad \text{(D1)}$$

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

D.3 Dark radiator (Type C), decentralised hot air generator (Type C)

Table D.3 — Losses factor

nominal heat output kW	**Factor** *f*
> 4 to 25	0.111
> 25 to 50	0.099

> 50	0.087

Annex E
(informative)

Calculation examples for method 1

E.1 Seasonal boiler performance method based on system typology (typology method)

Input data:

Efficiency test results: $\eta_{gn,Pn}$ = 93 % (full-load net efficiency)

$\eta_{gn,Pint}$ = 99 % (30% part-load net efficiency)

Produced in accordance with standard tests as required for the Council Directive 92/42/EEC about Boiler Efficiency and independently certified

Boiler type: Condensing boiler

Nominal power: 70 kW

Fuel used: Natural gas

Ignition method: No permanent pilot flame

Burner type: Modulating, fan assisted

Data according to other parts of this standard

$Q_{d,in} = Q_{g,out}$ = 220 days x 86.400 s/day x 70.000 W x 0,35 = 465.696 MJ

Calculation:

1 Determine fuel for boiler type: Natural gas

2 Obtain test data: $\eta_{gn,Pn}$ = 93 %; $\eta_{gn,Pint}$ = 99 %

3 Reduce to maximum net efficiency values (Table A.1): $\eta_{gn,Pn}$ = 93 %; $\eta_{gn,Pint}$ = 99 %

4 Convert the efficiencies from net to gross values (Table A.2): $\eta_{Px,gross} = f \times \eta_{Px,net}$

Net-to-gross conversion factor: f = 0,901

$\eta_{Pn,gross}$ = 83,8 %; $\eta_{Pint,gross}$ = 89,2 %

5 Categorise the boiler:

(a) Select the boiler category: condensing, natural gas fuelled, modulating, regular boiler

(b) If a gas or LPG boiler, permanent pilot light ? p=0 (no permanent pilot light)

6 Calculate seasonal efficiency

(a) Choose appropriate SEDB_UK equation (Table A.3 and Table A.4/A.5): equation 102
$\eta = 0,5 \times (\eta_{full} + \eta_{part}) - 2,0 - 4 \times p$

(b) Substitute values: $\eta_{g,gross} = 0,5 \times (83,8 + 89,2) - 2,0 - 4 \times 0$

$\eta_{g,gross} = 84,5$ %

(c) Convert to net seasonal efficiency (equation A2): **$\eta_{g,net} = 84,5 / 0,901 = 93,8$ %**

7 Calculate total generation heat loss (equation A3): $Q_{g,l,t} = 465.696 \times (100 - 93,8) / 93,8$ MJ

$Q_{g,l,t} = 30.886$ MJ

$Q_{g,l,t} = 30,886\ 10^9$ J

8 Calculate fuel heat requirement (equation A4): $Q_{g,in} = 465.696 \times 100 / 93,8$ MJ

$Q_{g,in} = 496.582$ MJ

$Q_{g,in} = 496,582\ 10^9$ J

9 Calculate auxiliary consumption (§ 5.3.6 and B.4): $\Phi_{aux,gn} = 20 + 1,8 \cdot 70$ W

TO BE CORRECTED

$\Phi_{aux,gn} = 146$ W

$W_g = \Phi_{aux,gn} \cdot t_{ON,gn}$

$t_{ON,gn} = 465.696$ MJ / 70 kW = 1.848 h

W_g = 146 x 1.848 = 269.808 Wh

W_g = 971 x 10^6 J

10 Calculate total recoverable heat loss: No recoverable generation heat loss is taken into account

Output data (connection to other parts of prEN 15316):

Fuel heat requirement:	$Q_{g,in} = 496,6\ 10^9$ J = 137.939 kWh
Total generation heat loss:	$Q_{g,l,t} = 30,9\ 10^9$ J = 8.579 kWh
Auxiliary consumption:	$W_g = 971\ 10^6$ J = 270 kWh
Recoverable heat loss:	$Q_{g,l,rl} = 0$ J = 0 kWh

Annex F
(informative)

Calculation examples for case specific boiler efficiency method

TO BE DONE Additional examples

CORRECTION OF EXAMPLE ACCORDING TO CHANGES

F.1 Case specific boiler efficiency method

Input data:

Specific boiler data:

Efficiency test results:	$\eta_{gn,Pn}$ = 93 % (full-load net efficiency)
	$\eta_{gn,Pint}$ = 99 % (30% part-load net efficiency)
	Produced in accordance with standard tests as required for the Council Directive 92/42/EEC about Boiler Efficiency and independently certified
Boiler type:	Condensing boiler
Nominal power(s):	70 kW (heat output)
Burner type:	Modulating, fan assisted
Boiler location:	Inside the heated space
Type of control:	Depending on inside temperature
Boiler room temperature:	$\theta_{i,gn}$ = 25 °C
Generation circuit typology	Direct connection of boiler

Data according to other parts of this standard

Energy to be supplied to the distribution sub-system: (according to prEN 15316-2-3)	$Q_{d,in}$ = 465.696 MJ
Energy to be supplied by the distribution sub-system to the space heating emission sub-system (according to prEN 15316-2-3)	$Q_{d,out}$ = 432.696 MJ
Internal temperature of heated space:	θ_i = 20 °C
Nominal power of installed heat emitters: (according to prEN 15316-2-1)	$\Phi_{em,n} = \Phi_{Pn}$ = 70 kW
Type of heat emitters:	radiators

Calculation period: t_{ci} = 220 days
= 220 · 24 · 3600 = 19,008 · 10^6 s

Calculation:

Calculation of the running temperature of the boiler according to 5.3.5

Control depending on the inside temperature, thus average power of the heat emitters (eq. 17):

$$\phi_{em} = \frac{Q_{d,out}}{t_{ci}} \quad [W]$$

$$\phi_{em} = \frac{432.696 \cdot 10^6}{19{,}008 \cdot 10^6} = 22.764\ W$$

Average temperature of the heat emitters (eq. 18):

$$\theta_{em} = \theta_i + \left(\frac{\phi_{em}}{\phi_{em,n}}\right)^{\frac{1}{n}} \cdot \Delta\theta_{em,n} \quad [°C]$$

θ_i = 20 °C

$\Delta\theta_{em,n}$ = 50 °C (Table B.8, radiators)

$\Phi_{em,n} = \Phi_{Pn}$ = 70.000 W

n= 1,3 (Table B.9, radiators)

$$\theta_{em} = 20\,°C + \left(\frac{22.764}{70.000}\right)^{\frac{1}{1,3}} \cdot 50\,°C$$

θ_{em} = 41,1 °C

Determination of running temperature of the boiler (eq. 16):

$$\theta_{gn,w} = \max(\theta_{gn,\min}, \theta_{em}) \quad [°C]$$

$\theta_{gn,min}$ = 20 °C (Table B.1, condensing boiler)

$\theta_{gn,w}$ = max (20 °C, 41,1 °C) = **41,1 °C**

Calculation of boiler heat loss at 100 % load according to 5.3.2.1

Boiler efficiency at full load $\eta_{gn,Pn}$ = 93 %

Correction factor for full load $f_{cor,Pn}$ given by Table B.3 is 0,1 (condensing boiler)

Boiler average water temperature at boiler test conditions $\theta_{gn,test,Pn}$ given by Table B.3 is 70 °C (condensing boiler)

Corrected boiler efficiency at 100 % load (eq. 4):

$$\eta_{gn,Pn,cor} = \eta_{gn,Pn} + f_{cor,Pn} \cdot (\theta_{gn,test,Pn} - \theta_{gn,w}) \quad [\%]$$

$$\eta_{gn,Pn,cor} = 93 + 0{,}1 \times (70 - 41{,}1)$$

$$\eta_{gn,Pn,cor} = \mathbf{95{,}89\ \%}$$

Boiler heat loss at 100 % load (eq. 5):

$$\Phi_{gn,l,Pn,cor} = \frac{(100 - \eta_{gn,Pn,cor})}{\eta_{gn,Pn,cor}} \cdot \Phi_{Pn} \cdot 1.000 \quad [W]$$

ϕ_{Pn} = 70 kW

$\Phi_{gn,l,Pn,cor}$ = **2.998 W**

Calculation of boiler heat loss at intermediate load according to 5.3.2.2

Boiler efficiency at intermediate load $\eta_{gn,Pint}$ = 99 %

Correction factor for intermediate load $f_{cor,Pint}$ given by Table B.4 is 0,2 (condensing boiler)

Boiler average water temperature at boiler test conditions $\theta_{gn,test,Pint}$ given by Table B.4 is 35 °C (condensing boiler)

Corrected boiler efficiency at intermediate load (eq. 6):

$$\eta_{gn,Pint,cor} = \eta_{gn,Pint} + f_{cor,Pint} \cdot (\theta_{gn,test,Pint} - \theta_{gn,w}) \quad [W]$$

$$\eta_{gn,Pint,cor} = 99 + 0{,}2 \times (35 - 41{,}1)$$

$$\eta_{gn,Pint,cor} = \mathbf{97{,}79\ \%}$$

Boiler heat loss at intermediate load (eq. 7):

$$\Phi_{gn,l,Pint,cor} = \frac{(100 - \eta_{gn,Pint,cor})}{\eta_{gn,Pint,cor}} \cdot \Phi_{Pint} \cdot 1.000 \quad [W]$$

Φ_{Pint} = 21 kW (30 % full load)

$\Phi_{gn,l,Pint,cor}$ = **476 W**

Calculation of boiler heat loss at 0 % load according to 5.3.2.3

Stand-by heat losses (eq. B3):

$$\Phi_{gn,l,P0} = \Phi_{Pn} \cdot \left(E + F \cdot \log \Phi'_{Pn}\right) \quad [W]$$

E = 17,5 and F = - 5,5 (Table B.2, condensing boiler)

$\Phi_{Pn} = \Phi'_{Pn}$ = 70 kW (B.1.2)

$\Phi_{gn,l,P0}$ = 70 x (17,5 – 5,5 x log(70))

$\Phi_{gn,l,P0}$ = 515 W

Corrected boiler heat loss at 0 % load (eq. 8):

$$\Phi_{gn,l,P0,cor} = \Phi_{gn,l,PO} \cdot \left(\frac{\theta_{gn,w} - \theta_{i,gn}}{30} \right)^{1,25} \qquad \text{[W]}$$

$\theta_{i,gn}$ = 25 °C (boiler room temperature)

$\Phi_{gn,l,P0,cor}$ = 515 x ((41,1 – 25) / 30) ^{1,25}

$\Phi_{gn,l,P0,cor}$ = **236 W**

Calculation of boiler heat loss at specific load and power output according to 5.3.2.4

Load factor (eq. 20):

$$FC = \frac{\Phi_{d,in}}{\Phi_{Pn}} \qquad \text{[-]}$$

FC = 0,35

The average load is 35 % (Φ_{Px} = 24,5 kW) and linear interpolation between intermediate load and 100 % load applies (eq. 9b):

$$\Phi_{gn,l,Px} = \frac{\Phi_{Px} - \Phi_{P\,\mathrm{int}}}{\Phi_{Pn} - \Phi_{P\,\mathrm{int}}} \cdot (\Phi_{gn,l,Pn,cor} - \Phi_{gn,l,P\,\mathrm{int},cor}) + \Phi_{gn,l,P\,\mathrm{int},cor} \qquad \text{[W]}$$

$$\Phi_{gn,l,Px} = \frac{24{,}5 - 21}{70 - 21} \cdot (2.998 - 476) + 476$$

$\Phi_{gn,l,Px} =$ **656 W**

Total generation heat loss $Q_{g,l,t}$ during the considered period (eq. 10):

$$Q_{g,l,t} = \Phi_{gn,l,Px} \cdot t_{ci} \qquad \text{[J]}$$

$Q_{g,l,t}$ = 656 · 19,008 · 10^6

$Q_{g,l,t}$ = **12,464 10^9 J**

$Q_{g,l,t}$ = 3.464 kWh

Calculation of auxiliary consumption according to 5.3.3 and B.2

Default power consumption of auxiliary equipment (eq. B4):

$$\Phi_{aux,gn} = G + H \cdot \Phi_{Pn} \qquad \text{[W]}$$

G = 20 and H = 1,8 (Table B.5, condensing boiler with fan assisted burner)

$\Phi_{aux,gn} = 20 + 1{,}8 \cdot 70$

$\Phi_{aux,gn} = 146$ W

Auxiliary energy consumption for generation (eq. 11):

$$W_g = \Phi_{aux,gn} \cdot t_{ON,gn} \qquad [J]$$

Running time (eq. 12):

$$t_{ON,gn} = \frac{\Phi_{gn,l,Px} + \Phi_{Px} \cdot 1.000}{\Phi_{gn,l,Px} + \Phi_{Pn} \cdot 1.000} \cdot t_{ci} \qquad [s]$$

$$t_{ON,gn} = \frac{656 + 24,5 \cdot 1.000}{656 + 70 \cdot 1.000} \cdot 19,008 \cdot 10^6 / 3.600 \qquad [h]$$

$t_{ON,gn} = 1.880$ h

W_g = 146 x 1.880 / 1.000 kWh

W_g = 274 kWh

W_g = **988 x 10^6 J**

Calculation of recoverable generation heat losses according to 5.3.4

Recoverable auxiliary energy transmitted to the heated space (eq. 13):

$$W_{g,rl} = W_g \cdot (1 - b_g) \cdot p_{aux,g} \qquad [J]$$

$p_{aux,g}$ = 1 – 0,4 = 0,6 (B.3.1)

b_g = 1 (Table B.7, boiler located inside heated space)

$W_{g,rl} = 0$ J

Recoverable heat losses through the boiler envelope (eq. 14):

$$Q_{gn,env,rl} = \Phi_{gn,l,P0,cor} \cdot (1 - b_g) \cdot p_{gn,env} \cdot t_{ci} \qquad [J]$$

$p_{gn,env}$ = 0,75 (Table B.6, fan assisted burner)

b_g = 1 (Table B.7, boiler located inside heated space)

$Q_{gn,env,rl} = 0$ J

Total recoverable generation heat loss (eq. 15):

$$Q_{g,l,rl} = Q_{gn,env,rl} + W_{g,rl} \qquad [J]$$

$Q_{g,l,rl} = 0$ J

Calculation of fuel heat requirement according to eq. 1:

$$Q_{g,in} = Q_{g,out} - k_{g,rd} \cdot W_g + Q_{g,l,t} \qquad [J]$$

$Q_{g,in}$ = 0,35 x 70 x 19,008 x 10^6 / 3.600 – 0 + 3.464 [kWh]

$Q_{g,in}$ = 129.360 + 3.464 = 132.824 [kWh]

$Q_{g,in}$ = 478,166 10^9 J

Output data (connection to other parts of prEN 15316):

Fuel heat requirement: $Q_{g,in}$ = 478,2 10^9 J = 132.824 kWh

Total generation heat loss: $Q_{g,l,t}$ = 12,5 10^9 J = 3.464 kWh

Auxiliary consumption: W_g = 988 10^6 J = 274 kWh

Total recoverable heat loss: $Q_{g,l,rl} = 0$ J = 0 kWh

Annex G
(informative)

Calculation examples for boiler cycling method

TO BE DONE Additional examples

CORRECTION OF EXAMPLE ACCORDING TO CHANGES (CONDENSATION)

G.1 Boiler cycling method

Input data:

Specific boiler data:

Φ_{cn}	75,3 kW	combustion power of the boiler
Φ_{ref}	= Φ_{cn}	= 75,3 kW
$P'_{ch,on}$	7 %	heat losses through the chimney with burner on (full load)
$P'_{ch,off}$	0,2 %	heat losses through the chimney with the burner off (default for boiler with automatic closure of air intake at burner off, Table C.6)
$P'_{gn,env}$	0,89 %	heat losses through the boiler envelope (default for high efficiency well insulated boiler and Φ_{cn} = 75.3 kW, C.1.2)
$k_{gn,env}$	0,7	reduction factor of boiler envelope heat losses (default for boiler located inside boiler room, Table C.4)
Φ_{br}	132 W	electrical power consumption of boiler auxiliaries at full load (before the burner)
k_{br}	0,8	default recovery factor of Φ_{br} (Table C.9)
Φ_{af}	0 W	electrical power consumption of boiler auxiliaries (after the burner) (direct connection to distribution sub-system, no primary pump)
k_{af}	0,8	default recovery factor of Φ_{af} (Table C.9)
$\theta_{gn,test}$	70 °C	average boiler water temperature at test conditions for $P'_{ch,on}$
$\theta_{i,test}$	20 °C	temperature of test room for $P'_{gn,env}$ and $P'_{ch,off}$
$\Delta\theta_{gn,env,ref}$	50 °C	= $\theta_{gn,test} - \theta_{i,test}$ at test conditions for $P'_{gn,env}$ and $P'_{ch,off}$
n	0,1	exponent for the load factor for calculation of $P_{ch,on}$ (default for steel boiler, Table C.2)
		steel boiler

		permanent circulation
m	0	exponent for the load factor for calculation of $P_{gn,env}$ (default for continuous circulation of water, Table C.5)
p	0	exponent for the load factor for calculation of $P_{ch,off}$ (default for continuous circulation of water, Table C.7)
Generation circuit typology		direct connection of boiler

Additional data for modulating burner

$\Phi_{cn,min}$	22,6 kW	minimum combustion power of the boiler
$P'_{ch,on,min}$	6%	heat loss factor $P_{ch,on}$ at minimum combustion power $\Phi_{cn,min}$
$\Phi_{br,min}$	60 W	electrical power consumption of boiler auxiliaries at minimum combustion power

Additional data for condensing boiler:

CH	3,18 MJ/Nm³	latent condensation heat of water produced
LH	34,53 MJ/Nm³	lower combustion heat of the fuel
c_{max}	1,6 kg/ Nm³	maximum condensate production
c_{30}	0,29 kg/ Nm³	specific condensate production with water return temperature 30 °C and full load
c_{50}	0,0 kg/ Nm³	specific condensate production with water return temperature 50 °C and full load

correction of $P_{ch,on}$ and c based on return temperature to the boiler

Additional data for condensing boiler and modulating boiler:

$c_{30,min}$	0,65 kg/Nm³	specific condensate production with water return temperature 30 °C and minimum power output
$c_{50,min}$	0,12 kg/Nm³	specific condensate production with water return temperature 50 °C and minimum power output

Data according to other parts of this standard

$Q_{g,out}$	465.696 MJ	net heat output to the distribution sub-system
$\theta_{d,f}$	44,6 °C	water flow temperature to the distribution sub-system
$\theta_{d,r}$	37,6 °C	water return temperature from the distribution sub-system
$\theta_{i,gn}$	25 °C	boiler room temperature
t_{ci}	220 days	calculation period

Calculation

Boiler flow, return and average water temperature

Direct connection of boiler (according to E.1 and E.4):

boiler flow temperature $\theta_{gn,w,f} = \theta_{b,f} = \theta_{g,f} = \theta_{d,f} = 44,6$ °C

boiler return temperature $\theta_{gn,w,r} = \theta_{b,r} = \theta_{g,r} = \theta_{d,r} = 37,6$ °C

boiler average water temperature $\theta_{gn,w,av} = (\theta_{gn,w,f} + \theta_{gn,w,r}) / 2 = 41,1$ °C

Selection of calculation procedure

The boiler is modulating and is equipped with a condensing boiler, thus the calculation procedure of 5.4.7 applies with extensions specified in 5.4.8.

Calculate correction factors R and Rmin for condensation

Equation 49a: $$c = \frac{(c_{50} - c_{30}) \cdot \theta_{gn,w,r}}{20} + 2,5 \cdot c_{30} - 1,5 \cdot c_{50}$$

$$= \frac{(0 - 0,29) \cdot 37,6}{20} + 2,5 \cdot 0,29 - 1,5 \cdot 0 = 0,180 \text{ kg/Nm}^3$$

Equation 49b: $$c_{\min} = \frac{(c_{50,\min} - c_{30,\min}) \cdot \theta_{gn,w,r}}{20} + 2,5 \cdot c_{30,\min} - 1,5 \cdot c_{50,\min}$$

$$= \frac{(0,12 - 0,65) \cdot 37,6}{20} + 2,5 \cdot 0,65 - 1,5 \cdot 0,12 = 0,448 \text{ kg/ Nm}^3$$

Equation 48a: $$R = 100 \cdot \frac{CH}{LH} \cdot \frac{c}{c_{\max}} = 100 \cdot \frac{3,18}{34,53} \cdot \frac{0,180}{1,6} = 1,04\ \%$$

Equation 48b: $$R_{\min} = 100 \cdot \frac{CH}{LH} \cdot \frac{c_{\min}}{c_{\max}} = 100 \cdot \frac{3,18}{34,53} \cdot \frac{0,448}{1,6} = 2,58\ \%$$

Equation 47: $P^*_{ch,on} = P'_{ch,on} - R = 7\ \% - 1,04\ \% = 5,96\ \%$

$P^*_{ch,on,min} = P'_{ch,on,min} - R_{min} = 6\ \% - 2,58\ \% = 3,42\%$

Apply the single-stage procedure of § 5.4.6 using minimum power output data

Start iteration with FC = 1

Step 1 - From input data: $Q_{g,out} = 465.696$ MJ

Step 2 - From input data: $t_{gn} = 220$ days $= 19,008 \times 10^6$ s

Step 3 FC = 1

Step 4 - Equation 34

$$P_{ch,on} = \left[P*_{ch,on,\min} + \left(\theta_{gn,w,r} - \theta_{gn,test}\right)\cdot 0{,}045\right]\cdot FC^{n}$$
$$= \left[3{,}42 + \left(37{,}6 - 70\right)\cdot 0{,}045\right]\cdot 1^{0,1} = 1{,}962\ \%$$

Equation 35

$$P_{gn,env} = P'_{gn,env}\cdot k_{gn,env}\cdot\frac{\left(\theta_{gn,w,av} - \theta_{i,gn}\right)}{\left(\theta_{gn,test} - \theta_{i,test}\right)}\cdot FC^{m}$$
$$= 0{,}89\cdot 0{,}7\cdot\frac{\left(41{,}1 - 25\right)}{\left(70 - 20\right)}\cdot 1^{0} = 0{,}201\ \%$$

Equation 38

$$P_{ch,off} = P'_{ch,off}\cdot\frac{\left(\theta_{gn,w,av} - \theta_{i,gn}\right)}{\left(\theta_{gn,test} - \theta_{i,test}\right)}\cdot FC^{p}$$
$$= 0{,}2\cdot\frac{\left(41{,}1 - 25\right)}{\left(70 - 20\right)}\cdot 1^{0} = 0{,}064\ \%$$

Step 5 - Equation 44 Q_{af} = 0 since Φ_{af} = 0 (otherwise Q_{af} = Φ_{af} x k_{af} x t_{gn})

Step 6 - Equation 45

$$FC = \frac{\dfrac{100\cdot\left(Q_{g,out} - Q_{af}\right)}{t_{gn}\cdot\Phi_{ref}} + P_{ch,off} + P_{gn,env}}{100\cdot\dfrac{\Phi_{cn} + k_{br}\cdot\Phi_{br}}{\Phi_{ref}} - \dfrac{\Phi_{cn}}{\Phi_{ref}}P_{ch,on} + P_{ch,off}}$$
$$= \frac{\dfrac{100\cdot\left(465.696\cdot 10^{6} - 0\right)}{19{,}008\cdot 10^{6}\cdot 75.300} + 0{,}064 + 0{,}201}{100\cdot\dfrac{22.600 + 0{,}8\cdot 60}{75.300} - \dfrac{22.600}{75.300}\cdot 1{,}962 + 0{,}064} = 1{,}110$$

Steps 4, 5 and 6 should be repeated until FC converges. The final value is 1,110.

The result shows FC>1. This means that the burner is modulating between minimum and maximum power and $\Phi_{br,avg}$ has to be calculated according to the procedure in § 5.4.7.3.

Calculate $\Phi_{br,avg}$

Step 1 - From input data: $Q_{g,out}$ = 465.696 MJ

Step 2 - Equation 35

$$P_{gn,env} = P'_{gn,env}\cdot k_{gn,env}\cdot\frac{\left(\theta_{gn,w,av} - \theta_{i,gn}\right)}{\left(\theta_{gn,test} - \theta_{i,test}\right)}\cdot FC^{m}$$
$$= 0{,}89\cdot 0{,}7\cdot\frac{\left(41{,}1 - 25\right)}{\left(70 - 20\right)}\cdot 1^{0} = 0{,}201\ \%$$

Step 3 - Equation 34

$$P_{ch,on,\max} = \left[P*_{ch,on} + \left(\theta_{gn,w,r} - \theta_{gn,test}\right)\cdot 0{,}045\right]\cdot FC^{n}$$
$$= \left[5{,}96 + \left(37{,}6 - 70\right)\cdot 0{,}045\right]\cdot 1^{0,1} = 4{,}498\ \%$$

$$P_{ch,on,\min} = \left[P*_{ch,on,\min} + \left(\theta_{gn,w,r} - \theta_{gn,test}\right)\cdot 0{,}045\right]\cdot FC^{n}$$
$$= \left[3{,}42 + \left(37{,}6 - 70\right)\cdot 0{,}045\right]\cdot 1^{0{,}1} = 1{,}962\ \%$$

Step 4 - Equation 44 — Q_{af} = 0 since Φ_{af} = 0 (otherwise Q_{af} = Φ_{af} x k_{af} x t_{gn})

Step 5 – Beginning of iteration — $\Phi_{cn,avg}$ = $\Phi_{cn,min}$ = 22.600 W

Step 6 – Equation 49

$$P_{ch,on,avg} = P_{ch,on,\min} + \left(P_{ch,on,\max} - P_{ch,on,\min}\right)\cdot\frac{\Phi_{cn,avg} - \Phi_{cn,\min}}{\Phi_{cn,\max} - \Phi_{cn,\min}}$$
$$= 1{,}962 + \left(4{,}498 - 1{,}962\right)\cdot\frac{22.600 - 22.600}{75.300 - 22.600} = 1{,}962\ \%$$

Step 7 – Equation 50

$$\Phi_{br,avg} = \Phi_{br,\min} + \left(\Phi_{br,\max} - \Phi_{br,\min}\right)\cdot\frac{\Phi_{cn,avg} - \Phi_{cn,\min}}{\Phi_{cn,\max} - \Phi_{cn,\min}}$$
$$60 + \left(132 - 60\right)\cdot\frac{22.600 - 22.600}{75.300 - 22.600} = 60\ \text{W}$$

Step 8 – Equation 51

$$\Phi_{cn,avg} = \frac{\dfrac{Q_{g,out} - Q_{af}}{t_{gn}} + \dfrac{P_{gn,env}}{100}\Phi_{ref} - k_{br}\cdot\Phi_{br,avg}}{1 - \dfrac{P_{ch,on,avg}}{100}}$$
$$= \frac{\dfrac{465.696\cdot 10^{6} - 0}{19{,}008\cdot 10^{6}} + \dfrac{0{,}201}{100}\cdot 75.300 - 0{,}8\cdot 60}{1 - \dfrac{1{,}962}{100}} = 25.094\ \text{W}$$

Step 9 - Second iteration — Repeat step 6, 7 and 8 with current new $\Phi_{cn,avg}$

Step 6 – Equation 49

$$P_{ch,on,avg} = P_{ch,on,\min} + \left(P_{ch,on,\max} - P_{ch,on,\min}\right)\cdot\frac{\Phi_{cn,avg} - \Phi_{cn,\min}}{\Phi_{cn,\max} - \Phi_{cn,\min}}$$
$$1{,}962 + \left(4{,}498 - 1{,}962\right)\cdot\frac{25.094 - 22.600}{75.300 - 22.600} = 2{,}082\ \%$$

Step 7 – Equation 50

$$\Phi_{br,avg} = \Phi_{br,\min} + \left(\Phi_{br,\max} - \Phi_{br,\min}\right)\cdot\frac{\Phi_{cn,avg} - \Phi_{cn,\min}}{\Phi_{cn,\max} - \Phi_{cn,\min}}$$
$$60 + \left(132 - 60\right)\cdot\frac{25.094 - 22.600}{75.300 - 22.600} = 63{,}4\ \text{W}$$

Step 8 – Equation 51

$$\Phi_{cn,avg} = \frac{\frac{Q_{g,out} - Q_{af}}{t_{gn}} + \frac{P_{gn,env}}{100} \Phi_{ref} - k_{br} \cdot \Phi_{br,avg}}{1 - \frac{P_{ch,on,avg}}{100}}$$

$$= \frac{\frac{465.696 \cdot 10^6 - 0}{19{,}008 \cdot 10^6} + \frac{0{,}201}{100} \cdot 75.300 - 0{,}8 \cdot 63{,}4}{1 - \frac{2{,}082}{100}}$$ = 25.124 W

Step 9

If iteration is continued, the final result for $\Phi_{cn,avg}$ is 25.123 W

Step 10 – Equation 52

Energy input (fuel) $Q_{g,in} = \Phi_{cn,avg} \cdot t_{gn}$

= 25.123 W x 19,008 x 10^6 s = 477.535 MJ

Equation 53

Total auxiliary energy $W_g = t_{gn} \cdot \left(\Phi_{af} + \Phi_{br,avg}\right)$

= 19,008 x 10^6 x (0 + 63,4) = 1.205 MJ

Equation 54

Recovered auxiliary energy $W_{g,rd} = t_{gn} \cdot \left(\Phi_{af} \cdot k_{af} + \Phi_{br,avg} \cdot k_{br}\right)$

= 19,008 x 10^6 x (0 x 0,8 + 63,4 x 0,8) = 964 MJ

Step 11 - Equation 55 or 1

Total losses $Q_{g,l,t} = Q_{g,in} - Q_{g,out} + k_{br} \cdot \Phi_{br} \cdot t_{gn} + k_{af} \cdot \Phi_{af} \cdot t_{gn}$

= 477.535 – 465.696 + 964 = 12.803 MJ

Output data (connection to other parts of prEN 15316):

Fuel heat requirement: $Q_{g,in}$ = 477,5 10^9 J = 132.638 kWh

Total generation heat loss: $Q_{g,l,t}$ = 12,8 10^9 J = 3.556 kWh

Auxiliary consumption: W_g = 1.205 10^6 J = 335 kWh

Total recoverable heat loss: $Q_{g,l,rl} = 0$ J = 0 kWh

Annex H
(informative)

Boiler water temperature calculation

H.1 Boiler flow temperature and return temperature

The following data:

- θ_{avg} average water temperature in the boiler;
- θ_r average return water temperature to the boiler;

are required to correct heat loss coefficients and calculate condensate production according to actual operation conditions.

Calculation of flow rates is not fully detailed in this standard. Any design flow rate value shall be calculated separately with appropriate methods.

Calculation is performed starting with the emission sub-system and taking into account the hydraulic design or the actual hydraulic layout as well as the operation of the heating system. Subsequently, the effect of the type of generation circuit is taken into account.

A generation circuit may include mixing, recirculation or buffer connections. Therefore, generation circuit flow rate and temperatures may differ from boiler flow rate and temperatures.

In this annex, the following indices are applied:

- b for boiler values (boiler);
- g for generation circuit values.

An example of a generation circuit is shown in Figure H1.

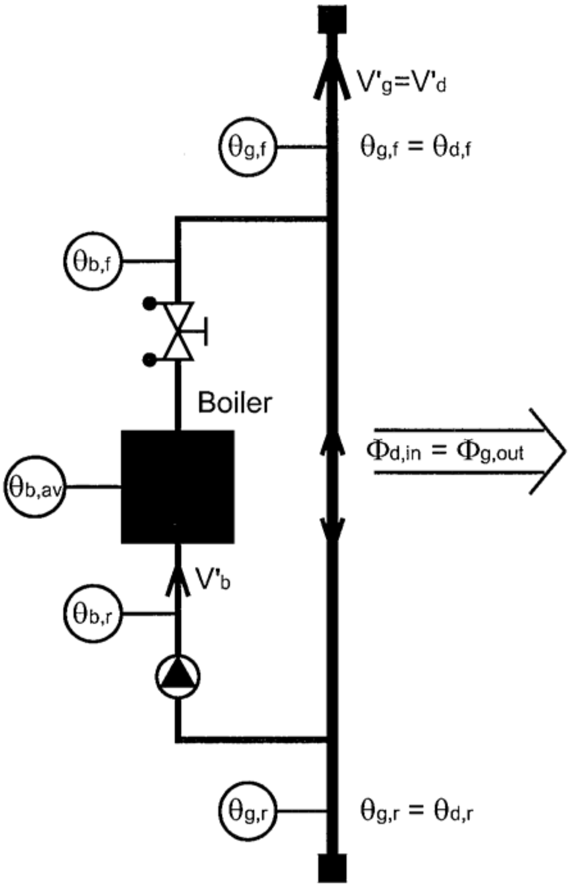

Figure H1 - Sample generation circuit

where:

$\theta_{g,f}$	generation circuit flow temperature, which is also the distribution flow temperature $\theta_{d,f}$.
$\theta_{g,r}$	generation circuit return temperature, which is also the distribution return temperature $\theta_{d,r}$;
V'_g	generation circuit flow rate, which is also the distribution flow rate;
$\Phi_{g,out}$	heat power output of the generation circuit
$\theta_{b,f}$	boiler flow temperature
$\theta_{b,r}$	boiler return temperature;
V'_b	boiler flow rate
$\theta_{b,av}$	boiler average water temperature

ADD UNITS

H.2 Boiler flow rate is the same as the distribution flow rate (no by-pass)

If the boiler flow rate V'_b is the same as the generation circuit flow rate V'_g, then

$$\theta_{b,f} = \theta_{g,f} \ ; \ \theta_{b,r} = \theta_{g,r} \quad [°C] \qquad (H1)$$

$$V'_b = V'_g \qquad [kg/h] \qquad (H2)$$

Examples of such circuits are given in Figure E2.

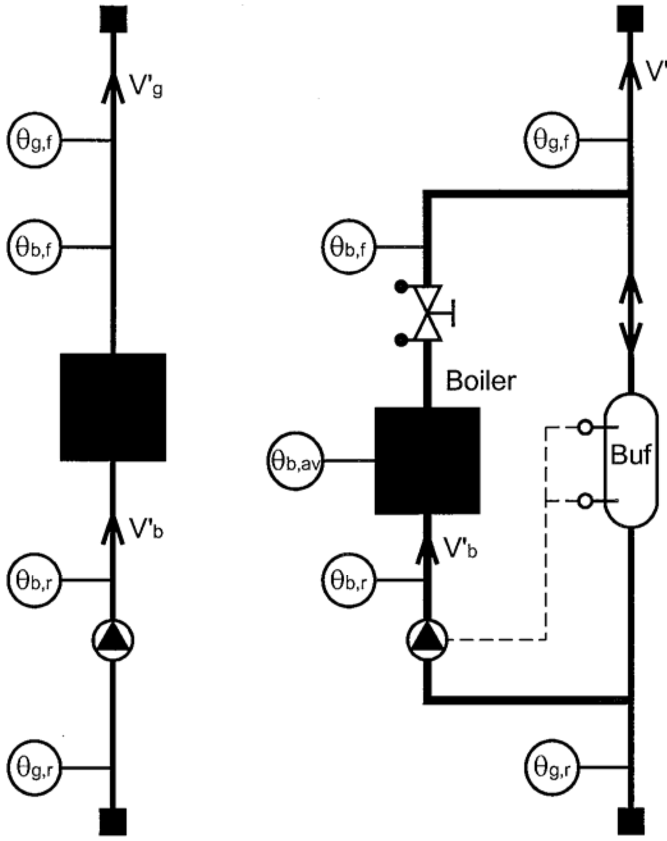

Figure H2 - Boiler flow rate is the same as generation circuit flow rate (the buffer, Buf, is controlled and not allowed to cool or heat completely)

H.3 Boiler flow rate is not the same as the distribution flow rate (by-pass connection)

If the boiler flow rate V'_b is greater than the generation circuit flow rate V'_g ($V'_b > V'_g$), then:

$$\theta_{b,f} = \theta_{g,f} \qquad [°C] \qquad (H3)$$

$$\theta_{b,r} = \theta_{g,f} - \frac{\Phi_{b,out} \cdot 0{,}86}{V'_b} \qquad [°C] \qquad (H4)$$

NOTE: $\theta_{b,r}$ is higher than $\theta_{g,r}$

If the boiler flow rate V'_b is less than the generation circuit flow rate V'_g ($V'_b < V'_g$), then:

$$\theta_{b,r} = \theta_{g,r} \qquad [°C] \qquad (H5)$$

$$\theta_{b,f} = \theta_{b,r} + \frac{\Phi_{b,out} \cdot 0{,}86}{V'_b} \qquad [°C] \qquad (H6)$$

NOTE 1: $\theta_{b,f}$ is higher than $\theta_{g,f}$

NOTE 2: $\theta_{b,r}$ and $\theta_{b,f}$ are in any case given by:

$$\theta_{b,r} = \max\left[\theta_{g,r}; \theta_{g,f} - \frac{\Phi_{b,out} \cdot 0{,}86}{V'_b}\right] \qquad [°C] \qquad (H7)$$

$$\theta_{b,f} = \max\left[\theta_{g,f}; \theta_{b,r} + \frac{\Phi_{b,out} \cdot 0{,}86}{V'_b}\right] \qquad [°C] \qquad (H8)$$

which combine equations (H3) to (H6).

Examples of such circuits are given in Figure H3.

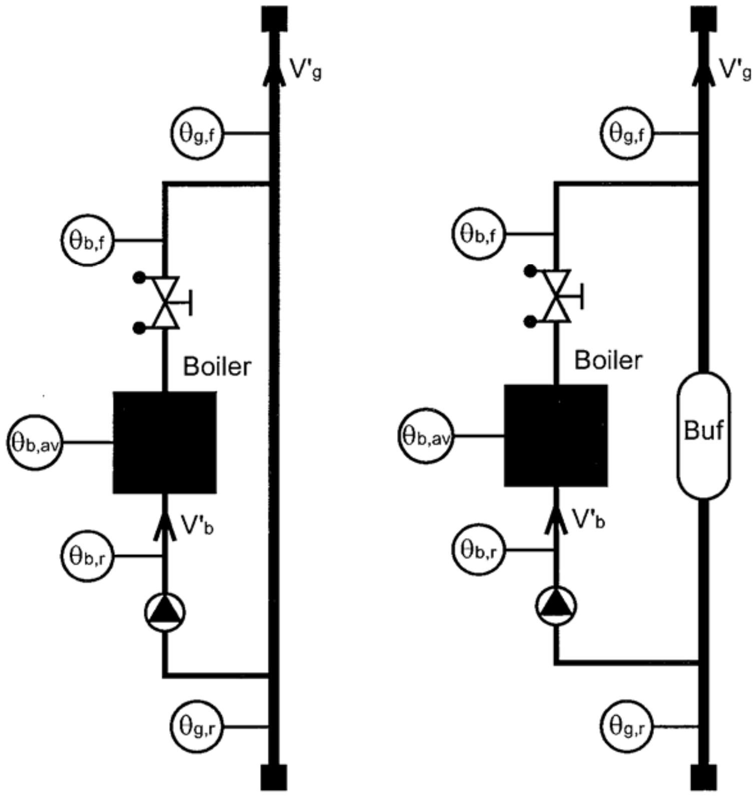

Figure H3 – Boiler flow rate is not the same as generation circuit flow rate

NOTE 1: The flow rate V'_b through the boiler is the average flow rate. Using a buffer allows low flow rate operation of the generation circuit through intermittent operation of the boiler pump.

NOTE 2: Some old systems incorporate a condensate prevention pump. Its flow rate adds to the generation circuit flow rate to give the boiler flow rate.

H.4 Parallel connection of boilers

If more boilers are connected in parallel, the common return temperature $\theta_{b,r}$ and the resulting flow temperature $\theta_{b,f}$ are calculated according to E.3.

The average heat power output $\Phi_{b,i}$ and flow rate $V'_{b,i}$ of each boiler have to be determined.

The flow temperature $\theta_{b,f,i}$ of boiler i is calculated by:

$$\theta_{b,f,i} = \theta_{b,r} + \frac{\Phi_{b,i} \cdot 0{,}86}{V'_{b,i}} \qquad \text{(H9)}$$

An example of a parallel connection is given in Figure E4.

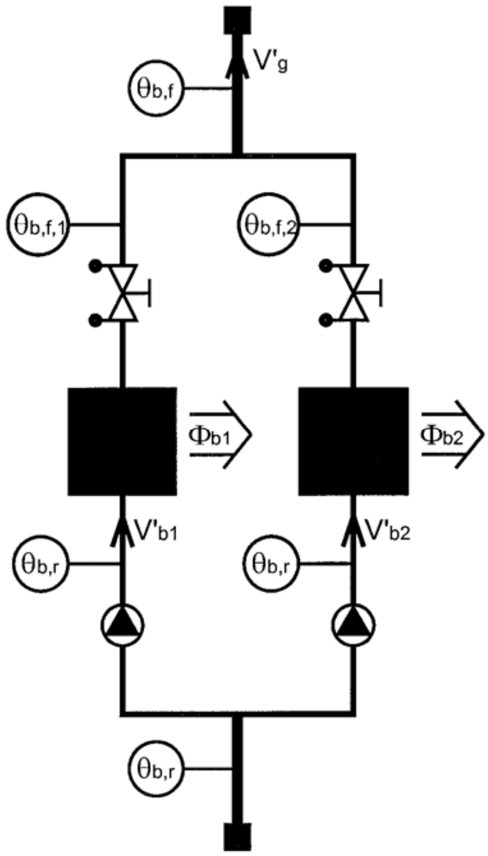

Figure H4 - Parallel connection of boilers

H.5 Boiler average water temperature

The boiler average water temperature $\theta_{b,av}$ is given by:

$$\theta_{b,av} = \frac{\theta_{b,f} + \theta_{b,r}}{2} \qquad [°C] \qquad \text{(H10)}$$