Doc. CEN/TC 228 N562 **CEN/TC 228**

Date: 2006-08

CEN/TC 228 WI 034

CEN/TC 228

Secretariat: DS

Heating systems in buildings — Method for calculation of system energy requirements and system efficiencies — Part 3-3: Domestic hot water systems, generation

Einführendes Element — Haupt-Element — Teil 3.3: Ergänzendes Element

Systèmes de chauffage dans les bâtiments — Élément central — Partie 3.3 : 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 00228034\TC version\N562_prEN 15316-3-3_WI00228034_2006-08.doc STD Version 2.2

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Foreword

This document prEN 15316-3-3:2005) 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 document is one of three documents that together describe methods for calculation of system energy requirements and system efficiencies related to domestic hot water systems. In particular this document describes methods for calculating the input energy requirements and energy losses for the generation units.

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

Only the calculation method is normative. All the values necessary to complete the calculations are to be given in a National Annex.

1 Scope

This standard is part of the method for calculation of system energy requirements and system efficiencies.

The scope of this specific part is to standardise the methods for calculation of the heat losses from the domestic hot water generation system and it defines the:

- inputs;
- outputs;
- calculation method.

This standard covers the domestic hot water requirements in all buildings.

The general approach to calculate energy consumptions and losses of domestic hot water systems is as follows:

- calculation of domestic hot water requirements of a dwelling, a zone or a building (Q_W);
- calculation of heat losses due to the distribution or circulation of domestic hot water supplied ($Q_{W,d}$);
- calculation of heat losses in hot water storage units ($Q_{W,s}$) and heat losses due to the production or generation ($Q_{W,g}$).

In order to be coherent with calculation methods for space heating systems, emission losses representing taps and control should be taken into account.

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 89, *Gas-fired storage water heaters for the production of domestic hot water*

EN 297, *Gas-fired central heating boilers - Type B11 and B11BS boilers, fitted with atmospheric burners of nominal heat input not exceeding 70 kW*

EN 304, *Heating boilers - Test code for heating boilers for atomizing oil burners*

EN 483, *Gas-fired central heating boilers - Type C boilers of nominal heat input not exceeding 70 kW*

EN 625, *Gas-fired central heating boilers - Specific requirements for the domestic hot water operation of combination boilers of nominal heat input not exceeding 70 kW*

EN 656, *Gas-fired central heating boilers - Type B boilers of nominal heat input exceeding 70 kW but not exceeding 300 kW*

EN 677, *Gas-fired central heating boilers - Specific requirements for condensing boilers with a nominal heat input not exceeding 70 kW*

IEC prEN 50440, *Efficiency of electrical storage water heaters*

prEN wi 9 part 2.2.1, *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 2.2.1: Space heating generation systems, Combustion systems*

prEN wi 9 part 2.2.2, *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 2.2.2: Space heating generation systems, Heat pump systems* prEN wi 9 part 2.2.3, *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 2.2.3: Space heating generation systems, Thermal solar systems*

prEN wi 9 part 2.2.4, *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 2.2.4: Space heating generation systems, The performance and quality of CHP electricity and heat (incl. on-site and micro-CHP)*

prEN wi 9 part 2.2.5, *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 2.2.5: Space heating generation systems, The performance and quality of district heating and large volume systems*

prEN wi 9 part 2.2.6, *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 2.2.6: Space heating generation systems, The performance of other renewables heat and electricity*

prEN wi 9 part 2.2.7, *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 2.2.7: Space heating generation systems, Biomass combustion systems*

3 Terms and definitions

THIS SECTION HAS STILL TO BE PROVIDED BY SEPARATE GROUP WORKING ON COMMON DEFINITIONS.

4 Symbols and Units

THE SYMBOLS AND UNITS ARE BEING CO-ORDINATED BY A SEPARATE GROUP. THESE SYMBOLS AND UNITS TO BE BROUGHT IN LINE WITH THE AGREED LIST WHEN IT IS AVAILABLE. SYMBOLS IN THE EQUATIONS THROUGHOUT THE DOCUMENT TO BE BROUGHT IN LINE.

For the purposes of this standard, the following symbols and units (see Table 1) and indices (see Table2) apply:

Table 1 : Symbols and units

Symbol	Name of quantity	Unit
A	area	m^2
C	specific heat capacity	J/(kg K)
e	system performance coefficient (expenditure factor)	-
d	diameter	mm
f	conversion factor	-
L	length	m
M	mass	kg
N	number of operating times	-
t	time, period of time	s
T	thermodynamic temperature	K
Q	quantity of heat, energy	J
ϕ	thermal power	W
P	electrical power	W
U	heat loss coefficient	W/mK

V	volume	m^3
W	electrical auxiliary energy	J
x,y	constants	-
z	running time	h/d
α	part	-
η	efficiency	-
θ	celsius temperature	°C
λ	heat conductivity	W/mK

Table 2 : Indices

amb	ambiant	hydr	hydraulic	p	pipe
ave	average	h	heating energy	P	primary
corr	corrected	int	internal	r	recovered
col	collectif	in	input to system	s	storage
d	distribution	ind	independent	sb	stand-by
e	external	l	loss	t	total
em	emission	nom	nominal	out	output from system
g	generation, losses	nhs	non heated space	W	domestic hot water
gs	gains	PM	pipe material	x	indices

5 Energy requirements of the domestic hot water system

The heat generator for a domestic hot water system must provide the energy required for meeting the hot water demand and the losses in the system. The energy requirement on the heat generator is therefore equal to the sum of the user hot water demand, the losses in the user outlet (if taken into account), the total losses in the distribution system (including circulation loops and individual draw off pipes), losses in the hot water storage vessel (if present), losses in the primary circulating pipes (if hot water storage vessel present) and losses from the heat generator itself.

$$Q = \sum Q_W + Q_{Wd} + Q_{Ws} + Q_{Wpp} + Q_{Whg}$$

where

Q_W domestic hot water requirement (kWh/day) (see pr EN 15316-3-1)

Q_{Wd} heat loss from distribution system (kWh/day) (see pr EN 15316-3-2)

Q_{Ws} heat loss from storage vessel (if present) (kWh/day)

Q_{Wpp} heat loss from primary pipes (if present) (kWh/day)

Q_{Whg} heat loss from heat generator (kWh/day)

If the heat generator or generators also provide space heating then the performance of the heat generator must be calculated separately for operation during the summer period, when the space heating demand is zero, and the winter period, when both space heating and domestic hot water is being provided.

5.1 Domestic hot water systems using a single heat generator

If a single heat generator is used then the total heat requirement has to be provided from that heat generator.

5.2 Domestic hot water systems using multiple heat generators

If several heat generators are used to provide the domestic hot water energy requirement, the contribution from each heat generator is calculated on the basis of the nominal output of each individual heat generator. If any or all of these heat generators have separate primary pipe circuits then the primary pipe loss and the auxiliary energy should be calculated separately for each circuit.

5.2.1 Domestic hot water systems using different types of heat generator (heat generators in series)

If the domestic hot water is heated by several different types of heat generator, the contribution of each individual heat generator shall be determined. Normally it is assumed, that the domestic hot water can be heated by a maximum of three heat generators: pre-heating by e.g. solar panels, base heating, and supplementary heating to meet the peak load. The sum of all the contributions is by definition 1.0.

If heat energy is supplied to the domestic hot water system from other appliance types (e.g. exhaust air heat pump, see prEN15243, prEN15316-4-3) (see also prEN15316-1). The remaining heat demand that is covered by the supplementary heat generator (e.g. a boiler), is given by:

$$Q^{*}_{\mathrm{w,outg}} = Q_{\mathrm{w,outg}} - Q_{\mathrm{w,sol}} - Q_{\mathrm{rv,w,outg}} \tag{1}$$

where

$Q^{*}_{\mathrm{w,outg}}$ is the remaining generator useful heat output (kWh)

$Q_{\mathrm{w\ tot}}$ is the total heat requirement of the domestic hot water system (kWh)

$Q_{\mathrm{rv,w,outg}}$ is the generator heat output of the domestic ventilation equipment for the domestic hot water system (see prEN 15243), (kWh)

$Q_{\mathrm{w,sol}}$ is the energy contribution of the solar system for domestic hot water preparation (kWh).

5.2.2 Domestic hot water systems using multiple heat generators of a similar type (heat generators in parallel)

If several heat generators are used to meet the heat required for the domestic hot water, the proportional contribution $\alpha_{TW,g,i}$ of each unit is calculated from the ratio of the nominal output of that unit to the total output of the installation available for heating the domestic hot water.

$$Q_i = \alpha_{TW,g,i} * \sum_{1}^{i} Q_i \tag{2}$$

For heating of the domestic water a number of heat generators (e.g. solar, boiler, heat pump, or electrical ancillary heating) can be available. The total heat requirement for all loads must correspond to the total heat output of all heat generators:

$$\sum_j Q_{\mathrm{w,outg,j}} = \sum_k Q_{\mathrm{in,d,k}} \qquad (4)$$

where

$Q_{W,outg,j}$ is the energy output of heat generator j (kWh)

$Q_{in,d,k}$ is the energy input to the distribution system k (kWh).

If several heat generators are present the total heat demand of the distribution system $Q_{\mathrm{in,d,t}}$ is distributed amongst the available heat generators. The calculations are to be performed independently for each heat generator j on the basis of $Q_{\mathrm{w,outg,j}}$.

If a number of heat generators are used they are to be calculated in the sequence of their use in energy generation.

6 Hot water storage vessel heat loss

The domestic hot water may be supplied from a storage vessel. This vessel may be directly heated i.e. by gas or electricity, or may be indirectly heated by means of a heat generator. This clause considers indirectly heated storage vessels. Directly heated storage vessels are considered to be heat generators and are covered by clauses 6.3 and 6.4.

Heat losses occur from hot water storage vessels. These heat losses have an impact on the overall efficiency of the domestic hot water system and contribute to the overall energy requirements of the building.

6.1 Indirectly heated hot water storage vessel

The storage heat loss from an indirectly heated hot water storage vessel can be obtained from the stand-by heat loss of the vessel. The total heat dissipated from the storage vessel over the period of a year is quantified as a loss.

The storage heat loss is calculated from a stand-by heat loss value, which is corrected for temperature difference as follows:

$$Q_{W,s} = \frac{(\theta_{W,s} - \theta_{Amb})}{\theta_{s,s-b}} * Q_{s-b} \qquad \text{(kWh/day)} \qquad (2)$$

where

$\theta_{W,s}$ average temperature of stored water (°C)

θ_{Amb} average ambient temperature (°C)

$\theta_{s,s-b}$ average temperature difference applied in stand-by heat loss tests (°C)

Q_{s-b} stand-by heat loss (kWh/day)

The stand-by heat loss has to be measured in accordance with a European or National Standard, i.e. pr EN12897, appropriate for the vessel size and type. The measured stand-by heat loss is based on the actual temperatures during the period of operation. The standard to be used for the measurement shall be specified in a National Annex.

If the stand-by heat loss from the storage vessel is not available, a value can be calculated on the basis of an equation of the form;

$$Q_{s-b} = x + y * V_s^{\ z} \qquad \text{(kWh/day)} \qquad (3)$$

where

V_s vessel volume (litres)

$x, y\ and\ z$ constants

Values for the constanst $x, y\ and\ z$ shall be given in a National Annex.

The storage heat loss from older storage vessels can be estimated in a similar way, where values for the constants $x, y\ and\ z$ also shall be given in a National Annex. Alternatively a National Annex may specify the stand-by heat loss based on storage volume and insulation type and thickness.

If the hot water storage vessel is located within the heated area of the building, part of the heat loss from the vessel may be recovered (see 8).

Connecting pipes to the storage water heater may increase the heat loss from the storage vessel particularly if they are not insulated. These losses are caused by circulation set up in the connecting pipes between the hot water in the storage vessel and cooler water in the pipes away from the vessel. If these losses are to be taken into account the method will be given in a National Annex.

7 Primary circulation pipes

Where the domestic hot water is supplied from an indirectly heated storage vessel, the heat energy is supplied from a separate heat generator. The hot water storage vessel may be located adjacent to or remote from the heat generator. Heat losses occur from the primary circulation pipes between the heat generator and the hot water storage vessel, and these losses can be calculated by two different methods, either a simple estimation method or a detailed calculation method.

The storage vessel may be incorporated into the appliance and the primary circulation pipe heat loss may then be included in the overall appliance efficiency measurements. For gas appliances, with storage incorporated and intended to be installed in single family dwellings, measurements to EN13203-2 will include the primary circulation pipe heat loss.

7.1 Heat losses by a simple estimation method

A simple method for estimating the heat losses from primary circulation pipes is to use a fixed representative value. Appropriate values shall be given in a National Annex. If a National Annex is not available or does not include this value, this method cannot be applied.

7.2 Heat losses by a detailed calculation method

Methods for calculating the heat loss from pipes are given in pr EN15316-3-2. These methods shall be followed for calculating the heat loss from primary circulation pipes.

For calculation of the heat losses from the primary circulation pipes, the actual length of the pipes should be used, if available. If the detailed pipe network plan is not available, representative values for the pipe lengths can be used. These values are to be given in a National Annex.

7.3 Auxiliary energy

Electrical energy is required for the circulation pump to overcome the pressure drop within the primary circulation system between the heat generator and the hot water storage vessel. If the circulation pump is contained within the heat generator, the energy required is considered as part of the auxiliary energy for the heat generator. The auxiliary energy measure in accordance with an appropriate appliance standard for the heat generator should then be used.

If a separate circulation pump is applied, the auxiliary energy requirement should be determined separately. The circulation pump may also be used in the space heating system. Care must be taken to avoid duplicating the energy requirement.

A simplified estimation method or a detailed calculation method may be applied to determine the energy required for the pumps in the primary circulation system between the heat generator and the storage vessel.

Methods for calculating the auxiliary energy for circulation loops are given in pr EN15316-3-2. These methods shall be followed for calculating the auxiliary energy from primary circulation pipes. Either the simplified method or the detailed calculation method may be used. Details and default values to be used will be given in a National Annex.

The specific power consumption of the pump should be used, if available. If the detailed pipe network plan and pump specifications are not available, a representative value for the power consumption can be used. This value shall be given in a National Annex.

8 Heat generation energy requirements

The domestic hot water requirement is provided by a heat generator, e.g. a liquid oil or gas fired boiler, a direct gas fired or electrical fired storage water heater or a renewable energy source such as solar heating.

Energy labelling legislation requires efficiency measurements to be obtained for hot water heat generators to be applied in single-family dwellings. These requirements are intended to be independent of the fuel source and heat generator type and are therefore treated separately in 8.1.

Where domestic hot water generation systems are installed in buildings providing multi family accommodation or in commercial buildings, the efficiency of the hot water generation is based on the appliance performance standards appropriate for that appliance technology.

8.1 Heat generation losses for systems in single-family dwellings

The domestic hot water generation efficiency for single-family dwellings will be required to meet energy labelling legislation. Standards developed to show compliance with this directive will incorporate test procedures against three common hot water tapping cycles. The results of these tests will give a hot water generation efficiency based on each of these tapping cycles. If the appliance is not intended to provide the hot water requirement corresponding to all the tapping cycles, this will be identified in the appliance specification and results will not be available for the corresponding hot water tapping cycle test.

It is not necessary to have results from all three tapping cycles. The method is based on an efficiency value corresponding to the average tapping cycle and either the higher tapping cycle or the lower tapping cycle, depending on whether the hot water energy requirement is above or below the average.

The domestic hot water generation efficiency related to the actual hot water use, can be obtained by linear interpolation as follows:

For hot water use below the average, i.e. $Q_1 < Q_{corr} < Q_2$

$$\eta_{W,g} = \eta_2 - 0.267 * (\eta_2 - \eta_1) * (5.845 - Q_{corr}) \quad (5)$$

For hot water use above the average, i.e. $Q_2 < Q_{corr} < Q_3$

$$\eta_{W,g} = \eta_2 + 0.172 * (\eta_3 - \eta_2) * (Q_{corr} - 5.845) \quad (6)$$

where;

η_1 efficiency at low tapping cycle

η_2 efficiency at average tapping cycle

η_3 efficiency at high tapping cycle

Q_{Corr} corrected annual energy requirement (kWh/day)

If $Q_{Corr} < Q_1$, use $Q_{Corr} = Q_1$

If $Q_{Corr} > Q_3$, test results may be available for higher tapping cycles. In this case, interpolation between Q_2 and the higher tapping cycle can be applied.

Q_{Corr} is obtained by adding up the domestic hot water energy requirement and the heat losses in the system.

$$Q_{Corr} = Q_W + Q_{em} + Q_d \quad \text{(kWh/day)} \quad (7)$$

8.2 Heat generation losses for systems in other buildings

8.2.1 Heat losses from oil and gas fired boilers

8.2.1.1 General

The heat losses from the boiler $Q_{TW,i}$ and the auxiliary energy for the boiler $W_{TW,g,HE}$ is calculated on the basis of the nominal heat output $\dot{Q}_n$, the efficiency $\eta_{100\%}$ at the nominal output as shown in EU Directive 92/42, the stand-by heat loss $q_{B,70}$, and the electrical input P_{HE} of the auxiliary units in the boiler. These values have to be determined either by measurements, e.g. in accordance with EN 304, EN 297, EN 483, EN 656, EN 625 (for combination boilers) or EN 677 (for condensing boilers), or – if measurements are not available – by fixed default values. Default values shall be provided in a National Annex.

8.2.1.2 Calculation of heat losses from boilers

The total heat loss from a boiler is based on the nominal output efficiency $\eta_{g,100\%}$, the stand-by heat loss $Q_{g,sb}$, and the nominal heat output $\dot{Q}_g$. The calculation method is given in Annex A.

A National Annex may specify default values if specific test results are not available.

For older boilers, for which the efficiency and the stand-by heat loss values may not be known, values may be given in a National Annex.

8.2.1.3 Auxiliary energy

Auxiliary energy is the energy, other than fuel, required for operation of the burner, operation of the primary circulation pump and operation of any other equipment related to the heat generation subsystem operation and being an integral part of that system. Auxiliary energy shall be measured according to the product standard. If there is no product standard then default values may be used. These will be detailed in a National Annex.

Auxiliary energy, normally in the form of electrical energy, may partially be recovered as heat for space heating or as energy transmitted to the water of the primary circulation circuit.

8.2.2 Direct gas fired domestic storage water heater

The efficiency of a direct gas fired domestic storage water heater should be obtained from tests in accordance with EN 89. If no efficiency values are available, minimum values may be provided in a National Annex. These values should not be lower than the default values given in Annex B.

The energy required to maintain the hot water temperature is assumed to be equal to the heat loss to the surroundings. This value should be obtained from the test method specified in EN 89 and may be quoted by the manufacturer. If no value is available, a default value shall be used. The default value is calculated on the basis of the maximum value specified in EN 89 for the maintenance energy requirement. This is assumed to be 20% less than the maximum value allowed.

The calculation method is described in annex B.

For older systems, where the manufacturer’s data is not available and measurements cannot be made, the values to be used shall be given in a National Annex.

8.2.3 Direct electrical heated domestic storage water heaters

Electrically heated storage water heaters may be heated continuously or heated for a defined period of the day.

8.2.3.1 Electrical heated domestic storage water heaters with power continuously on

Where the storage water heater is heated continuously the energy required can be considered as the sum of the thermal losses of the electrical heater and energy demand (energy delivered + energy losses of the distribution system).

The efficiency of a direct electrical fired domestic storage water heater shall be obtained from tests in accordance with pr EN 50440.

The energy required to maintain the hot water temperature is assumed to be equal to the heat loss to the surroundings. This value shall be obtained from the test method specified in pr EN 50440 and may be quoted by the manufacturer.

The calculation method is described in Annex C. If values of the parameters for determining the stand-by heat loss are not available, default values shall be provided in a National Annex.

For older systems, where the manufacturer’s data is not available and measurements cannot be made, the values to be used shall be given in a National Annex.

8.2.3.2 Electrical heated domestic storage water heaters with power on timed

These appliances provide domestic hot water from a stored quantity of hot water. As the hot water is supplied to the user outlets the hot water in the storage vessel is depleted. These appliances use power during a timed period, usually to coincide with a low tariff period, to recover the stored hot water temperature.

The total energy of the hot water taken from the store is equal to the energy of the hot water requirement and the loss in the distribution system. In addition energy is needed to overcome the losses from the hot water storage vessel.

Efficiency, for electrical storage water heater is directly related to standby losses, that are measured in steady conditions (EN 60379) or obtained from dynamic tests representing daily tapping patterns (pr EN 50440). The method to be used is partly dependant on building type and the application of the hot water system. The standard to be used will be given in a National Annex.

The calculation method, to estimate daily thermal losses corresponding to average design tapping cycles, is described in Annex D. If values of the parameters for determining the daily thermal losses are not available, default values shall be provided in a National Annex.

For older systems, where the manufacturer's data is not available and measurements cannot be made, the values to be used shall be given in a National Annex.

8.2.4 Heat losses from alternative generators

For systems, where all or part of the domestic hot water energy requirement is provided by heat generators which are not oil or gas fired units or electrically heated systems, the efficiency of the heat generator is determined from the relevant standard for the space heating systems, corresponding to the type of heat generation system.

9 Recoverable heat losses, recovered heat losses and unrecoverable heat losses

The calculated heat losses are not all necessarily lost. Part of the heat losses, termed recoverable heat losses, may be recovered and contribute to the space heating. The extent of recoverable heat losses depends on the location of the pipes and the storage vessel. Only part of the recoverable losses are actually useful, however, as recoverable losses can only be considered during periods of the year where there is a significant space heating demand. Under some circumstances, the recoverable heat losses may add to the cooling load required in a building. The proportion of the total recoverable losses that can be recovered is determined in pr EN15315-1, for which the total recoverable losses are provided as an input.

Some of the auxiliary energy may be recovered as heat in the domestic hot water system, e.g. electrical energy supplied to the circulation pump ends up as thermal energy in the water. The recovered heat losses from the circulation pump transmitted to the water is taken into account directly as a reduction of the heat losses.

In many systems, the same heat generator supplies space heating and heating for the domestic hot water. Care shall be taken to ensure, that only those recoverable heat losses – which are not already accounted for in the analysis of the space heating system – are taken into account in the analysis of the domestic hot water system.

Annex A
(informative)

Calculation of heat loss from a gas or oil fired boiler

A.1 Calculation of total boiler heat loss

The total heat loss from a boiler is calculated from the heat loss during operation and the stand-by heat loss as follows:

$$Q_{W,gl} = Q_{W,gl,100\%} + Q_{g,sb} \quad \text{(kWh/day)} \quad \text{(A1)}$$

where;

$Q_{W,gl}$ total heat loss from boiler (kWh/day)

$Q_{W,gl,100\%}$ heat loss from boiler during operation for a 24 hour period (kWh/day)

$Q_{g,sb}$ stand-by heat loss from boiler (kWh/day)

A.2 Calculation of heat loss during boiler operation

The heat loss during the boiler operation period is calculated by:

$$Q_{W,gl,100\%} = (H_s / H_i - \eta_{100\%}) * \dot{Q} / \eta_{100\%} \quad \text{(kWh/day)} \quad \text{(A2)}$$

where;

$Q_{W,gl,100\%}$ heat loss of the boiler for a day (kWh/day)

$\dot{Q}$ nominal heat output of boiler (kWh/day)

$\eta_{100\%}$ efficiency of boiler at nominal output

H_s higher calorific value of the fuel (kWh/kg or kWh/m^3)

H_i lower calorific value of the fuel (kWh/kg or kWh/m^3)

A.3 Calculation of stand-by heat loss

The stand-by heat loss, $Q_{B,}$ during periods where the boiler is not providing heat to a storage vessel or directly to the domestic hot water, is calculated by:

$$Q_{sb} = q_{B,70} * (\theta_{g,m} - \theta_{u,m}) / (70 - 20) * (Q_n / \eta_{100\%}) * (24 - t_{w,100\%}) * H_s / H_i \quad \text{(A3)}$$

where;

Q_{sb} stand-by heat loss of the boiler (kWh/day)

Q_n nominal heat output of boiler (kW)

$q_{B,70}$ stand-by heat loss at a boiler temperature of 70 °C and room temperature of 20 °C

$\Theta_{g,m}$ average boiler temperature during a stand-by period (°C)

$\Theta_{u,m}$ average room temperature (°C)

$t_{tw,100\%}$ period of provision of energy for domestic hot water at nominal heat output (h/day)

During periods where the boiler provides space heating, the present stand-by heat losses are assumed to be zero. Any heat energy generated during these periods and not used in the provision of space heating is considered as heat losses in the assesment of the space heating energy requirements.

A.3.1 Average boiler temperature during a stand-by period

The average boiler temperature during a stand-by period depends on a number of factors. These include the boiler controls, type of storage vessel (if applied) and associated space heating operation. For simplification, the average boiler temperature during a stand-by period, $\theta_{g,m}$, is assumed to be 50°C, except for flow water heaters where it is assumed to be 40 °C.

A.3.2 Load factor of a boiler

The load factor of a boiler is calculated as folows:

$$\varphi_{TW} = \frac{t_{100\%}}{t_{TW,g}} = \frac{\left(Q_{tw} + Q_{TW,ce} + Q_{TW,d} + Q_{TW,s}\right) \cdot \alpha_{TW,g}}{\left(\dot{Q}_n \cdot t_{TW,g}\right)} \quad \text{(A4)}$$

where;

φ_{TW} part load factor of the boiler

$t_{100\%}$ running time of the boiler at nominal heat output (hrs/day)

$t_{TW,g}$ duration of provision of energy for domestic hot water (hrs/day)

Q_{tw} domestic hot water heat requirement (kWh/day)

$Q_{TW,ce}$ heat losses from the domestic hot-water user outlets (kWh/day)

$Q_{TW,d}$ heat losses from the domestic hot-water distribution system (kWh/day)

$Q_{TW,s}$ heat losses from the domestic hot-water storage system (kWh/day)

Q_n nominal heat output of the boiler (kW)

$\alpha_{TW,g,}$ heat generator’s proportional contribution

A.3.3 Auxiliary energy for a boiler

The area related auxiliary energy requirement for operation of the boiler is calculated on the basis of the auxiliary output P_{HE} of the boiler measured at 100% full load in accordance with Council Directive 92/42, i.e. at a volume flow rate corresponding to nominal heat output and a temperature difference between flow temperature and return temperature of 15K. If the boiler is permanently equipped with a pump operated for heating the domestic hot water in an external and indirectly heated storage vessel, P_{HE} is determined at an external hydraulic pressure loss of 10 kPa. If the boiler is permanently equipped with a circulation pump and a storage vessel or heat transfer agent (a combination boiler), determination of P_{HE} has to be carried out on this combination boiler.

$$Q_{TW,g,HE} = t_{100\%} * P_{HE} = \varphi_{TW} * P_{HE} \qquad \text{(kWh/day)} \qquad \text{(A5)}$$

where;

$Q_{TW,g,HE}$ area-related auxiliary energy requirement for the boiler (kWh/day)

$t_{100\%}$ running time of the boiler at nominal heat output (hrs/day)

P_{HE} electrical power consumption of the boiler (kW)

φ_{TW} load factor of the boiler

If values of the parameters for determining the auxiliary energy requirement are not available, default values shall be provided in a National Annex.

A.3.4 Nominal output efficiency of a boiler

Nominal output efficiency of a boiler, $\eta_{100\%}$, is determined from the nominal heat output of the boiler, $\dot{Q}_n$ in (kW) at a test temperature of 70°C, as follows:

Standard boiler: $\eta_{100\%} = (85,0 + 2,0 \cdot \log(\dot{Q}_n))/100$ (A6)

Low-temperature boiler: $\eta_{100\%} = (88,5 + 1,5 \cdot \log(\dot{Q}_n))/100$ (A7)

Condensing boiler: $\eta_{100\%} = (92,0 + 1,0 \cdot \log(\dot{Q}_n))/100$ (A8)

Improved condensing boiler: $\eta_{100\%} = (94,0 + 1,0 \cdot \log(\dot{Q}_n))/100$ (A9)

Annex B
(informative)

Thermal loss from a gas fired hot water storage heater

The following minimum efficiency values can be used as default values:

- 84% for all appliances, except for condensing appliances;
- 98% for condensing appliances.

The energy required to maintain the hot water temperature is assumed to be equal to the heat loss to the surroundings. This value is obtained by the test method specified in EN 89 and may be quoted by the manufacturer. If no value is specified by the manufacturer, a default value shall be used. The default value is calculated on the basis of the maximum value specified in EN 89 for the maintenance energy requirement and is assumed to be 20% lower than the maximum value allowed.

The maintenance energy consumption, Q_{m-c}, is calculated by:

For appliances of any nominal capacity with a heating-up time of 45 min. or more and for appliances with a nominal capacity up to 200 l with a heating-up time less than 45 min.:

$$Q_{m-c} = 0.8 * (11 * V_s^{0.67} + 0.015 * Q) \quad \text{(W)} \qquad \text{(B1)}$$

or Q_{m-c} = 250 W if the value given by the equation is lower

For appliances with a nominal capacity exceeding 200 l with a heating-up time less than 45 min.:

$$Q_{m-c} = 0.8 * (9 * V_s^{0.67} + 0.017 * Q) \quad \text{(W)} \qquad \text{(B2)}$$

or Q_{m-c} = 250 W if the value given by the equation is lower

where;

V_s nominal capacity (litres)

Q nominal heat input (W)

It is assumed that the total heat dissipated from the storage water heater is quantified as a loss.

The heat loss is calculated from the maintenance energy consumption and is corrected for temperature difference as follows:

$$Q_{Ws} = \frac{(\theta_{Ws} - \theta_{Amb})}{\theta_{s,m-c}} * 24 * Q_{m-c} \quad \text{(Wh/day)} \qquad \text{(B3)}$$

where;

θ_{Ws} average water temperature in the storage water heater (°C)

θ_{Amb} average ambient temperature (°C)

$\theta_{s,m-c}$ average temperature difference used for determination of the maintenance energy consumption (°C)

Q_{m-c} maintenance energy consumption (W)

Annex C
(informative)

Thermal loss from an electrically heated hot water storage heater (with continuous power on)

The energy required to maintain the hot water temperature is assumed to be equal to the stand-by heat loss of the storage water heater. This value is obtained by the test method specified in pr EN 50440 and may be quoted by the manufacturer.

The stand-by heat loss per day, Q_{Ws}, is corrected to a temperature difference of 45 K and is calculated by:

$$Q_{Ws} = \frac{\theta_M - \theta_{amb}}{45} * \frac{24}{(t_6 - t_5)} * E_1 + \frac{1.16 * C_{act} * (\theta_{out} - \theta_{in})}{1000} \quad \text{(C1)}$$

θ_M average water temperature in the storage water heater (°C)

θ_{amb} average ambient temperature (°C)

$t_6 - t_5$ duration of test period (h)

E_1 maintenance energy consumption during test period (kWh)

C_{act} xxxxxxxxxxxxxxxxxxx

θ_{in} water temperature at each thermostat cut-in (°C)

θ_{out} water temperature at each thermostat cut-off (°C)

Annex D
(informative)
Thermal loss from an electrically heated hot water storage vessel (with timed power on)

This calculation method is used to predict the energy consumption of a hot water storage vessel relevant to daily tapping cycles.

The energy consumption of electrical water-heater is calculated when adding:

- the energy demand at the entry of the water-heater (hot water demand and distribution losses)
- the thermal losses.

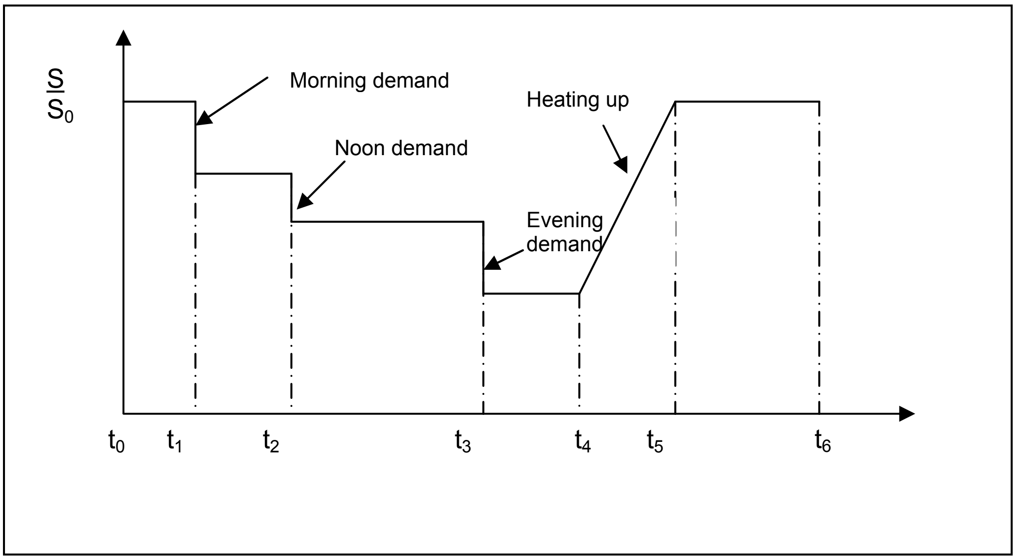
The hot water is thermally stratified within the hot water storage vessel, due to the fact that the heating up period and hot water period are separated. The thermal losses can be considered as a function of the surface of the storage water-heater that is adjacent to the hot part of the stored water and which therefore could loose thermal energy to the environment surrounding the water heater.

The basis of the calculation is to consider the average value of the surface of the water that corresponds to the part of the vessel that remains hot during a daily cycle.

The method is based on simplified hot water draw off schedules dividing the daily hot water demand into three periods of morning, noon and evening.

The energy E_{ab} is calculated as follows:

Fig D.1 Indication of the change in surface relevant to heat loss estimations due to hot water draw offs



$$E = E_{WATER} + Q_{pr} \cdot \left(\frac{S^*}{S_0} \right)^n \qquad \text{(D1)}$$

with

$$S_0 = \pi \cdot D \cdot h + 2 \cdot \pi \cdot \frac{D^2}{4} \cdot n \cdot \frac{h}{D} \qquad \text{(D2)}$$

$E_i =$ Energy corresponding to morning, noon or evening demand according to the simplified tapping pattern

$$E_{ESWH} = \frac{1{,}16 \cdot V \cdot (65 - 15)}{1000} \qquad \text{(D3)}$$

$$S^* = \frac{1}{24} \int_{i=0}^{i=7} S_i \cdot (t_{(i+1)} - t_i) \qquad \text{(D4)}$$

with $$S_i = \pi \cdot D \cdot h \cdot \left(1 - \frac{E_i}{E_{ESWH}}\right) \cdot \pi \cdot \frac{D^2}{4} \qquad \text{(D5)}$$

$$t_5 - t_4 = \frac{E_{WATER} + Q_{pr}}{P} \qquad \text{(D6)}$$

and $$t_6 - t_5 = 8 - (t_5 - t_4) \qquad \text{(D7)}$$

where:

D	external diameter	(m)
H	external high of the appliance	(m)
n =1, 25	heat transfer coefficient	
ti	time switch for water withdrawal or heating up	(h)
Q_{pr}	standardized value for thermal losses	(kWh/24h)
V	Rated capacity	(l)
P	Power of the energy supply	
C_m	quantity of hot water delivered	(l)
E_{WATER}	Energy delivered regarding the tapping pattern considered (2,1 kWh, 5,85 kWh or 11,65 kWh)	
S_0	surface taken in account for calculation when the water heater is in hot conditions	(m²)
S*	surface of the appliance equivalent of a medium value for a daily cycle	(m²)
X_i	coefficient representing the relative quantity of energy delivered versus the maximum energy stored	
E_{ESWH}	maximum value of energy that could be stored in the appliance	(kWh)

<u>Example:</u>

External diameter	D = 0, 52	(m)
External high of the appliance	h = 1, 42	(m)
Heat transfer coefficient	n = 1, 25	
Time switch for water withdrawal or heating up	t_i = 0	(s)
Standardized value for thermal losses	Qpr = 1, 71	(kWh/24h)
Rated capacity	V = 200	(l)
Quantity of hot water delivered C_m [l]		
	P = 2, 2	(kW)

E_{WATER}: Energy delivered regarding to the tapping pattern considered (2, 1 kWh, 5, 85 kWh or 11, 65 kWh)

Other parameters needed:

- Surface taken into account for calculation when the water heater is in hot condition S_0 = 3,77 (m²)
- Surface of the appliance equivalent to the medium value for the daily cycle concerned S* (m²)
- Coefficient representing the relative quantity of energy delivered versus the maximum energy stored X_i
- Maximum value of energy that could be stored in the appliance E_{ESWH} = 10, 44 kWh

Calculated figures	Result with tapping pattern I	Result with tapping pattern II
$t_1 - t_0$	0,50 h	0,25
$t_2 - t_1$	5,25 h	5,75
$t_3 - t_2$	7,25 h	7,75
$t_4 - t_3$	3,00 h	2,75
$t_5 - t_4$	1,74 h	3,44
$t_6 - t_5$	6,26 h	4,56
S_0	3,77 m²	3,77 m²
S_X	2,50 m²	2,42 m²
E	3,13 kWh	6,84 kWh
η	0,69	0,86