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Heating systems in buildings — Method for calculation of system energy requirements and system efficiencies — Part 2-1: Space heating emission systems

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Foreword

This document (EN 15316-2.1:2006) has been prepared by Technical Committee CEN/TC 228 “Heating systems in buildings”, the secretariat of which is held by DS.

This document is part of a series of standards developed for implementation of the European Energy Performance of Buildings Directive (EPBD)

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.
- methods for design and dimensioning embedded, radiant surface heating and cooling 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 constitutes the specific part related to space heating emission, of a set of standards determining methods for calculation of energy losses/requirements of space heating systems and domestic hot water systems in buildings.

This standard specifies the structure for calculation of the additional heat losses and energy requirements of a heat emission system for meeting the building net energy demand.

The calculation method is used for the following applications:

— calculation of the additional energy losses in the heat emission system;

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

— assessing the effect of possible energy conservation measures on an existing heat emission system, by calculation of the energy requirements with and without the energy conservation measure implemented.

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

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1 Scope

The scope of this specific part is to standardise the required inputs, the outputs and the links (structure) of the calculation method in order to achieve a common European calculation method.

The energy performance may be assessed either by values of the heat emission system efficiency or by values of the increased space temperatures due to heat emission system inefficiencies.

The method is based on an analysis of the following characteristics of a space heating emission system including control:

— non-uniform space temperature distribution;

— emitters embedded in the building structure;

— control accuracy of the indoor temperature.

The energy required by the emission system is calculated separately for thermal energy and electrical energy in order to determine the final energy, and subsequently the corresponding primary energy is calculated.

The calculation factors for conversion of energy requirements to primary energy shall be decided on a national level.

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 12828, *Heating systems in building – Design for water based heating systems*

EN 12831, *Heating systems in buildings - Method for calculation of the design heat load.*

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

EN 15316-2.3, *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies – Part 2.3: Space heating distribution system.*

EN 15232. *Calculation methods for energy efficiency improvements by the application of integrated building automation systems*

EN ISO 7345:1995, *Thermal insulation - Physical quantities and definitions (ISO 7345:1987)*

EN ISO 13790, *Thermal performance of buildings - Calculation of energy use for space heating (ISO 13790:2007)*

3 Definitions and symbols (to be updated according to the umbrella document and other related standards)

3.1 Definitions

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

3.1.1
calculation period
time period (time step) considered for the calculation of the heat losses and gains (e.g. year, month, day, hour boosted sub-period) of the heating system

3.1.2
energy requirements for heating
energy to be delivered to the heating system to satisfy the heat demand of the building

3.1.3
final energy
energy required for the space heating of the building including auxiliary energy

3.1.4
heat demand, building
heat to be delivered to the heated space to maintain the internal set-point temperature of the heated space

3.1.5
heated space
room or enclosure heated to a given set-point temperature

3.1.6
heating system heat losses, emission
heat losses through the building envelope due to non-uniform temperature distribution, control inefficiencies and losses of emitters embedded in the building structure

3.1.7
heating system heat losses, total
sum of the heat losses from the heating system, including recoverable heat loss

3.1.8
performance factor, emission
ratio between the energy demand for space heating with a uniform internal temperature distribution in the heated space and the energy requirements for space heating with a non-ideal heat emission system causing non-uniform temperature distribution and a non-ideal room temperature control

3.1.9
primary energy
energy that has not been subject to any conversion or transformation process (e.g. oil in the oil fields)

3.1.10
recoverable (usable) system 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

3.1.11
recovered (used) system heat loss
part of the recoverable system heat loss which lowers the heat demand for space heating and which is not directly taken into account by reduction of the heating system heat losses

3.1.12
thermal zone
part of the heated space with a given set-point temperature, in which a negligible spatial variation of the internal temperature is assumed

3.2 Symbols and units

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

Table 1: Symbols and units

Symbol	**Name of quantity**	**Unit**
A	surface area	m^2
b	temperature reduction factor	-
e	system performance coeff. (performance factor)	-
E	primary energy	J
f	conversion factor	-
g	gain/loss ratio	-
k	part of recoverable auxiliary energy	-
L	steady state part of heat loss	%
Q	quantity of heat, energy	J
R	thermal resistance	$m^2 \cdot K/W$
t	time, period of time	s
T	thermodynamic temperature	K
U	heat transfer coefficient	$W/m^2 \cdot K$
x	percentage of losses	%
W	electrical auxiliary energy	kWh
Φ	thermal power	W
η	efficiency	-
γu	utilisation factor	-
θ	celsius temperature	°C

Table 2: Indices

avg average	gs gains	*p* primary
c control	*h* heating energy	*out* output from system
e external	*i* internal	*r* recovered
em emission	*in* input to system	*str* stratification
emb embedded	*inc* increased	*t* total
el electrical energy	*l* loss	*x* indices
f final	*m* medium (heating)	Δ additional
G Ground	nr non recovered losses	

4 Relation to other EPBD-standards

The present standard follows the general concept outlined in EN15316-1

The user shall refer to other European Standards or to national documents for input data and detailed calculation procedures not provided by this standard. The interaction with other standards is shown in Figure 1. The method for calculation of the building net heating energy is provided by EN ISO 13790. The results of this standard is used in EN 15316-2-3 as input to calculations for the space heating distribution system or in EN 15316-4.x as input for the calculations for the heat generators. More detailed information on control systems is found in EN15232.

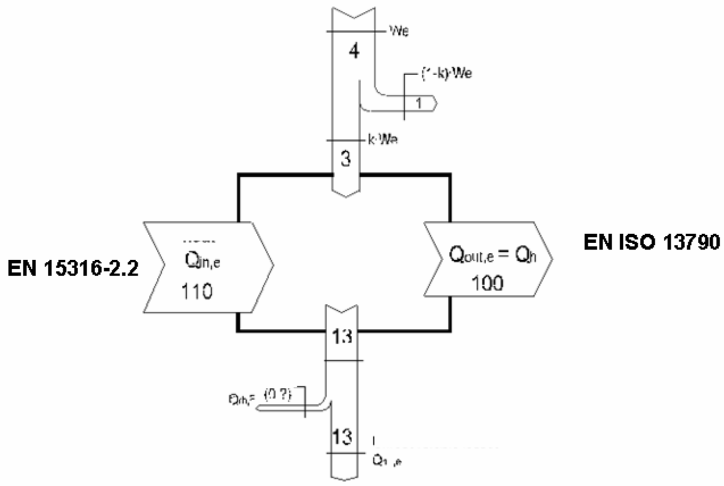

Figure 1: Sample sub-system for heat emission. The symbols used are explained in 3.2

5 Principle of the method

5.1 Primary energy calculation

Heat losses for heat emission and control of the indoor temperature in a building depends on:

- the building energy need for space heating (building thermal properties and the indoor and outdoor climate);
- non-uniform internal temperature distribution in each thermal zone (stratification, emitters along outside wall/window, differences between air temperature and mean radiant temperature);
- emitters embedded in the building structure towards the outside or unheated spaces;
- control of the operative temperature (local, central, set-back , thermal mass, etc);
- auxiliary consumption;

The calculation of emission losses shall take into account:

- energy interaction between type of emitters (radiator, convector, floor/wall/ceiling heating systems) and space ;
- type of room/zone thermal control strategy and equipment (thermostatic valve, P, PI, PID control, etc) and their capability to reduce the temperature variations and drift;
- position and characteristics of emitters.

Based on these data, the following output parameters for the heat emission sub-system, including control, shall be calculated:

- total emission system heat losses;
- auxiliary energy consumption;
- recoverable heat losses.

The calculation may be based on tabulated values or more detailed calculation methods. In section 7 two concepts are given with recommended default values in Annex A and B.

The net energy demand for space heating, without taking into account the system losses, shall be calculated under standardised conditions according to EN ISO 13790 or similar national method.

The system losses are calculated separately for thermal energy and electrical energy, in order to determine the final energy, and subsequently the corresponding primary energy is calculated (EN15316-1).

5.2 Thermal energy required for heat emission

The thermal energy required for heat emission, $Q_{in,em}$, is given by:

$$Q_{in,em} = Q_{out,em} - k \cdot W_{em} + Q_{l,em} \qquad [J] \qquad (2)$$

where:

$Q_{out,em}$ thermal output of the heat emission system in Joule (J). This is equal to the net heating energy of the building, Q_h , (EN ISO 13790);

k part of recoverable auxiliary energy (-);

$Q_{l,em}$ heat losses in Joule (J).

5.3 Auxiliary energy W_{em}

Auxiliary energy, normally in the form of electrical energy, is used for fans which facilitate the heat emission (fan coil), valves and control. Part of the auxiliary energy may be recovered as heat $Q_{w,em}$:

$$Q_{w,em} = k \cdot W_{em} \qquad [J] \qquad (3)$$

5.4 Recoverable heat losses $Q_{rh,em}$ and un-recoverable heat losses $Q_{nr,em}$

Not all of the calculated heat losses, $Q_{l,em}$, are necessarily lost. Some of the heat losses are recoverable.

However, only part of the recoverable heat losses is actually recovered. This depends on the utilisation factor (gain/loss ratio), because if the gains of a heated space are very high in comparison with the losses of the space, only few gains can be recovered (see EN ISO 13790).

For the heat emission system, only part of the auxiliary energy may be recovered as heat. Only heat losses to an unheated space or to the outside (embedded, back of radiator) are regarded as losses.

5.5 Heat demand for space heating, building heat requirement Q_h

The heat requirement for the building or a part of the building, Q_h, shall be calculated according to EN ISO 13790 or similar national method as:

$$Q_h = Q_l - \gamma_u \cdot Q_{gs} \qquad [J] \qquad (4)$$

where:

Q_l heat losses in Joule (J);

Q_{gs} heat gains in Joule (J);

γ_u utilisation factor (-).

This calculation takes into account the heat losses of the building envelope and the recovered part of the total heat gains (metabolic gains from occupants, power consumption of lighting devices, household appliances and solar gains). However, it does not take into account the space heating and domestic hot water system losses due to non-uniform temperature distribution, control inefficiencies, recoverable losses and auxiliary energy.

Depending on the input data chosen for the set-point temperature, EN ISO 13790 gives a method to calculate directly the sum of the heat demand and the heat losses of the heat emission system, without differentiating one from the other. The way to determine the internal temperature for taking into account part of the emission heat loss is defined in the present standard.

The effects of intermittent space heating with an ideal programming device can be calculated according to EN ISO 13790 and are taken into account in determination of the heat demand, Q_h. The effects of a non-ideal programming device (late or early heating up) are taken into account in the present standard as heat emission system heat loss.

The effect of a non-ideal space temperature control is taken into account in the present standard.

5.6 Heat losses $Q_{l,em}$

The heat losses of heat emission are calculated as:

$$Q_{l,em} = Q_{em,str} + Q_{em,emb} + Q_{em,c} \quad [J] \qquad (5)$$

where:

$Q_{em,str}$ heat loss due to non-uniform temperature distribution in Joule (J);

$Q_{em,emb}$ heat loss due to emitter position (e.g. embedded) in Joule (J);

$Q_{em,c}$ heat loss due to control of indoor temperature in Joule (J).

Methods for calculation of these heat losses are given in 6.

5.7 Calculation periods

The objective of the calculation is to determine the annual energy demand of the space heating emission 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 annual average values;

— by dividing the year into a number of calculation periods (e.g. year, month, week, day, hour, boosted sub-period) and perform the calculations for each period using period-dependent values and adding up the results for all the periods over the year.

5.8 Spatial division of the space heating system

A heating system may, as required, be split up in zones with different heat emission systems, and the heat loss calculations can be applied individually for each zone. The considerations given in EN 15316, part 1 regarding splitting up or branching of the heating system shall be followed. If the principle of adding up the heat losses is respected, it is always possible to combine zones with different heat emission systems.

6 Energy calculations for a heat emission system

This section give in details methods for calculation of losses in the heat emission systems. The concept is exemplified in two approaches in section 7 with default values in annexes:

Method using efficiencies section 7.1, Annex A

Method using equivalent internal temperature increase section 7.2, Annex B

The two recommended methods may not give exactly the same results; but the same relative trent. The two methods shall not be mixed.

6.1 Non-uniform temperature distribution

6.1.1 General approach for calculation of energy losses due to a non-uniform temperature distribution

The energy loss can be caused by (see Figure 2):

- a temperature stratification, resulting in an increased internal temperature under the ceiling and upper parts of the room;

- an increased internal temperature and heat transfer coefficient near windows;
- convection and radiation from the heating system through other outside surfaces.

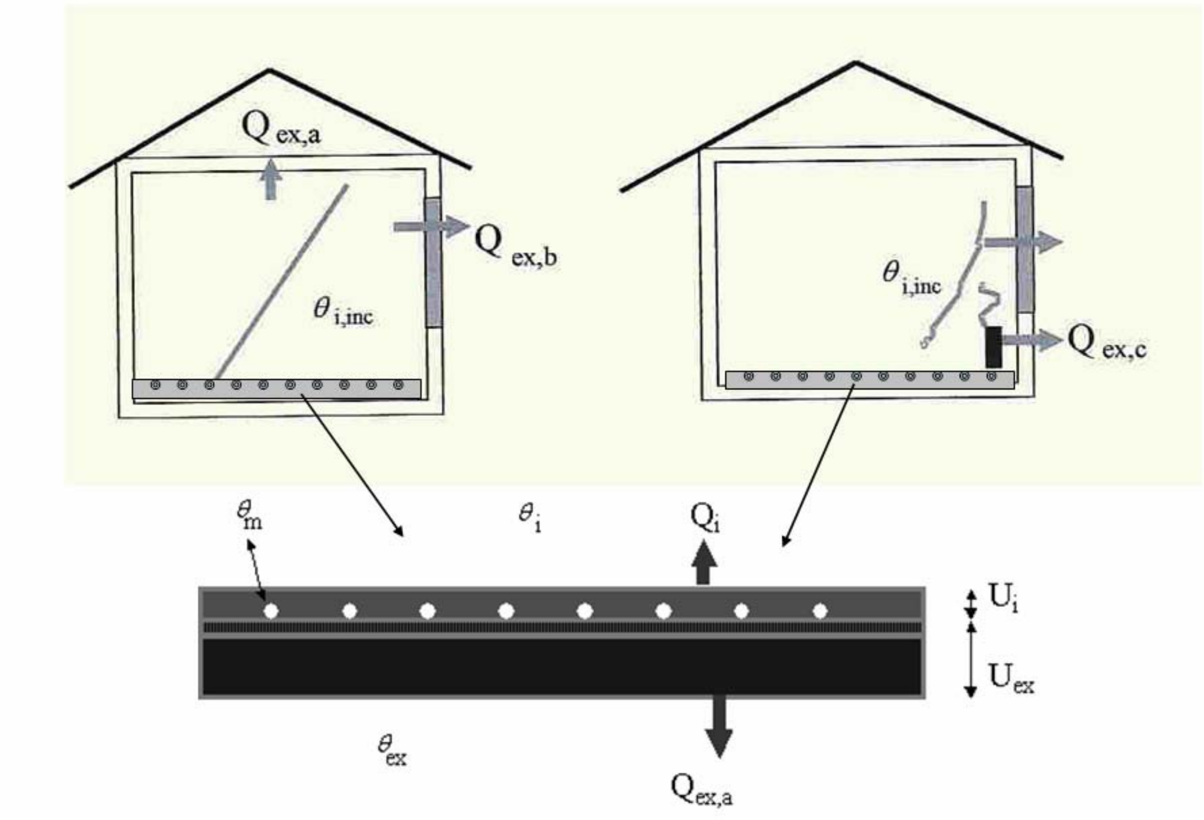

Figure 2: Effects due to non-uniform temperature distribution and position of heat emitter

The heat loss due to a non-uniform temperature distribution is calculated using the general equation for transmission heat loss, taking into account the increased internal temperature, $\theta_{i,inc}$, and the increased heat transfer coefficient, which is included in the U-value, U_{inc}, of the surface area exposed:

$$Q_{em,emb} = \Sigma A \cdot U_{inc} \cdot (\theta_{i,inc} - \theta_e) \cdot t \qquad [J] \qquad (7)$$

where:

A area of the ceiling, outside wall behind heat emitter or window in square metres (m²);

U_{inc} calculated from the insulation of the surface and the surface coefficient in Watts per square metres per Kelvin (W/m²·K). This is influenced by the convective air flow from the heat emitter, reflective material behind the heat emitter, etc.

$\theta_{i,inc}$ locally increased internal temperature in degrees Celsius (°C) which is a function of the heating system and the surface temperature or the supply air temperature of the heating system;

θ_e external temperature in degrees Celsius (°C)

t time in hours (h).

Calculation of the net energy use according to EN 13790 is based on the assumption that air temperature and mean radiant temperature are equal and uniformly distributed. For systems with a significant part of radiant heating and spaces with large cold surfaces, the mean radiant temperature may differ significantly from the air temperature. This will for convective systems result in an increased ventilation heat loss and for radiant heating systems result in a decreased ventilation heat loss.

The calculations are in this standard simplified by using tabled efficiencies (6.1.2 or equivalent increase in space temperature 6.1.3)

6.1.2 Use of tabled efficiency values for a non-uniform temperature distribution

If the efficiency, η_L ,of the internal temperature distribution of the heat emission system is given, the additional heat loss $Q_{em,str}$, can be calculated as:

$$Q_{em,str} = \frac{1-\eta_L}{\eta_L} \cdot Q_h \qquad [J] \qquad (8)$$

Annex A provide examples of efficiency values for heat emission systems.

6.1.3 Use of tabled values for the equivalent increase in internal temperature due to a non-uniform temperature distribution.

The heat loss due to a non-uniform temperature distribution may be calculated according to EN ISO 13790 using an equivalent increased internal temperature. The equivalent increase in internal temperature may be used to calculate the corresponding increase in heat loss in two different ways:

- by multiplying the calculated building heat demand, Q_h, with a factor based on the ratio between the equivalent increase in internal temperature, $\Delta\theta_i$, and the average temperature difference for the heating season between the indoor and outdoor temperature for the space:

$$Q_{em,str} = Q_h \cdot (1 + \Delta\theta_i / (\theta_i - \theta_{e,avg})) \qquad [J] \qquad (9)$$

- by recalculation of the building heat energy requirements, according to EN ISO 13790 or similar national method, using the equivalent increased internal temperature.

The second method gives more accurate results.

Annex B provides examples of values for the equivalent increase in internal temperature, $\Delta\theta_i$, for different types of heat emitters.

6.2 Heat loss of embedded surface heating devices due to additional transmission to the outside

This applies to floor heating, ceiling heating and wall heating systems and similar.

This is only considered as a loss when one side of the building part containing the embedded heating device is facing the outside, the ground, an unheated space or a space belonging to another building unit.

If embedded heat emitters with different characteristics (e.g. insulation) are used in the heating installation, it is necessary to take this into account by separate calculations.

Note : If the increased temperature in the building element has been taken into account in the calculations according to EN ISO 13790, this shall not be done again. For a slab on ground, it is for large buildings important to use the equivalent U_e value according to EN ISO13370 or EN 12831.

The heat loss due to additional transmission to the outside is calculated as follows (see Figure 2):

Necessary room heat emission:

$$Q_i = A \cdot U_i \cdot (\theta_m - \theta_i) \cdot t \qquad [J] \qquad (10)$$

Heat loss to the other side:

$$Q_{ex,a} = A \cdot U_{ex} \cdot (\theta_m - \theta_{ex}) \cdot t \qquad [J] \qquad (11)$$

Combining these equations gives:

$$Q_{ex,a} = [(U_{ex}/U_i) \cdot Q_i + A \cdot U_{ex} \cdot (\theta_i - \theta_{ex})] \cdot t \qquad [J] \qquad (12)$$

where:

A surface area with embedded heating device in square metres (m²);

U_{ex} heat transfer coefficient between the level of the heating medium and the outside, ground, neighbouring unit, or unheated space in Watts per square metres per degrees Celsius (W/m²·°C);

U_i heat transfer coefficient between the level of the medium and the heated space in Watts per square metres per degrees Celsius (W/m²·°C);

θ_m average temperature at the level of the heating medium in degrees Celsius (°C);

θ_{ex} external temperature, ground temperature, temperature in neighbouring unit or temperature in unheated space in degrees Celsius (°C);

θ_i internal temperature in degrees Celsius (°C);

t time in hours(h).

Heat transfer to the ground can be calculated according to ISO EN 13370.

Another way to express the heat losses of an embedded heat emitter is to present the losses as a percentage of the heat demand (heat requirement) of the space.

The heat losses are calculated as follows:

$$Q_{em,emb} = Q_h \cdot \sum_{emb} \frac{A_{emb}}{A_{zone}} \cdot \frac{x_l}{100} \qquad [J] \qquad (13)$$

where:

A_{emb} surface area heated by the embedded emitter in square metres (m^2);

A_{emb} surface area of the zone in square metres (m^2);

x_l percentage of heat losses (between 0 and 100):

$$x_l = 100 \cdot \frac{R_i}{\frac{1}{b \cdot U} - R_i} \qquad [\%] \qquad (14)$$

where:

R_i thermal resistance of the building envelope component between the level of the heating medium and the heated space in square metres by Kelvin per Watts ($m^2 \cdot K/W$);

U heat transfer coefficient of the building envelope component in Watts per square metres per degrees Celsius ($W/m^2 \cdot °C$);

b temperature correction factor taking into account the temperature reduction, e.g. unheated space, unless it is already taken into account in the value of U.

Building envelope component in contact with ground:

If the building envelope component is in contact with the ground, the percentage of heat losses is calculated by:

$$x_l = 100 \cdot \frac{R_i}{\frac{A_G}{L_G} - R_i} \qquad [\%] \qquad (15)$$

where:

L_G is the steady state part of the heat loss coefficient according to EN ISO 13370;

A_G is the surface of the building envelope component in contact with the ground in square metres (m^2).

6.3 Control of the indoor temperature

6.3.1 General Approach

This method covers only control of the heat emission system and does not take into account the influences, which the control (central or local) may have on efficiency of the heat generation system and on heat losses from the heat distribution system.

A non-ideal control may cause temperature variations and drifts around the prefixed set point temperature, due to the physical characteristics of the control system, sensor locations and characteristics of the heating system itself. This may result in increased or decreased heat losses through the building envelope compared to heat losses calculated with the assumption of constant internal temperature. The ability to utilise internal gains (from people, equipment, solar radiation) depends on the type of heat emission system and control method (figure 3)

The heat loss due to control of the heat emission system may be calculated in different ways. The method to apply depends on the type of data available for the performance of the control system, i.e. either control efficiency, η_c (see 6.3.2), or equivalent increase in internal temperature, $\Delta\theta_i$ (see 6.3.3).

6.3.2 Method using control efficiency.

If efficiency of the control is given, the heat loss due to control of the heat emission system, $Q_{c,em}$, can be calculated as:

$$Q_{c,em} = \frac{1-\eta_c}{\eta_c} \cdot Q_h \qquad [J] \qquad (16)$$

where:

η_c efficiency of the control

Annex A provides examples of values for η_c

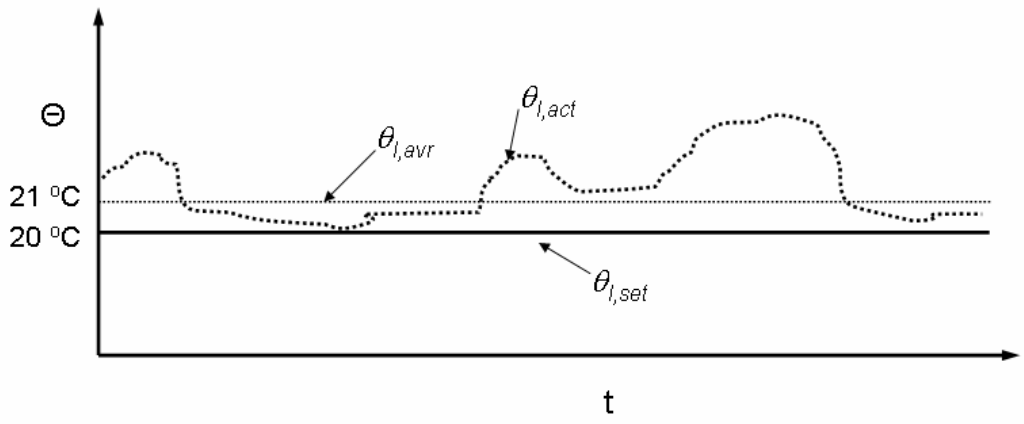

Figure 3: Effect of control accuracy as efficiency or equivalent increase in space temperature.

$\theta_{i,set}$ = Set point for internal temperature

$\theta_{i,act}$ = Actual internal temperature

$\theta_{i,avr}$ = Average internal temperature over the time period

t = time

6.3.3 Method using equivalent increase in internal temperature

The influence of the control is given by an equivalent increase in internal temperature. The heat loss due to control of the heat emission system may be calculated in two different ways:

— by multiplying the calculated building heat demand, Q_h, with a factor based on the ratio between the equivalent increase in internal temperature, $\Delta\theta_i$, and the average temperature difference for the heating season between the indoor and outdoor temperature for the space:

$$Q_{c,em,} = Q_h \cdot (1 + \Delta\theta_i / (\theta_i - \theta_{e,avg})) \quad [J] \quad (17)$$

— by recalculation of the building heat energy requirements, according to EN ISO 13790, using the equivalent increased internal temperature.

The second method gives more accurate results.

Annex B provides examples of values for the equivalent increase in internal temperature, $\Delta\theta_i$, for different types of heat emitters and controls.

6.4 Auxiliary energy, W_e

For each electrical device of the heat emission system, the following data has to be determined:

- electrical power;
- duration of operation;
- part of the electrical energy converted to heat and emitted into the heated space.

The electrical energy of fans used in local emitters is calculated by:

$$Q_{locfan} = P_{lacfan}.F_{clf}$$

where :

P_{locfan} : power of the fan (W)

F_{clf} : correction factor depending on the control of the local fan associated wit the emitter. This factor has to be fixed in a national Annex. If such date are not available, defaults values indicated in Annex B should be used

The recoverable energy from the local fan is calculated by

$$Q_{locfan,rec} = Q_{locfan} \cdot T_{auxrec}$$

T_{auxrec} can be taken equal to 1.

7 Recommended calculation methods.

One of the two methods outlined in this section are recommended. The two methods do not give exactly the same results but the same trend. The two methods shall not be mixed.

Other national methods used should fit into the general framework of three kind of additional losses.

The present standard will present two overall methods to calculate the additional heat losses and energy efficiency for heating emission systems. Section 7.1 and Annex A presents a method based on tabelized values for efficiencies described above. Section 7.2 and Annex B presents a method based on an equivalent increase in space temperature as described above.

7.1 Method using efficiencies

The evaluation of $Q_{\mathrm{l,em}}$ takes place monthly or other time period in accordance with equation (18).

$$Q_{\mathrm{l,em}} = \left(\frac{f_{\mathrm{Radiant}} f_{\mathrm{int}} f_{\mathrm{hydr}}}{\eta_{\mathrm{l,em}}} - 1 \right) Q_{\mathrm{h}} \tag{18}$$

where

$Q_{\mathrm{l,em}}$ is the additional loss of the heat emission (time period), in kWh;

Q_{h} is the net heating energy (time period) (EN ISO 13790), in kWh;

f_{hydr} is the factor for the hydraulic equilibrium.

f_{int} is the factor for intermittent operation (as intermittent operation is to be understood the time-dependent option for temperature reduction for each individual room space);

f_{Radiant} is the factor for the radiation effect (only relevant for radiant heating systems);

$\eta_{\mathrm{l,em}}$ is the total efficiency level for the heat emission in the room space.

f_{int} and f_{Radiant} are to be set to 1, insofar as they are not described in more detail in the following sections.

The total efficiency level $\eta_{\mathrm{l,em}}$ is fundamentally evaluated as

$$\eta_{\mathrm{h,ce}} = \frac{1}{(4 - (\eta_{\mathrm{L}} + \eta_{\mathrm{C}} + \eta_{\mathrm{B}}))} \tag{19}$$

where

η_{L} is the part efficiency level for a vertical air temperature profile;

η_{C} is the part efficiency level for room temperature control regulation;

η_{B} is the part efficiency level for specific losses of the external components (embedded systems).

In individual application cases this breakdown is not required. The annual expenditure for the heat emission in the room space is calculated as

$$Q_{\mathrm{l,em,a}} = \sum Q_{\mathrm{l,em}} \tag{20}$$

where

$Q_{\mathrm{l,em,a}}$ is the annual loss of the heat emission, in kWh;

$Q_{\mathrm{l,em}}$ is the loss of the heat emission (in the time period) in accordance with equation (18), in kWh.

7.2 Method using equivalent increase in internal temperature

The internal temperature is increased by:

- The spatial variation due to the stratification, depending on the emitter;
- The temporal variation depending on he capacity of the control device to assure an homogeneous and constant temperature.

The equivalent increase in internal temperature, $\theta_{l,e}$, taking into account the emitter, is calculated by:

$$\theta_{i,e} = \theta_{ii} + \Delta\theta_l + \Delta\theta_c \qquad (°C) \qquad (21)$$

where:

θ_{ii} initial internal temperature (°C);

$\Delta\theta_l$ spatial variation of temperature;

$\Delta\ \theta_c$ control accuracy.

The influence of an equivalent increase in internal temperature. of the heat emission system may be calculated in two different ways:

— by multiplying the calculated building heat demand, Q_h, with a factor based on the ratio between the equivalent increase in internal temperature, $\Delta\theta_{l,e}$, and the average temperature difference for the heating season between the indoor and outdoor temperature for the space:

$$Q_{c,em,} = Q_h \cdot (1 + \Delta\theta_{i,e} / (\theta_i - \theta_{e,avg})) \qquad [J] \qquad (22)$$

— by recalculation of the building heat energy requirements, according to EN ISO 13790, using the equivalent increased internal temperature. as the set point temperature of the conditioned zone. This second approach leads to a better accuracy.

The second method gives more accurate results.

Annex A
(informative)

ENERGY LOSSES OF THE HEAT EMISSION SYSTEM adapted from German regulation DIN 18599

A.1 Heat emission

In this section are prescribed the energy parameters that are required for heating system for determination of the losses associated with heat emission in the room space.

The evaluation of $Q_{l,em}$ takes place monthly or another time period in accordance with equation (23).

$$Q_{l,em} = \left(\frac{f_{Radiant} f_{int} f_{hydr}}{\eta_{l,em}} - 1 \right) Q_h \tag{23}$$

where

$Q_{l,em}$ is the additional loss of the heat emission (in the time period), in kWh;

Q_h is the net heating energy (in the time period) (EN ISO 13790), in kWh;

f_{hydr} is the factor for the hydraulic equilibrium.

f_{int} is the factor for intermittent operation (as intermittent operation is to be understood the time-dependent option for temperature reduction for each individual room space);

$f_{Radiant}$ is the factor for the radiation effect (only relevant for heating of large indoor spaces with h > 4 m);

$\eta_{l,em}$ is the total efficiency level for the heat emission in the room space.

f_{int} and $f_{Radiant}$ are to be set to 1, insofar as they are not described in more detail in the following sections.

The total efficiency level $\eta_{l,em}$ is fundamentally evaluated as

$$\eta_{h,ce} = \frac{1}{(4 - (\eta_L + \eta_C + \eta_B))} \tag{24}$$

where

η_L is the part efficiency level for a vertical air temperature profile;

η_C is the part efficiency level for room temperature regulation;

η_B is the part efficiency level for specific losses of the external components.

In individual application cases this breakdown is not required. The annual expenditure for the heat emission in the room space is calculated as

$$Q_{\mathrm{l,em,a}} = \sum Q_{\mathrm{l,em}} \tag{25}$$

where

$Q_{\mathrm{l,em,a}}$ is the annual loss of the heat emission, in kWh;

$Q_{\mathrm{l,em}}$ is the loss of the heat emission (in the time period) in accordance with equation (23), in kWh.

The part and total efficiencies levels prescribed in the following tables are based on the following assumptions:

- standard room heights $h \leq$ 4m (with the exception of large indoor space buildings with h > 4 m);
- domestic and non-domestic buildings;
- different heat protection levels;
- continuous mode of operation (intermittent modes of operation are taken into account via the data in EN ISO 13790 by means of the factor f_{int});
- reference to one room space in each case.

In this section system solutions not covered are to be taken from other documented sources

or

- are to be interpolated or matched in a suitable manner.

A.1.1 Efficiencies for free heating surfaces (radiators); room heights ≤4 m

In Table A1 the efficiencies for free heating surfaces are prescribed.

Table A1 — Efficiencies for free heating surfaces (radiators); room heights ≤4 m

Influence parameters		Efficiencies η_L		η_C	η_B
		η_{L1}	η_{L2}		
Room space temperature regulation	unregulated, with central supply temperature regulation			0.80	
	Master room space			0.88	
	P-controller (2 K)			0.93	
	P-controller (1 K)			0.95	
	PI-controller			0.97	
	PI-controller (with optimisation function, e.g. presence management, adaptive controller)			0.99	
Over-temperature (reference ϑ_i = 20 °C)	60 K (e.g. 90/70)	0.88			
	42.5 K (e.g. 70/55)	0.93			
	30 K (e.g. 55/45)	0.95			
specific heat losses via external components (GF = glass surface area)	radiator location internal wall		0.87		1
	radiator location external wall				
	- GF without radiation protection		0.83		1
	- GF with radiation protection[a]		0.88		1
	- normal external wall		0.95		1

[a] The radiation protection must prevent 80% of the radiation losses from the heating body to the glass surface area by means of insulation and/or reflection.

The determination of the total efficiencies $\eta_{h,ce}$ takes place in accordance with equation (24).

For h_L an average value is to be formed from the data for the main influence parameters "over-temperature" and "specific heat losses via external components".

$$\eta_L = (\eta_{L1} + \eta_{L2})/2 \tag{26}$$

EXAMPLE radiator external wall; over-temperature 42.5 K; P-controller (2 K)

$$\eta_L = (\eta_{L1} + \eta_{L2})/2 = (0.93 + 0.95)/2 = 0.94$$

$$\eta_C = 0.93$$

$$\eta_B = 1$$

$$\eta_{h,ce} = 1/(4 - (0.94 + 0.93 + 1)) = 0.88$$

Factor for intermittent operation f_{int} = 0.97

COMMENT For continuous operation f_{int} is set = 1.

Factor for radiation effect: $f_{Radiant}$ = 1.0

Factor for hydraulic balancing: f_{hydr}

1.00 Hydraulic balanced by automatic balancing valves at each raiser and group of 8 emitters.
1.03 Documented hydraulic balancing at installation or by commisioning.
1.05 For others

A.1.2 Efficiencies for component integrated heating surfaces (panel heaters) (room heights ≤4 m)

In table A2 the efficiencies for component integrated heating surfaces (panel heaters) (room heights ≤4 m) are prescribed.

Table A2 —Efficiencies for component integrated heating surfaces (panel heaters); room heights ≤4 m

influence parameters		Part efficiencies			
		η_L	η_C	η_B	
Room space temperature regulation	Heat carrier medium water				
	- unregulated		0.75		
	- unregulated, with central supply temperature regulation		0.78		
	- unregulated with average value formation ($\vartheta_V - \vartheta_R$)		0.83		
	- Master room space		0.88		
	- two-step controller/P-controller		0.93		
	- PI-controller		0.95		
	Electrical heating				
	-two-step controller		0.91		
	- PI-controller		0.93		
System	Floor heating			η_{B1}	η_{B2}
	- wet system	1		0.93	
	- dry system	1		0.96	
	- dry system with low cover	1		0.98	
	Wall heating	0.96		0.93	
	Ceiling heating	0.93		0.93	
Specific heat losses via laying surfaces	Panel heating without minimum insulation in accordance with DIN EN 1264				0.86
	Panel heating with minimum insulation in accordance with DIN EN 1264				0.95
	Panel heating with 100% better insulation than required by DIN EN 1264				0.99

The determination of the total efficiency $\eta_{h,ce}$ takes place in accordance with equation (28).

For η_B an average value is to be formed from the data for the main influence parameters "system" and "specific heat losses via laying surfaces".

$$\eta_B = (\eta_{B1} + \eta_{B2})/2 \qquad (27)$$

EXAMPLE Floor heating - wet system (water); two-step controller; floor heating with high level of heat protection

η_L = 1.0

η_C = 0.93

$\eta_B = (\eta_{B1} + \eta_{B2})/2 = (0.93 + 0.95)/2 = 0.94$

$\eta_{h,ce} = 1/(4 – (1.0 + 0.93 + 0.94)) = 0.88$

Factor for intermittent operation: f_{int} = 0.98

COMMENT For continuous operation f_{int} is set = 1.

Factor for radiation effect: $f_{Radiant}$ = 1.0

Factor for hydraulic balancing: f_{hydr}

1.00 Hydraulic balanced by automatic balancing valves at each raiser and group of 8 emitters.
1.03 Documented hydraulic balancing at installation or by commisioning.
1.05 For others

A.1.3 Efficiencies for electrical heating (room heights ≤4 m)

In Table A3 the efficiencies for electrical heating (room heights ≤4 m) are prescribed.

Table A3 — Efficiencies for electrical heating (room heights ≤4 m)

Influence parameters		Total efficiency $\eta_{h,ce}$
External wall region	E- direct heating P-controller (1 K)	0.91
	E- direct heating PI-controller (with optimisation)	0.94
	Storage heating unregulated without external temperature dependent charging and static/dynamic discharging	0.78
	Storage heating P-controller (1 K) with external temperature dependent charging and static/dynamic discharging	0.88
	Storage heating PID-controller with optimisation with external temperature dependent charging and static and continuous dynamic discharging	0.91
Internal wall region	E- direct heating P-controller (1 K)	0.88
	E- direct heating PI-controller (with optimisation)	0.91
	Storage heating unregulated without external temperature dependent charging and static/dynamic discharging	0.75
	Storage heating P-controller (1 K) with external temperature dependent charging and static/dynamic discharging	0.85
	Storage heating PID-controller with optimisation with external temperature dependent charging and static and continuous dynamic discharging	0.88

Factor for intermittent operation: f_{int} = 0.97 (to be used for electrical heating systems with an integrated feedback control system)

COMMENT For continuous operation f_{int} is set = 1.

Factor for radiation effect: $f_{Radiant}$ = 1.0

A.1.4 Efficiencies air heating/domestic ventilation (room heights ≤4 m)

Domestic ventilation systems are systems that supply and/or extract air, which supply residential buildings with external air, with heat recovery and air treatment possibly being present.

The efficiency $\eta_{h,ce}$ for air heating and domestic ventilation are described in DIN V 18599-6.

Should this be deleted in this standard???

A.1.5 Efficiencies air heating (non-domestic ventilation systems) (room heights ≤4 m)

In table A4 the efficiency $\eta_{h,ce}$ for air heating (non-domestic ventilation systems) (room heights ≤4 m) are prescribed.

Table A4 — Efficiencies for air heating (non-domestic ventilation systems) (room heights ≤4 m)

System configuration	Control parameter	$\eta_{h,ce}$	
		low quality of control	high quality of control
Additional heating in the incoming air (additional heater)	Room space temperature	0.82	0.87
	Room space temperature (cascade control of incoming air temperature)	0.88	0.90
	Exhaust air temperature	0.81	0.85
Recirculation air heating (induction equipment, ventilator convectors)	Room space temperature	0.89	0.93

COMMENT The auxiliary energy for the recirculation air heating is to be taken from Table 7. As values for ventilation systems with part heating function the data for domestic ventilation systems from DIN V 18599-6 can be used.

A.1.6 Efficiencies for room spaces with heights ≥4 m (large indoor space buildings)

In Table A5 the efficiencies for room spaces with heights from 4 m to 10 m are prescribed.

Table A5 — Efficiencies for room spaces with heights from 4 m to 10 m

Influence parameters			Part efficiencies					
			η_L				η_C	η_B
			4 m	6 m	8 m	10 m		
Room space	Unregulated						0.80	

temp. regulation	Two-step controller						0.93	
	P-controller (2 K)						0.93	
	P-controller (1 K)						0.95	
	PI-controller						0.97	
	PI-controller with optimisation						0.99	
Heating Systems	Warm air heating Air distribution with normal induction ratio, radiators	Air outlet at the side	0.98	0.94	0.88	0.83		1
		Air outlet above	0.99	0.96	0.91	0.87		1
	Warm air heating Air distribution additionally with regulated vertical recirculation	Air outlet at the side	0.99	0.97	0.94	0.91		1
		Air outlet above	0.99	0.98	0.96	0.93		1
	Hot water ceiling-mounted radiant panels		1.00	0.99	0.97	0.96		1
	Dark radiators (radiator tubes)		1.00	0.99	0.97	0.96		1
	Bright radiators		1.00	0.99	0.97	0.96		1
	Floor heating (high heat protection level)		1.00	0.99	0.97	0.96		
		Floor heating component integrated						0.95
		Floor heating thermally decoupled						1

Evaluation of large indoor space heating systems with heating radiators (existing buildings):

The warm air heating parameters with normal induction ratio, air outlet at the side, are to be applied. (should this be deleted)

Warm air heating systems with increased induction ratio of air distribution:

The parameters are determined by the arithmetic averaging of the parameters for the systems with air outlet at the side and above.

With the use of hot water ceiling-mounted radiant panels in room spaces with a height < 4 m the total efficiency $\eta_{h,ce}$ for a room height of 4 m is used. Furthermore the factor $f_{Radiant} = 1$.

The determination of the total efficiency $\eta_{h,ce}$ takes place in accordance with equation (24).

EXAMPLE Room height 8 m, warm air heating with air outlet above, P-controller (1 K)

$\eta_L = 0.91$

$\eta_C = 0.95$

$\eta_B = 1$

$\eta_{ges} = 1/(4 - (0.91 + 0.95 + 1)) = 0.88$

Factor for radiation effect: $f_{Radiant} = 0.85$ for ceiling-mounted radiant panels, bright radiators, dark radiators and floor heating.

The energy parameters of the efficiencies of heating systems in large indoor spaces and the factor $f_{Radiant}$ represent average values for the heating systems and types of products, which can also approximately be used for configurations that deviate from these.

A.1.7 Efficiencies for room spaces with heights > 10 m

In Table A6 the efficiencies for room heights > 10 m) are prescribed.

Table A6 — Efficiencies for room spaces with heights > 10 m

Influence parameters			Part efficiencies				
			η_L			η_C	η_B
			12 m	15 m	20 m		
Room space temp. regulation	Unregulated					0.80	
	Two-step controller					0.93	
	P-controller (2 K)					0.93	
	P-controller (1 K)					0.95	
	PI-controller					0.97	
	PI-controller with optimisation					0.99	
Heating systems	Warm air heating	Air outlet at the side	0.78	0.72	0.63		1
	Air distribution with normal induction ratio	Air outlet above	0.84	0.78	0.71		1
	Warm air heating	Air outlet at the side	0.88	0.84	0.77		1
	Air distribution additionally with regulated vertical recirculation	Air outlet above	0.91	0.88	0.83		1
	Hot water ceiling-mounted radiant panels		0.94	0.92	0.89		1
	Dark radiator (radiator tubes)		0.94	0.92	0.89		1
	Bright radiators		0.94	0.92	0.89		1
	Floor heating (high heat protection level)		0.94	0.92	0.89		
		Floor heating component integrated					0.95
		Floor heating thermally decoupled					1

Warm air heating systems with increased induction ratio of air distribution:

The parameters are determined by the arithmetic averaging of the parameters for the systems with air outlet at the side and above.

The determination of the total efficiency $\eta_{h,ce}$ takes place in accordance with equation (24).

EXAMPLE Room height 12 m. dark radiators, P-controller (2 K)

η_L = 0.94

η_C = 0.93

η_B = 1

η_{ges} = 1/(4 –(0.94 + 0.93 + 1)) = 0.88

Factor for radiation effect: $f_{Radiant}$ = 0.85 for ceiling-mounted radiant panels, bright radiators, dark radiators and floor heating.

The energy parameters of the efficiencies of heating systems in large indoor spaces and the factor $f_{Radiant}$ represent average values for the heating systems and types of products, which can also approximately be used for configurations that deviate from these.

A.1.8 Auxiliary energy $Q_{H,ce,aux}$

With equation (28) the auxiliary energy is balanced that serves to improve the heat emission processes in the room space and is not recorded in the above calculations.

$$Q_{h,ce,aux} = Q_C + Q_{V,P} \tag{28}$$

where

$Q_{h,ce,aux}$ is the auxiliary energy (in the period), in kWh;

Q_C is the auxiliary energy of the control system (in the period), in kWh;

$Q_{V,P}$ is the auxiliary energy of ventilators, fans and additional pumps (in the period), in kWh;

The individual components Q_c and $Q_{V,P}$ are to be determined from equations (29) and (30) respectively.

$$Q_C = \frac{P_C \cdot d_{mth} \cdot 24}{1000} \tag{29}$$

$$Q_{V,P} = \frac{\left(P_V \cdot n_V + P_P \cdot n_P\right) \cdot t_{h,rL}}{1000} \tag{30}$$

where

P_C is the electrical rated power consumption of the control system with auxiliary energy (from Table A7 or product data), in W;

d_{mth} is the number of days in the period;

n_V is the number of ventilator/fan units;

n_P is the number of additional pumps;

P_V is the electrical rated power consumption of the ventilators/fans (from Table A8 or product data), in W;

P_P is the electrical power consumption of the pump from manufacturer data, in W

or

$$P_P = 50 \cdot \left[\dot{Q}_{LH}\right]^{0,08} \tag{31}$$

where

$\dot{Q}_{LH}$ is the electrical rated power consumption of the air heater, in kW.

COMMENT The electrical rated power consumption of an additional pump may only be applied if the hydraulic circuit of the air heater requires an additional pump (e.g. injection circuit), which is not already taken into account in the heat distribution.

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

The operating duration of the ventilator/fan and/or pump is set equal to the operating time of the heating system.

Table A7 — Standard values for the auxiliary energy for the control system

Influence parameters		Power W
Control system with auxiliary energy P_C	Electrical control system with electrical motor actuation	0.1 (per actuator)
	Electrical control system with electro thermal actuation	1.0 (per actuator)
	Electrical control system with electromagnetic actuation	1.0 (per actiator)

Table A8 — Standard values for the auxiliary energy of fans for air supply in room spaces h ≤4 m

Influence parameters		**Power** W
Ventilator/ fan P_V	Fan convector	10
	E- direct heating fan convector	10
	Storage heating with dynamic discharge	12
	Storage heating with continuous dynamic discharge	12

A.1.8.1 Auxiliary energy in large indoor space buildings (h > 4 m) – systems with direct heating

In large indoor space buildings in particular, heating equipment is used, the method of working of which cannot logically be differentiated into sub-systems of heat generation and heat emission, and which at the same time is installed in the room space in which it is used (e.g. gas and infrared radiators).

The total auxiliary energy of these systems is credited to the heat demand of the installation room space (see Table A9, upper section).

$$Q_{h,ce,aux} = \frac{P_{h,aux} \cdot t_{h,rL}}{1000} \qquad (32)$$

A.1.8.2 Auxiliary energy in large indoor space buildings (h > 4 m) – systems without direct heating

For large indoor space heating systems with a central heat generator and a separate unit for heat emission into the working space only the auxiliary energy for the heat emission of these systems is credited to the room space heat demand (see table A9, lower section).

$$Q_{\text{h,ce,aux}} = \frac{P_{\text{h,aux}} \cdot t_{\text{h,rL}}}{1000} \tag{33}$$

where (for equations (32) and (33))

$Q_{\text{h,ce,aux}}$ is the monthly auxiliary energy (heat emission and, if necessary, heat generation in accordance with equation (32)), in kWh;

$P_{\text{h,aux}}$ is the rated power consumption of the equipment from Table A9 or manufacturer data (heat generation and heat emission), in W;

$P_{\text{h,ce,aux}}$ is the rated power consumption of the equipment from Table A9 or manufacturer data (heat emission), in W;

$t_{\text{h,rL}}$ is the monthly or other period analytical running time, in h.

The operating duration of the ventilator/fan including control system is set equal to the operating time of the heating system.

In Table A9 are prescribed the standard values for the auxiliary energy of fans and for the control system in room spaces h > 4 m in height (large indoor space buildings).

Table A9— Standard values for the auxiliary energy of fans and for the control system in room spaces h > 4 m in height (large indoor space buildings).

Influence parameters		Power W
$P_{h,aux}$ Directly heated heat generator (installed in the working space)	Bright radiators (control and regulation)	25 (per unit)
	Dark radiators up to 50 kW (control, regulation and fan for combustion air supply)	80 (per unit)
	Dark radiators above 50 kW (control, regulation and fan for combustion air supply)	100 (per unit)
	Warm air generator with atmospheric burner and recirculation air axial fan (control, regulation and fan for combustion air supply)	$0.014 \cdot Q_{h,b}$
	Warm air generator with fan-assisted burner and recirculation air radial ventilator (control, regulation and fan for combustion air supply, fan for warm air supply)	$0.022 \cdot Q_{h,b}$
$P_{h,ce,aux}$ Heat emission system air heating	Air heater in working space (room height < 8 m) (central heat generator with indirectly heated air heater)	$0.012 \cdot Q_{h,b}$
	Air heater in working space (room height > 8 m) (central heat generator with indirectly heated air heater)	$0.016 \cdot Q_{h,b}$
	Vertical recirculation fan (room height < 8 m)	$0.002 \cdot Q_{h,b}$
	Vertical recirculation fan (room height > 8 m)	$0.013 \cdot Q_{h,b}$

COMMENT The connected ratings prescribed in Table A8 represent average values for the equipment technology. Parameters for auxiliary energy heat generators are only introduced, insofar as these are not taken into account in 6.4.3.4.

$Q_{h,b}$ is determined from 4.1.

The annual resource is determined in accordance with equation (25).

Type of control of the local fan	F_{clf}
Permanent operation of the local fan during the heating period	1
The fan is stopped when the heating is off	0 during off period 1 during on period
The fan is stopped when the heating is off and is regulated according to heating needs in on period	0 during off period 0.5 during on period

Annex B
(Informative)

Equivalent increase in internal temperature - adapted from the French regulation RT2005

B.1 General

The internal temperature is increased by:

- The spatial variation due to the stratification, depending on the emitter;
- The temporal variation depending on he capacity of the control device to assure an homogeneous and constant temperature.

The equivalent increase in internal temperature, $\theta_{I,e}$, taking into account the emitter, is calculated by:

$$\theta_{i,e} = \theta_{ii} + \Delta\theta_l + \Delta\theta_c \qquad (°C) \qquad (21)$$

where:

θ_{ii} initial internal temperature (°C);

$\Delta\theta_l$ spatial variation of temperature;

$\Delta\ \theta_c$ control accuracy.

The increased internal temperature is used in the calculation instead of the initial internal temperature.

Remarks:

The spatial variations of temperatures may depend on the thermal load. Tables B1 and B2 provide values for minimal and nominal thermal load.

B.2 Zones

When the considerations according to 4.8 imply splitting of the heating system into zones, i.e. groups of space, calculation of the internal temperature is done for each zone. The internal temperature of a zone is obtained by considering the internal temperature of the associated spaces. The coefficient of weighting are determined from the surface of each space.

B.3 Spatial variation

The spatial variation depends on:

- Type of heat emitter;
- Ceiling height.

Table B.1 indicates the spatial variation classes according to the type of emitter and the ceiling height.

Table B.2 provides additional information's for radiators depending on the water temperature level and the thermal load.

Table B.1 spatial variations by type of emitter and the corresponding spatial class at nominal load

		Spatial variation for ceiling height			
Class of spatial variation	Heat emitter	< 4m	Between 4 and 6 m	Between 6 and 8m	> 8m
A	Floor	0	0	0	0
B	Air with air return < 3m Radiative emitters Low temperature emitters Radiated ceiling panels Fan coils with discharge air at the bottom	0.2	0.8	1.2	1.6
C	Other emitters	0.4	1.2	2	2.8

Table B.2 spatial variations for radiators depending on water temperature and thermal load

Excess Temperature Reference internal temperature : 20°C	Off	Nominal load
$\Delta T > 40$ K	0	0.4
$\Delta T \leq 40$ K	0	0.2

For other thermal load, the spatial variation is determined by linear interpolation.

B.4 Control accuracy

The control accuracy depends on the emitter and the associated control system.

Table 1 indicates for the different types of products the applicable standards and the relevant certifications

Table 1 — Control accuracy

	Standard	**Certification**	**Control accuracy $\Delta\ \theta_c$ (K)**
			heating
Direct electric emitter with built in controller	NF EN 60 675	NF Performance categorie C	0,9
Thermostatic radiator valve	NF EN 215	CENCER	0,45*(hysteresis+ water temperature effect)[1]
Individual zone control equipment	Pr EN 15500	EUBAC cert	Cah[2] (defined in the standard and certified)
Other controller if emission can be totally stopped			1,8

Annex C
(Informative)

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