Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2-3: Space heating distribution systems

Einführendes Element — Haupt-Element — Teil 2-3: Ergänzendes Element

Systèmes de chauffage dans les bâtiments — Élément central — Partie 2-3 : Élément complémentaire

ICS:

Descriptors:

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Foreword

This document (prEN 15316-2-3:2005) 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

In a distribution system, energy is transported by a fluid from the heat generation to the heat emission. As the distribution system is not adiabatic, part of the energy carried is emitted to the surrounding environment. Energy is also required to distribute the heat carrier fluid within the distribution system. In most cases this is electrical energy required by the circulation pumps. This leads to additional thermal and electrical energy demand.

The thermal energy emitted by the distribution system and the electrical energy required for the distribution may be recovered as heat if the distribution system is placed inside the heated envelope of the building.

This standard provides three methods of calculation.

The detailed calculation method describes the basics and the physical background of the general calculation method. The required input data are part of the detailed project data assumed to be available (such as length of pipes, type of insulation, manufacturer's data for the pumps, etc.). The detailed calculation method provides the most accurate energy demand and heat emission.

For the simplified calculation method, some assumptions are made for the most relevant cases, reducing the required input data (e.g. the length of pipes are calculated by approximations depending on the outer dimensions of the building and efficiency of pumps are approximated). This method may be applied if only few data are available (in general at an early stage of design). With the simplified calculation method, the calculated energy demand is generally higher than the calculated energy demand by the detailed calculation method. The assumptions for the simplified method depend on national designs. Therefore this method is part of Annex A.

The tabulated calculation method is based on the simplified calculation method with some further assumptions being made. Only input data for the most important influences are required with this method. The further assumptions depend on national design also. Therefore the tabulated method is part of Annex A also.

Other influences, which are not reflected by the tabulated values, shall be calculated by the simplified or the detailed calculation method. The energy demand determined from the tabulated calculation method is generally higher than the calculated energy demand by the simplified calculation method. Use of this method is possible with a minimum of input data.

The general calculation method for the electrical energy demand of pumps consists of two parts. The first part is calculation of the hydraulic demand of the distribution system and the second part is calculation of the expenditure energy factor of the pump. Here, it is possible to combine the detailed and the simplified calculation method. For example, calculation of pressure loss und flow may be done by the detailed calculation method and calculation of the expenditure energy factor may be done by the simplified calculation method (when the data of the building are available and the data of the pump are not available) or vice versa.

In national annexes, the simplified calculation method as well as the tabulated calculation method could be applied through a. o. relevant boundary conditions of each country, thus facilitating easy calculations and quick results. In national annexes it is only allowed to change the boundary conditions. The calculation methods must be used as described. The recoverable energy of the auxiliary energy demand is given as a fixed ratio and is therefore also easy to determine.

1 Scope

This standard provides a methodology to calculate/estimate the heat emission of water based distribution systems for heating and the auxiliary energy demand, as well as the recoverable energy. The actual recovered energy depends on the gain to loss ratio. Different levels of accuracy corresponding to the needs of the user and the input data available at each design stage of the project are defined in the standard. The general method of calculation can be applied for any time-step (hour, day, month or year).

Pipework lengths for the heating of decentralised non-domestic ventilation systems equipment are to be calculated in the same way as for water based heating systems. For central non-domestic ventilation systems equipment the length is to be specified in accordance with its location.

NOTE: It is possible to calculate the heat emission and auxiliary energy demand for cooling systems with the same calculation methods as shown in this standard. Specifically, determination of auxiliary energy demand is based on the same assumtions for efficiency of pumps, because the standard curve is an approximation for inline and external motors. It has to be decided by the standardisation group of CEN if the extension for cooling systems should be made in this standard. This is also valid for distribution systems in HVAC (in ducts) and also for special liquids.

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

EN ISO 13790, *Thermal performance of buildings - Calculation of building energy demand for heating (ISO 13790: 2004)*

3 Symbols, units and indices

For the purposes of this standard, the symbols, units and indices given in Table 1 apply.

Table 1 — Symbols, units and indices

A	Heated floor in the zone [m²]	
B	Building width	[m]
c_P	Specific heat capacity	[kJ/kg K]
$e_{d,e}$	Expenditure energy factor for operation of circulation pump	[-]
f_S	Correction factor for supply flow temperature control	[-]
f_{NET}	Correction factor for hydraulic networks (layout)	[-]
f_{SD}	Correction factor for heating surface disign	[-]
f_{HB}	Correction factor for hydraulic balance	[-]
$f_{G,PM}$	Correction factor for generators with integrated pump management	[-]
f_{PL}	Correction factor for partial load characteristics	[-]
f_C	Correction factor for control of the pump	[-]
f_{PSP}	Correction factor for selection of design point	[-]
f_ϑ	Correction factor for differential temperature dimensioning	[-]

$f_{\dot{q}}$	Correction factor for surface related heating load	[-]
f_{η}	Correction factor for efficiency	[-]
L	Building length	[m]
$L_{\max}$	Maximum length of pipe	[m]
$\overline{m}$	ratio of flow over the heat emitter to flow in the ring	[-]
n	exponent of the emission system	[-]
n_G	Number of floors	[-]
Δp	Differential pressure at design point	[kPa]
Δp_{HS}	Differential pressure of heating surfaces	[kPa]
Δp_{CV}	Differential pressure of control valves for heating surfaces	[kPa]
Δp_{ZV}	Differential pressure of zone valves	[kPa]
Δp_G	Differential pressure of heating supply	[kPa]
Δp_{FH}	Differential pressure of floor heating systems	[kPa]
Δp_{ADD}	Differential pressure of additional resistances	[kPa]
P_{hydr}	Hydraulic power at design point	[W]
P_{Pump}	Actual power input	[W]
$P_{Pump,ref}$	Reference power input	[W]
$\dot{Q}_N$	design heating load	[kW]
$Q_{d,r,w}$	Recoverable energy into heating water	[kWh/timstep]
$Q_{d,r,a}$	Recoverable energy into surrounding air	[kWh/timstep]
R	Pressure loss in pipes	[kPa/m]
t_H	Heating hours per year	[h/year]
U_L	linear thermal transmittance	[W/mK]
$\dot{V}$	Flow in design point	[m³/h]
$\dot{V}_{\min}$	minimum volume flow	[m³/h]
$W_{d,e}$	Electrical energy demand	[kWh/year]
$W_{d,e}''$	Electrical energy demand (tabulated)	[kWh/year]
$W_{d,e,M}$	Monthly total electrical energy demand	[kWh/month]
$W_{d,hydr}$	Hydraulic energy demand	[kWh/year]
z	Resistance ratio of components	[-]
α	time factor	[-]
α_{setb}	set back time factor	[-]
$\Delta\vartheta_{HK}$	Dimensioned heating system temperature difference	[K]
η_P	Efficiency of pump at design point	[-]
β_D	Mean part load of the distribution	[-]
ρ	Specific density	[kg/m³]
ϑ_i	surrounding temperature	[° C]
ϑ_m	mean medium temperature	[° C]
ϑ_u	temperature in unheated space	[° C]

ϑ_s	supply temperature	[° C]
ϑ_r	return temperature	[° C]
ϑ_{sa}	design supply temperature	[° C]
ϑ_{ra}	design return temperature	[° C]

4   Principle of the method and definitions

The method allows the calculation of the heat emission and the auxiliary energy demand of water based distribution systems for heating circuits (primary and secondary) as well as the recoverable energy. As shown in Figure 1 a heating system can divided in three parts – emission and control, distribution and generation. An easy heating system has no buffer-storage and no distributor/collector and also only one pump. Larger heating systems have more then one heating circuits with different emitters as so called secondary heating circuits. Mostly such heating systems have also more than one heat generator (individual or equal) with so called primary heating circuits (in figure 1 only one primary circuit is shown). The subdivision in primary and secondary circuits is given by any hydraulic separator which can be a buffer-storage with a large volume or a hydraulic separator with a small volume. Anyhow the calculation method is valid for a closed heating circuit and therefore the equations have to used for each circuit taking into account the corresponding values.
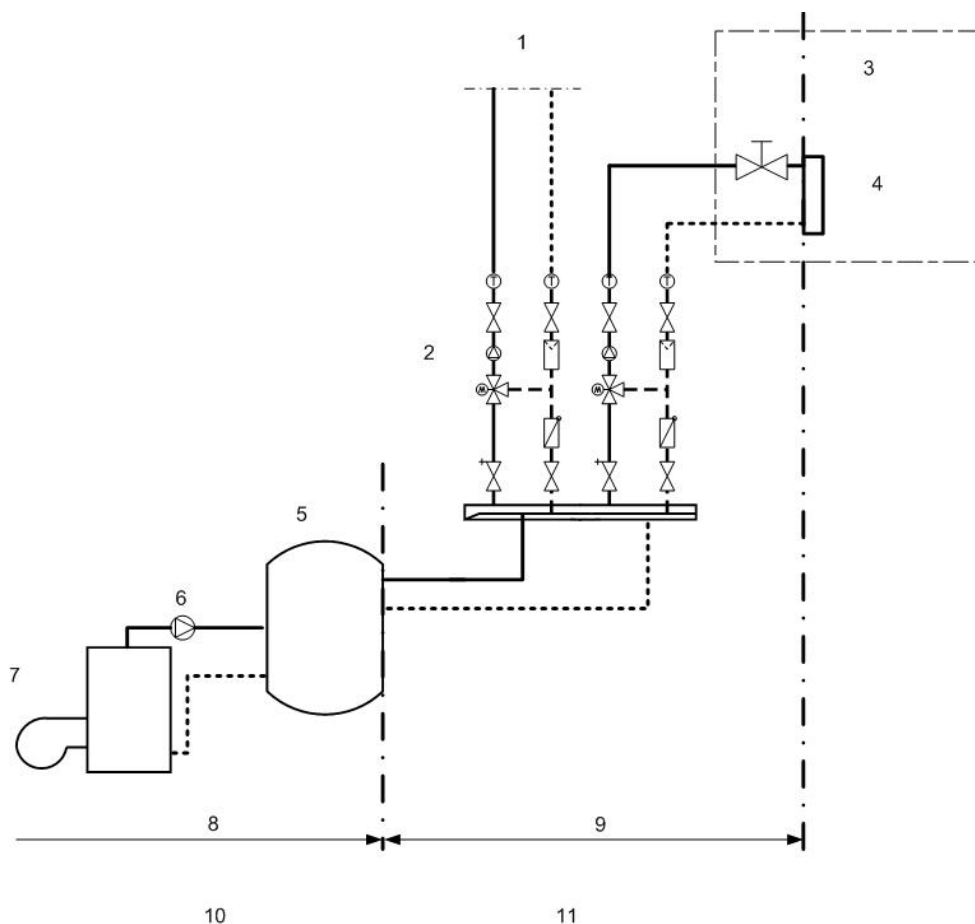

Figure 0 - Scheme distribution and definitions of heating circuits

Key

1   Next heating circuit
2   pump
3   room
4   emission
5   buffer-storage
6   pump
7   generator
8   generation
9   distribution
10   primary heating circuits
11   secondary heating circuits

Controls in distribution systems are thermostatic valves at the emitter which throttles the flow or room thermostats which shut on/off the pump. Only if the flow is throttled the control of the pump (speed control) is valid.

5   Electrical energy demand – Auxiliary energy demand

5.1 General

The auxiliary energy demand of hydraulic networks depends on the distributed flow, the pressure drop and the operation condition of the pump. While the design flow and pressure drop is important for determining the pump size, the part load factor determines the energy demand in a time step. The hydraulic power at the design point can be calculated from physical basics. However, for calculation of the hydraulic power during operation, this can only be achieved by a simulation. Therefore, for the detailed calculation method in this standard correction factors are applied, which represent the most important influences on auxiliary energy demand, such as part load, controls, design criteria, etc. The general calculation approach is to separate the hydraulic demand, which depends on the design of the network, and the expenditure energy for operation of the pump, which take into account the efficiency of the pump in general. However, for calculation of the expenditure energy during operation, the knowledge of the efficiency of the pump at each operation point is required, Therefore, for the detailed calculation method in this standard correction factors are applied also, which represent the most important influences an expenditure energy, such as efficiency, part load, design point selection and control.

All the calculations are made for a zone of the building with the affiliated area, length, width, height and levels.

5.2 Design Hydraulic power

For all the calculations, the hydraulic power and the differential pressure of the distribution system at the design point are important. The hydraulic power is given by:

$$P_{hydr} = 0,2778 \cdot \Delta p \cdot \dot{V} \qquad [W] \qquad (1)$$

where:

$\dot{V}$ Flow at design point [m³/h]

Δp Differential pressure at design point [kPa]

The flow is calculated from the heat load $\dot{Q}_N$ of the zone (design heat load according to EN 12831) and the design temperature difference $\Delta\vartheta_{HK}$ of the heating system

$$\dot{V} = \frac{3600 \cdot \dot{Q}_N}{c_P \cdot \rho \cdot \Delta\vartheta_{HK}} \qquad \text{[m³/h]} \qquad (2)$$

where:

c_P Specific heat capacity [kJ/kg K]

ρ Density [kg/m³]

$\Delta\vartheta_{HK}$ Design temperature difference [K]

The differential pressure for a zone at the design point is determined by the resistance in the pipes (including components) and the additional resistances (the most important are listed below):

$$\Delta p = (1+z) \cdot R \cdot L_{max} + \Delta p_{HS} + \Delta p_{CV} + \Delta p_{ZV} + \Delta p_G + \Delta p_{ADD} \qquad \text{[kPa]} \qquad (3)$$

where:

z Resistance ratio of components [-]

R Pressure loss per m [kPa/m]

L_{max} Maximum pipe length of the heating circuit [m]

Δp_{HS} Differential pressure of heating surface [kPa]

Δp_{CV} Differential pressure of control valve for heating surface [kPa]

Δp_{ZV} Differential pressure of zone valves [kPa]

Δp_G Differential pressure of heat supply [kPa]

Δp_{ADD} Differential pressure of additional resistances [kPa]

5.3 Detailed Calculation Method

5.3.1 Input- / Output data

The input data for the detailed calculation method are listed below. These are all part of the detailed project data.

P_{hydr} Hydraulic power at the design point for the zone [in W], calculated by the knowledge of

$\dot{Q}_N$ Design heat load of the zone according to EN 12831

$\Delta\vartheta_{HK}$ Design temperature difference for the distribution system in the zone [K]

L_{max} Maximum pipe length of the heating circuit in the zone [m]

Δp Differential pressure of the circuit in the zone [kPa]

β_D Mean part load of the distribution [-]

t_H Heating hours per year [h/year]

f_S Correction factor for supply flow temperature control [-]

f_{NET} Correction factor for hydraulic networks [-]

f_{SD}	Correction factor for heating surface dimensioning [-]
f_{HB}	Correction factor for hydraulic balance [-]
	Pump control
$e_{d,e}$	Expenditure energy factor for operation of the circulation pump [-], calculated by this standard,

using:

f_{η}	Correction factor for efficiency [-]
f_{PL}	Correction factor for part load [-]
f_{PSP}	Correction factor for design point selection [-]
f_C	Correction factor for control of the pump [-]

Design temperature level

emitter type

Intermittent operation

The output data are:

$W_{d,e}$	Total electrical energy demand [kWh/year]
$W_{d,e,M}$	Monthly total electrical energy demand [kWh/month]
$Q_{d,r,w}$	Recoverable energy to the water [kWh/timstep]
$Q_{d,r,a}$	Recoverable energy to the surrounding air [kWh/timstep]

5.3.2 Calculation Method

The electrical energy demand for circulation pumps for water based heating systems is calculated by:

$$W_{d,e} = W_{d,hydr} \cdot e_{d,e} \qquad (4)$$

where

$W_{d,e}$	Electrical energy demand [kWh/year]
$W_{d,hydr}$	Hydraulic energy demand [kWh/year]
$e_{d,e}$	Expenditure energy factor for operation of circulation pump [-]

The hydraulic energy demand for the circulation pumps in heating systems is determined from the hydraulic power at the design point (P_{hydr}), the mean part load of the distribution (β_D) and the heating hours in the time step (t_H):

$$W_{d,hydr} = \frac{P_{hydr}}{1000} \cdot \beta_D \cdot t_H \cdot f_S \cdot f_{NET} \cdot f_{SD} \cdot f_{HB} \cdot f_{G,PM} \qquad \text{(kWh/year)} \qquad (5)$$

where:

P_{hydr}	Hydraulic power at design point [W]

β_D	Mean part load of the distribution [-]
t_H	Heating hours per year [h/year]
f_S	Correction factor for supply flow temperature control [-]
f_{NET}	Correction factor for hydraulic networks [-]
f_{SD}	Correction factor for heating surface dimensioning [-]
f_{HB}	Correction factor for hydraulic balance [-]
$f_{G,PM}$	Correction factor for generators with integrated pump management [-]

The correction factors, f_S, f_{NET} and f_{SD} include the most important parameters related to dimensioning of the heating system. The factor f_{HB} take into account the hydraulic balance of the distribution system. The correction factor $f_{G,PM}$ for generators with integrated pump management take into account the reduction of operation time in relation to the heating time.

5.3.3 Correction factors

The correction factors are based on a wide range of simulations of different networks. Some of the correction factors can not changed without changing the method. Correction factors which are based on assumptions can be changed on national requirements (see Annex A.1.3).

5.3.3.1 Correction factor for supply flow temperature control f_S

$f_S = 1$ for systems with outdoor temperature compensation

f_S see Figure 1, for systems without outdoor temperature compensation (i.e. constant flow tempera-ture) or very much higher flow temperature than necessary

Key
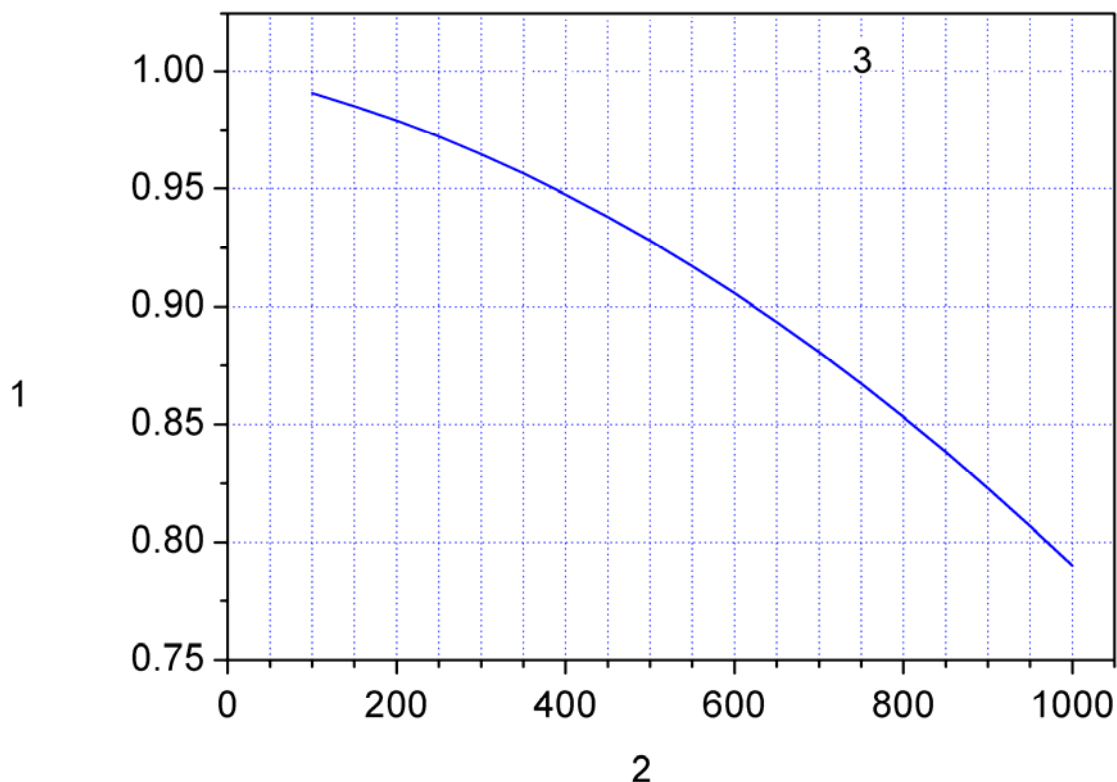
1   Correction factor f_S [-]
2   Ground plan A_N [m²]
3   Flow temperature characteristics

Figure 1 — Correction factor f_S for constant flow temperature and very much higher flow temperature

5.3.3.2   Correction factor for hydraulic networks f_{NET}

$f_{NET} = 1$ for a two-pipe ring line horizontal layout (on each floor)

f_{NET} see Table 2 for other types of layout

Table 2 — Correction factors for hydraulic network

Network design	One family house	Dwellings
2 – pipe system		
Ring line	1,0	1,0
Ascending – pipe	0,93	0,92
Star-shaped	0,98	0,98

The star-shaped network design is also valid for floor heating systems.

For one-pipe heating systems, the correction factor f_{NET} is given by

$$f_{NET} = 8,6 \cdot \overline{m} + 0,7 \tag{6}$$

where:

$\overline{m}$ ratio of flow over the heat emitter to flow in the ring [-]

5.3.3.3 Correction factor for heating surface dimensioning f_{SD}

$f_{SD} = 1$ for dimensioning according to design heat load

$f_{SD} = 0,96$ in case of additional over-sizing of the heating surfaces

5.3.3.4 Correction factor for hydraulic balance f_{HB}

See Annex A.1.3

5.3.3.5 Correction factor for generators with integrated pump management $f_{G,PM}$

See Annex A.1.3

5.3.4 Expenditure energy factor

For assessment of partial load conditions and control performance of the circulation pump, the expenditure energy factor is determined by:

$$e_{d,e} = f_\eta \cdot f_{PL} \cdot f_{PSP} \cdot f_C \tag{7}$$

where

f_η Correction factor for efficiency [-]

f_{PL} Correction factor for part load [-]

f_{PSP} Correction factor for design point selection [-]

f_C Correction factor for control [-]

With these four correction factors, the expenditure energy factor take into account the most important influences on the energy demand, representing the design, the efficiency of the pump, the part load and the control.

The physical relations are shown in Figure 2.
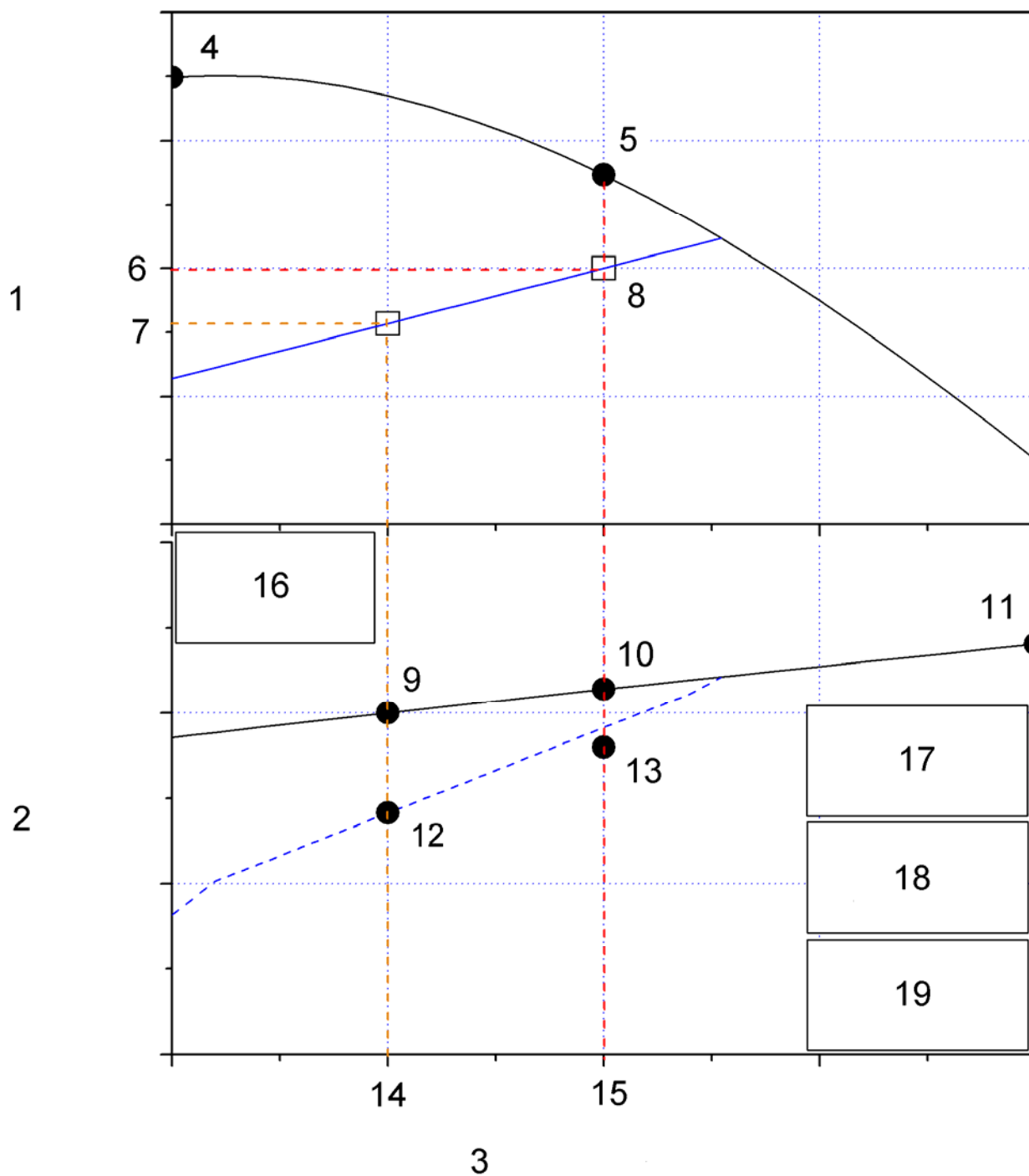
Key

1	Pressure Head H [m]	2	Power P_1 [W]
3	Flow rate [m³/h]	4	$H_{0,max}$
5	H_{pump}	6	H_{Ausl}
7	H_{PL}	8	P_{hydr}
9	P_{PL}	10	P_{pump}
11	$P_{pump,max}$	12	$P_{PL,C}$

13 $P_{pump,ref}$

14 $\dot{V}_{PL}$ 15 $\dot{V}$

16 $f_{PL} = \dfrac{P_{PL,C}}{P_{PL}}$ 17 $f_{PSP} = \dfrac{P_{pump}}{P_{pump,ref}}$

18 $f_\eta = \dfrac{P_{pump,ref}}{P_{hydr}}$ 19 $f_{PL} = \dfrac{P_{PL}}{\beta_D \cdot P_{pump}}$

Figure 2 — Expenditure energy - physical interpretation of the correction factors

5.3.4.1   Correction factor for efficiency f_η

The correction factor for efficiency is given by the relation between the reference power input at the design point and the hydraulic power at the design point.

$$f_\eta = \frac{P_{Pump,ref}}{P_{hydr}} \tag{8}$$

The reference power input is calculated by means of the pump characteristic line:

$$P_{Pump,ref} = P_{hydr} \cdot \left(1,25 + \left(\frac{200}{P_{hydr}} \right)^{0,5} \right) \tag{9}$$

5.3.4.2   Correction factor for part load f_{PL}

The correction factor for part load take into account the reduction of pump efficiency by partial load. It also take into account the hydraulic characteristics of non-controlled pumps. The impact of the partial load on the pipe system, and thus on the hydraulic energy demand, is taken into account by the mean part load of the distribution β_D, according to 5.3.2.

Figure 3 shows the correction factor for part load of the pump depending on the mean part load of the distribution.
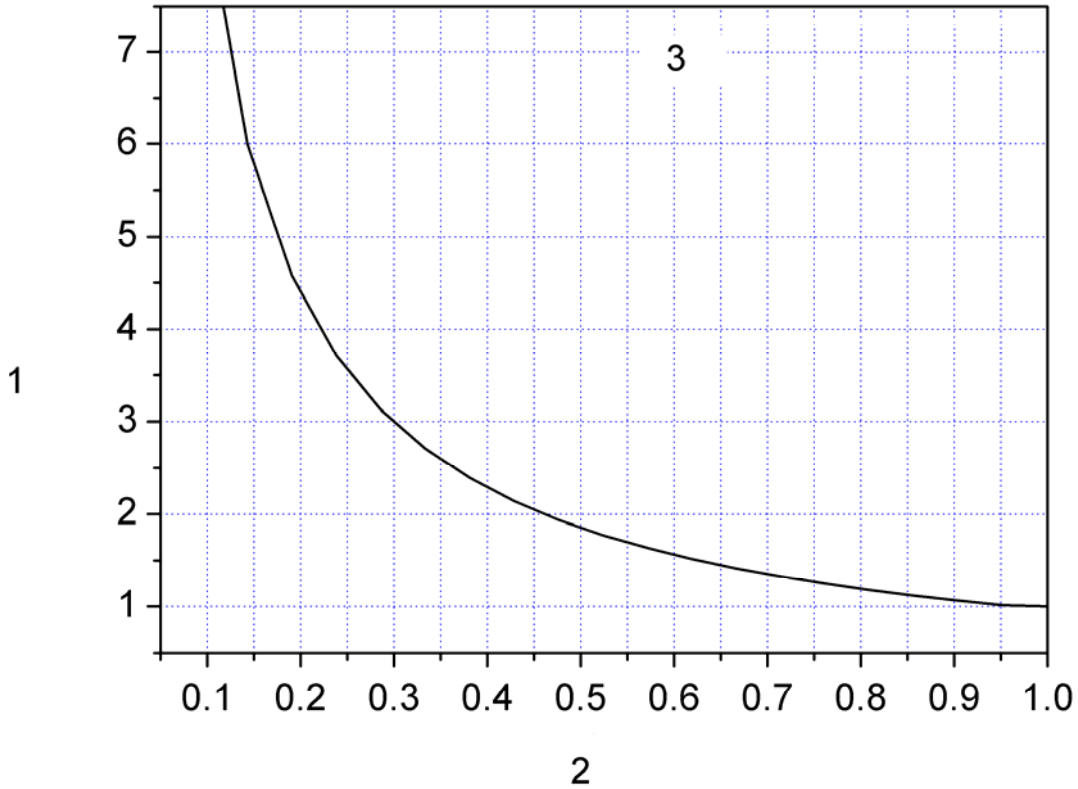
Key

12 Correction factor f_{PL} [-]
13 Mean part load of distribution β_D
14 Mean part load Ratio (PLR)

Figure 3 — Correction factor for part load of the pump

5.3.4.3 Correction factor for design point selection f_{PSP}

The correction factor for design point selection f_{PSP} is given by the relation between the actual power input of the pump and the reference power input at the design point:

$$f_{PSP} = \frac{P_{Pump}}{P_{Pump,ref}} \qquad (10)$$

where

P_{Pump} actual power input of pump at design point [W]

$P_{Pump,ref}$ reference power input of pump at design point [W]

5.3.4.4 Correction factor for control of the pump f_C

$f_C = 1$ for non-controlled pumps

f_C see Figure 4 for controlled pumps

Key
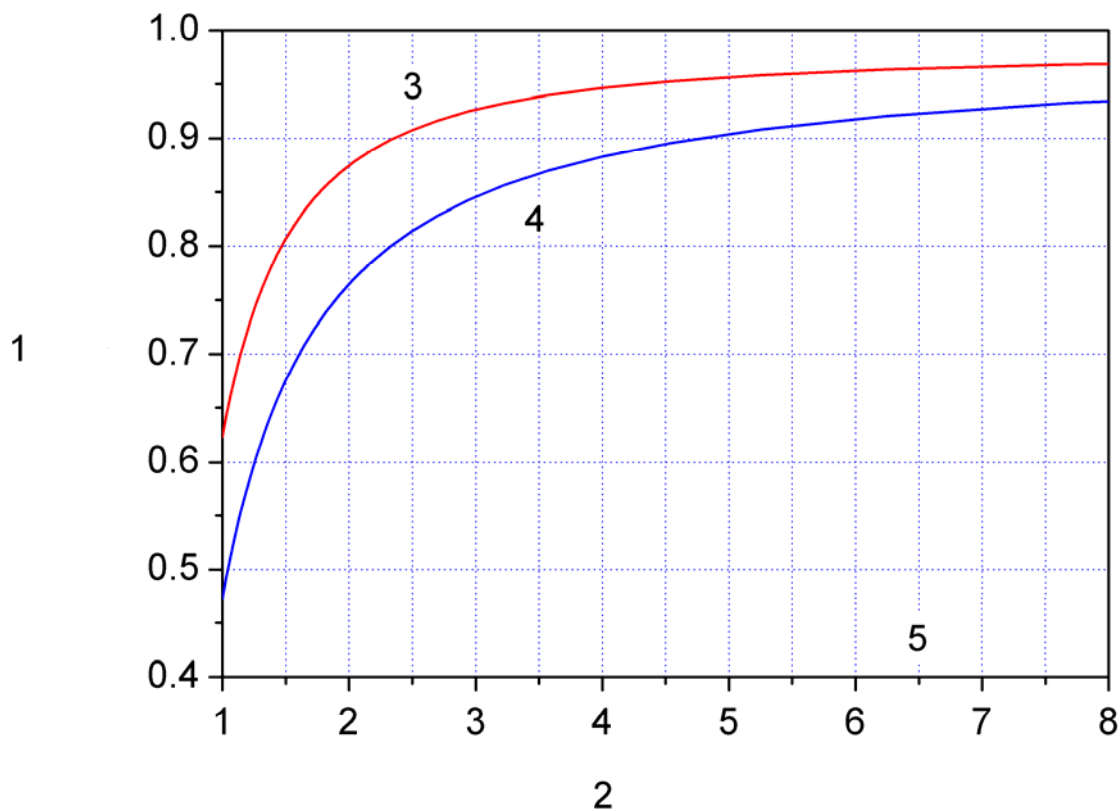
1   Correction factor for control of the pump f_C [-]
2    $P_{pump,max} / P_{pump}$
3   Δp_{const} - control
4    $\Delta p_{var\,i}$ - control
5   Pump control

Figure 4 — Correction factor for control of the pump

The constant pressure difference control of the pump keeps the pressure difference of the pump within the whole flow area constant at the design value. The variable pressure difference control varies the pressure difference of the pump from the design value at design flow to mostly the half of the design value at zero flow.

If a wall hanging generator with integrated pump management has a modulation control of the pump depend on the temperature difference between supply and return then the correction factor for $\Delta p_{var\,i}$ is valid.

5.3.5   Intermittent operation

For intermittent operation there are three different phases (see Figure 5):

—   set back mode;

— boost period;

— regular mode.
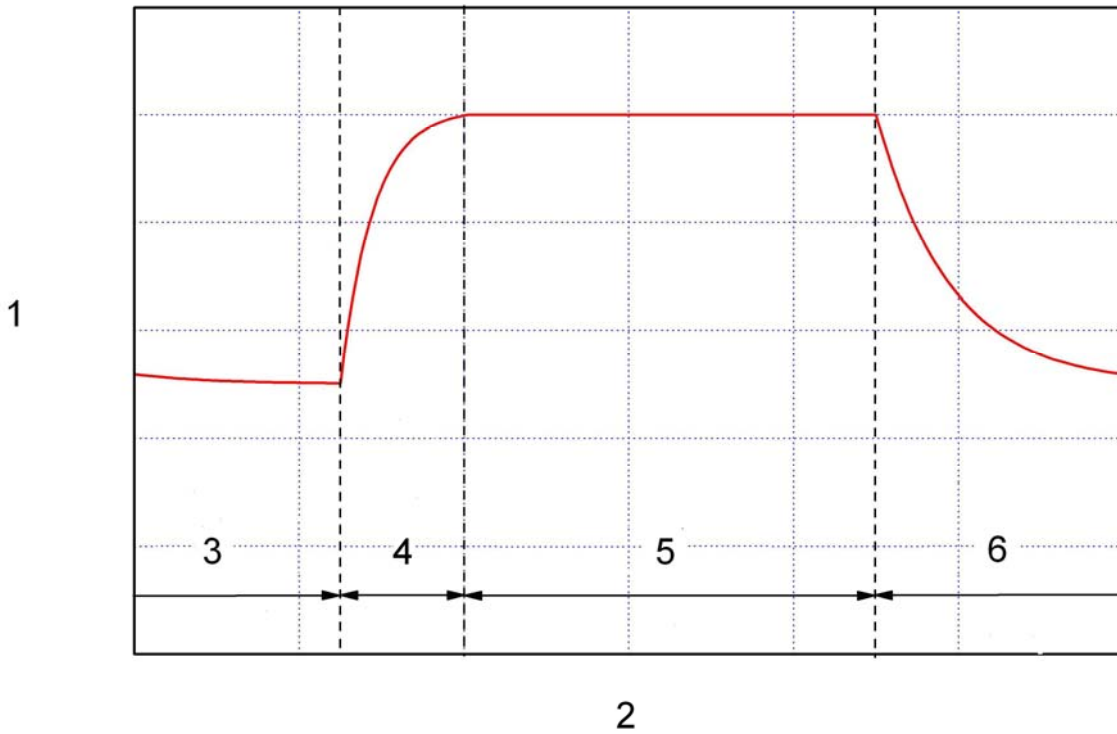
Key

   1   Room temperature
   2   time
   3   Set back
   4   boost
   5   Regular mode
   6   Set back

Figure 5 — Intermittent operation, phases

The total electrical energy demand for intermittent operation is given by the sum of energy demand for each phase:

$$W_{d,e} = W_{d,e,reg} + W_{d,e,setb} + W_{d,e,boost} \qquad (11)$$

For the the regular mode operation, the energy demand is determined by multiplication with a time factor for the proportional time of regular mode operation, α_r :

$$W_{d,e,reg} = \alpha_r \cdot W_{d,hydr} \cdot e_{d,e} \qquad (12)$$

For the set back operation it is necessary to distinguish between:

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— turn off mode, for which the energy demand of the pump is zero - $W_{d,e,setb} = 0$

— set back of supply temperature and minimum speed of the pump. When the pump is operated at minimum speed, the power is assumed to be constant as follows:

$$P_{Pump,setb} = 0{,}3 \cdot P_{Pump,max} \tag{13}$$

and the electrical energy demand is determined by multiplication with a time factor for the proportional time of set back operation, α_{setb}:

$$W_{d,e,setb} = \alpha_{setb} \cdot \frac{P_{Pump,setb}}{1000} \cdot t_H \tag{14}$$

— set back of supply temperature. If thermostatic valves in this mode are not set back, the flow compensates the lower supply temperature and the energy demand is not reduced. The energy demand for set back operation can be calculated as for the regular mode operation. The correction factor for control is $f_C = 1$ in case of room temperature control with constant value (no changes between regular mode and set back mode) and in case of room temperature control with set back, f_C depends on the type of pump control (see figure 4).

For the boost mode operation, the power P_{boost} is equal to the power P_{Pump} at the design point. The electrical energy demand for the boost mode operation is determined by multiplication with a time factor for the proportional time of boost mode operation, α_b:

$$W_{d,e,booth} = \alpha_b \cdot \frac{P_{Pump,boost}}{1000} \cdot t_H \tag{15}$$

The time factors can be calculated as relations of time periods.

The regular mode time factor, α_r, expresses the number of hours of regular mode operation t_r per total number of hours per time period t_P (period could be day, week, month or year):

$$\alpha_r = \frac{t_r}{t_P} \tag{16}$$

The boost mode time factor, α_b, expresses the number of hours of boost mode operation per total number of hours per time period t_P. The number of hours of boost mode operation is typically one or two hours per day as an average over the year or can be calculated in accordance to EN ISO 13790:

$$\alpha_b = \frac{t_{boost}}{t_P} \tag{17}$$

The set back mode time factor, α_{setb}, expresses the number of hours of set back mode operation per total number of hours per time period t_P and is determined from α_r and α_b:

$$\alpha_{setb} = 1 - \alpha_r - \alpha_b \tag{18}$$

5.4 Deviations from the detailed calculation method

For some applications, deviations from the detailed calculation method are taken into account:

— One-pipe heating systems
The total flow in the heating circuit and in the pump is constant. The pump is always working at the design point. The mean part load of distribution is $\beta_D = 1$

— Overflow valves
Overflow valves are used to ensure a minimum flow at the heat generator or a maximum pressure difference at the heat emitter. The function of the overflow valve is given by the interaction between the pressure loss of the system, the characteristics of the pump and the set point of the overflow valve. The influence on hydraulic energy demand can be estimated by applying a corrected mean part load of distribution, β_D':

$$\beta_D' = \beta_D + (1 - \beta_D) \cdot \frac{\dot{V}_{min}}{\dot{V}} \tag{19}$$

where:

β_D mean part load of distribution

$\dot{V}$ design volume flow [m³/h]

$\dot{V}_{min}$ minimum volume flow [m³/h]

The minimum volume flow take into account the requirements of the heat generator or the maximum pressure loss of the heat emitter.

5.5 Monthly energy demand

The detailed calculation method, as well as the simplified and tabulated calculation methods, determines an annual energy demand. Where necessary, the monthly energy demand is calculated by:

$$W_{d,e,M} = W_{d,e,Y} \cdot \frac{\beta_{D,M} \cdot t_{H,M}}{\beta_{D,Y} \cdot t_{H,Y}} \tag{20}$$

where:

$\beta_{D,M}$ mean part load of distribution for the month

$\beta_{D,Y}$ mean part load of distribution for the year

$t_{H,M}$ heating hours per month

$t_{H,Y}$ heating hours per year

Calculation of β_D is given in 7.

5.6 Recoverable auxiliary energy

For pumps operated in heating circuits, part of the electrical energy demand is converted to thermal energy. Part of the thermal energy is recovered as heat transferred to the water and another part of the thermal energy is recoverable as heat transferred to the surrounding air. This both parts are partially recoverable:

Recovered energy to the water:

$$Q_{d,r,w} = f_{P,rec} \cdot W_{d,e} \qquad (21)$$

Recoverable energy to the surrounding air:

$$Q_{d,r,a} = (1 - f_{P,rec}) \cdot W_{d,e} \qquad (22)$$

Values $f_{P,rec}$ see Annex A.1.3.4.

6 Heat emission of distribution systems

6.1 General

The heat emission of a distribution system depends on the mean temperature of the supply and return and the temperature of the surroundings. Also the kind of insulation has an important influence on the heat emission.

6.2 Detailed Calculation Method

6.2.1 Input- / Output data

The input data for the detailed calculation method are listed below. These are all part of the detailed project data:

L length of pipes in the zone

U_L linear thermal transmittance in W/mK for each pipe in the zone

ϑ_m mean medium temperature in the zone in °C

ϑ_i surrounding temperature in the zone (unheated and heated space) in °C

t_H heating hours in the time step in h/(time step)
        Number of valves and hangers taken into account

The output data are:

Q_D Total heat emission of the distribution system in the zone [kWh/year]

$Q_{d,r}$ Recoverable energy in the zone [kWh/timstep]

$Q_{d,u}$ Unrecoverable energy in the zone [kWh/timstep]

6.2.2 Calculation method

The heat emission for the sum of the pipes j in a time step is given by

$$Q_D = \sum_j U_{L,j} \cdot \left(\vartheta_m - \vartheta_{i,j} \right) \cdot L_j \cdot t_H \qquad (23)$$

where:

U linear thermal transmittance in W/mK

ϑ_m mean medium temperature in °C

ϑ_i surrounding temperature in °C

L length of the pipe

j Index for pipes with the same boundary conditions

t_H heating hours in the time step in h/(time step)

For parts of the distribution system with the same linear thermal transmittance, the same mean medium temperature and the same surrounding temperature, the heat emission is given by a shorter term:

$$Q_D = \sum_j \dot{q}_{D,j} \cdot L_j \cdot t_H \tag{24}$$

The mean medium temperature of heating circuits, with outdoor temperature compensation of the supply temperature, depends on the mean part load of distribution and the temperature difference between mean emission system design temperature and room temperature. Calculation of the mean medium temperature is given in 7.

Therefore, the heat emission per length in a space with surrounding temperature ϑ_i depends on the mean part load of distribution and is given by:

$$\dot{q}_{D,j}(\beta_D) = U_{L,j} \cdot \left(\vartheta_m(\beta_D) - \vartheta_{i,j}\right) \tag{25}$$

For distribution systems with:

— constant supply temperature ϑ_m not depending on the mean part load of distribution.

— a temperature difference between a heated and an unheated space

$$\Delta\vartheta_U = \vartheta_i - \vartheta_u \tag{26}$$

— the linear thermal transmittance $U_L, U_{L,U}$ per length for pipes in heated and unheated spaces, respectively

the heat emission in unheated spaces is given as a function of the heat emission in heated spaces (so that the heat emission of the pipes has to be calculated only once for parts with the same boundary conditions):

$$\dot{q}_{D,u}(\beta_D) = \dot{q}_D(\beta_D) \cdot \left(\frac{U_{L,U}}{U_L} + U_{L,U} \cdot \frac{\Delta\vartheta_U}{\dot{q}_D(\beta_D)} \right) \tag{27}$$

The expression in the brackets of equation (34) can be written as a factor f_U

$$f_u = \frac{U_{L,U}}{U_L} + U_{L,U} \cdot \frac{\Delta\vartheta_U}{\dot{q}_D(\beta_D)} \tag{28}$$

and the heat emission in unheated spaces depends only on the heat emission in heated spaces and a factor which contains the relation between the different U-Values per length and the temperature difference in heated and unheated spaces:

$$\dot{q}_{D,u}(\beta_D) = \dot{q}_D(\beta_D) \cdot f_U \qquad (29)$$

Given the sum of pipe length L_H in heated spaces and L_U - for parts of the distribution system with the same values of linear thermal transmittance U_L in heated spaces and $U_{L,U}$ in unheated spaces, the recoverable part of the heat emission is given by:

$$a_n = \frac{L_H}{L_H + \dfrac{U_{L,U}}{U_L} \cdot L_U \cdot \left(1 + \dfrac{\Delta \vartheta_U}{\vartheta_m(\beta_D) - \vartheta_a}\right)} \qquad (30)$$

6.2.3 Heat emission of accessories

The heat emission of a distribution system is not only given by the emission of the pipes. The heat emission of accessories such as valves and hangers is also taken into account.

To take the heat emission of hangers into account, an additional equivalent length of 15 % could be used as an approximation. If special insulated pipe hangers are used with their thermal resistance equal to the one of the pipe insulation, the additional heat emission due to the hangers should not be taken into account.

The equivalent length of valves including flanges is given in Annex A.3.4.

6.2.4 Recoverable and non-recoverable heat emission

In heated rooms the heat emission of the pipes is a part of useful heat demand. So this part of heat emission is recoverable. In uncontrolled or unheated rooms the heat emission of pipes is not recoverable.

Given the sum of pipe length $L_{r,j}$ in heated space, the heat emission of the time step, $Q_{D,r}$, which may be recovered is calculated by:

$$Q_{D,r} = \sum_j \dot{q}_{D,r,j} \cdot L_{r,j} \cdot t_H \qquad (31)$$

Given the sum of pipe length $L_{u,i}$ in uncontrolled or unheated space, the heat emission of the time step, $Q_{D,u}$, which can not be recovered is calculated by:

$$Q_{D,u} = \sum_j \dot{q}_{D,u,j} \cdot L_{u,j} \cdot t_H \qquad (32)$$

6.2.5 Total heat emission

The total heat emission is the sum of the recoverable heat emission in heated spaces an the non-recoverable heat emission in unheated spaces:

$$Q_D = Q_{D,r} + Q_{D,u} \qquad (33)$$

6.3 Calculation of linear thermal transmittance (W/mK):

The linear thermal transmittance for insulated pipes in air with a total heat transfer coefficient including convection and radiation at the outside is given by

$$U_L = \frac{\pi}{\left(\frac{1}{2 \cdot \lambda_D} \cdot \ln \frac{d_a}{d_i} + \frac{1}{\alpha_a \cdot d_a} \right)} \qquad (34)$$

where:

d_i, d_a inner diameter (without insulation), outer diameter of the pipe (with insulation) (m)

α_a outer total heat transfer coefficient (convection and radiation) (W/m²K)

λ_D thermal conductivity of the insulation (material) (W/mK)

For embedded pipes the linear thermal transmittance is given by

$$U_{L,em} = \frac{\pi}{\frac{1}{2} \left[\frac{1}{\lambda_D} \cdot \ln \frac{d_a}{d_i} + \frac{1}{\lambda_E} \cdot \ln \frac{4 \cdot z}{d_a} \right]} \qquad (35)$$

where:

z depth of pipe from surface

λ_E thermal conductivity of the embedded material (W/mK)

For non-insulated pipes the linear thermal transmittance is given by

$$U_{L,non} = \frac{\pi}{\frac{1}{2 \cdot \lambda_P} \cdot \ln \frac{d_{p,a}}{d_{p,i}} + \frac{1}{\alpha_a \cdot d_{p,a}}} \qquad (36)$$

where:

$d_{p,i}, d_{p,a}$ inner diameter, outer diameter of the pipe (m)

λ_P thermal conductivity of the pipe (material) (W/mK)

As an approximation the linear thermal transmittance for non insulated pipes is given by

$$U_{L,non} = \alpha_a \cdot \pi \cdot d_{p,a} \qquad (37)$$

For heating systems, the inner total heat transfer coefficient must not be taken into account.

7 Calculation of mean part load of distribution per zone

The mean part load of distribution is given by:

$$\beta_D = \frac{Q_{em,in}}{\dot{Q}_N \cdot t_H} \tag{38}$$

where:

$Q_{em,in}$ Energy including emission and control per time step

$\dot{Q}_N$ design heat load per zone

t_H heating hours in the zone per time step

8 Calculation of supply and return temperature depending on mean part load of distribution

For heating systems with supply temperature control depending on the outdoor temperature, the supply temperature ϑ_s and the return temperature ϑ_r as well as the mean emission system temperature ϑ_m are given as functions of the mean part load of distribution in each process area:

$$\vartheta_m(\beta_i) = \Delta\vartheta_a \cdot \beta_i^{\frac{1}{n}} + \vartheta_i \tag{39}$$

$$\vartheta_s(\beta_i) = (\vartheta_{sa} - \vartheta_i) \cdot \beta_i^{\frac{1}{n}} + \vartheta_i \tag{40}$$

$$\vartheta_r(\beta_i) = (\vartheta_{ra} - \vartheta_i) \cdot \beta_i^{\frac{1}{n}} + \vartheta_i \tag{41}$$

where:

β_i mean part load of distribution in the process area

$\Delta\vartheta_a$ temperature difference in °C between mean emission system design temperature and room temperature

$$\Delta\vartheta_a = \frac{\vartheta_{sa} + \vartheta_{ra}}{2} - \vartheta_i \tag{42}$$

n exponent of the emission system (standard value = 1,33 for radiators, 1,1 for floor heating systems)

ϑ_{sa} design supply temperature in °C

ϑ_{ra} design return temperature in °C

ϑ_i room temperature in °C

For heating circuits between a hydraulic decoupling system or a storage vessel, the temperature is sometimes not influenced by outside temperature control.

For heating systems, where the temperature of the decoupling system or a storage vessel does not depend on the supply temperature of the emission system, the heat emission of the pipes between the heat generator and the storage vessel has to be calculated with the fixed temperature given by the heat generator, i.e. non gas- or oil fired burner.

Annex A
(informative)

Preferred procedures

A.1 Simplified Calculation Method of annual electrical auxiliary energy demand

For the simplified calculation method, some assumptions are made for the most relevant cases, reducing the required input data (e.g. the length of pipes are calculated by approximations depending on the outer dimensions of the building and efficiency of pumps are approximated). This method may be applied if only few data are available (in general at an early stage of design). The assumptions in A.1.2 can be changed on national requirements but the calculation method must be used as described in A.1.3, A.1.4 and A.1.5.

A.1.1 Input- / Output data

The input data for the simplified calculation method are listed below. These are all part of the detailed project data.

P_{hydr}	Hydraulic power at the design point for the zone [in W], calculated by the knowledge of
$\dot{Q}_N$	design heat load according to EN 12831 of the zone
$\Delta\vartheta_{HK}$	design temperature difference [K] for the distribution system in the zone
L_{max}	Maximum pipe length of the heating circuit [m] in the zone
Δp	Differential pressure of the circuit in the zone [kPa] – simplified calculated
β_D	Mean part load of distribution [-]
t_H	Heating hours per year [h/year]
f_{NET}	Correction factor for hydraulic networks [-]
f_{HB}	Correction factor for hydraulic balance [-]
	Pump control
$e_{d,e}$	Expenditure energy factor for operation of circulation pump [-], simplified calculated by this standard

Design temperature level

emitter type

Intermittent operation

The output data are:

$W_{d,e}$	Total electrical energy demand [kWh/year]
$W_{d,e,M}$	Monthly total hydraulic energy demand [kWh/month]
$Q_{d,r,w}$	Recoverable energy to the water [kWh/timstep]
$Q_{d,r,a}$	Recoverable energy to the surrounding air [kWh/timstep]

A.1.2 Calculation method

For defined values of correction factors ($f_S \cdot f_{SD} = 1,0$), the hydraulic energy demand can be expressed as a function of heating hours per time step and the mean part load of distribution:

$$W_{d,hydr} = \frac{P_{hydr}}{1000} \cdot \beta_D \cdot t_H \cdot f_{NET} \cdot f_{HB} \cdot f_{G,PM} \qquad (43)$$

The correction factor for hydraulic networks f_{NET} is only necessary to distinguish between one-pipe and two-pipe heating systems.

An approximation for the differential pressure at the design point can be made with a fixed pressure loss per length of heating circuit (100 Pa/m) and an additional pressure loss ratio for components of 0,3. Variables for determining the differential pressure at the design point are thus only the maximum length of the heating circuit in the zone and the pressure losses of the heat emission system and the heat generation system:

$$\Delta p = 0.13 \cdot L_{max} + 2 + \Delta p_{FH} + \Delta p_G \qquad \text{(kPa)} \qquad (44)$$

where:

L_{max} Maximum length of the heating circuit [m]

Δp_{FH} additional pressure loss for floor heating systems [kPa]

Δp_G pressure loss of heat generators [kPa]

This approximation is applicable for the primary heating circuit as well as for the secondary heating circuit.

If the manufacturer's data for Δp_{FH} and/or Δp_G is not available, the following default values can be applied:

Δp_{FH} = 25 kPa including valves and distributor

Δp_G see Table A1

Table A.A.1 — A.Pressure loss of heat generators

Type of heat generator	Δp_G [kPa]
Generator with water content > 0,3 l/kW	1
Generator with water content <= 0,3 l/kW	
$\dot{Q}_{h,max} < 35 kW$	$20 \cdot \dot{V}^2$
$\dot{Q}_{h,max} \geq 35 kW$	80

where:

$\dot{Q}_{h,max}$ maximum heat load [kW]

$\dot{V}$ design flow [m³/h]

The maximum length of the heating circuit in a zone can be calculated approximately from the outer dimensions of the zone:

$$L_{max} = 2 \cdot \left(L + \frac{B}{2} + n_G \cdot h_G + l_c \right) \qquad \text{(m)} \qquad (45)$$

where:

L Length of the zone (part of building) [m]

B Width of the zone (part of building) building [m]

n_G Number of heated levels in the zone (part of building) [-]

h_G Mean height of the levels in the zone (part of building) [-]

l_c = 10 m for two-pipe heating systems

         = $L + B$ for one-pipe heating systems

A.1.3 Correction factors

A.1.3.1 Correction factor for hydraulic networks f_{NET}

$f_{NET} = 1$ for two-pipe heating systems;

$f_{NET} = 8,6 \cdot \overline{m} + 0,7$ for one-pipe heating systems, where $\overline{m}$ is the ratio of flow over the heat emitter to flow in the ring [-]

A.1.3.2 Correction factor for hydraulic balance f_{HB}

$f_{HB} = 1$ for hydraulic balanced systems
$f_{HB} = 1,15$ for hydraulic non-balanced systems

A.1.3.3 Correction factor for generators with integrated pump management $f_{G,PM}$

$f_{G,PM} = 1$ for outdoor temperature controlled standard generator (OTC)

$f_{G,PM} = 0,75$ for outdoor temperature controlled wall hanging generator (OTC)

$f_{G,PM} = 0,45$ for room temperature controlled wall hanging generator (RTC)

A.1.3.4 Recoverable auxiliary energy $f_{P,rec}$

$f_{P,rec} = 0,75$ for not insulated pump
$f_{P,rec} = 0,90$ for insulated pump

A.1.4 Expenditure energy factor

For the simplified calculation method, the expenditure energy factor is calculated similarly as for the detailed calculation method, ref. equation (7) in 4.3.4, with the following additional assumptions:

— Correction factor for control, f_C, is determined from figure 4 with $\dfrac{P_{Pump,\max}}{P_{Pump}} = 1,11$

— Correction factor for design point selection $f_{PSP} = 1,5$ (see figure 2)

— Efficiency factor $f_e = f_\eta \cdot f_{PSP}$

— Approximation of the efficiency curve of the pump

Thus, the expenditure energy factor is simplified to:

$$e_{d,e} = f_e \cdot (C_{P1} + C_{P2} \cdot \beta_D^{-1}) \tag{46}$$

where:

C_{P1}, C_{P2} Constants, according to Table A2 [-]

f_e Efficiency factor, given by:

$$f_e = \frac{P_{Pump}}{P_{hydr}} \tag{47}$$

or for pumps where P_{Pump} is not available

$$f_e = \left(1,25 + \left(\frac{200}{P_{hydr}}\right)^{0.5}\right) \cdot 1,5 \cdot b \tag{48}$$

where b = 1 for new buildings and b = 2 for existing buildings, and P_{hydr} given in W.

Table A.A.2 — Constants C_{P1}, C_{P2} for calculation of the expenditure energy factor (simplified method)

Pump control	C_{P1}	C_{P2}
Not controlled	0,25	0,75
Δp_{const}	0,75	0,25
$\Delta p_{variabel}$	0,90	0,10

For existing installations, it is approximately correct to use the power rating given on the label at the pump for P_{Pump}. (In case of non-controlled pumps with more than one speed level, P_{Pump} shall be taken from the speed level at which the pump is operated).

A.1.5 Intermittent operation

For the simplified calculation method, the boost mode time factor is assumed to be 3 %, and the electrical energy demand is given by

$$W_{d,e} = W_{d,hydr} \cdot e_{d,e} \cdot \left(\alpha_r + 0,6 \cdot \alpha_{setb} + \alpha_b \right) \qquad (49)$$

The expression in the brackets represents the energy saving by intermittent operation.

The time factors should be calculated as shown in 5.3.5 of the standard.

A.2 Tabulated calculation method of annual electrical auxiliary energy demand

The input data for the tabulated calculation method are listed below. These are all part of the detailed project data.

A Heated floor area in the zone [m²]
          Type of heat generator
          One-pipe/two-pipe heating system
          Type of pump control

The output data are:

$W_{d,e}$ Total electrical energy demand [kWh/year]

$W_{d,e,M}$ Monthly total electrical energy demand [kWh/month]

$Q_{d,r,w}$ Recovered energy to the water [kWh/timstep]

$Q_{d,r,a}$ Recoverable energy to the surrounding air [kWh/timstep]

The tabulated calculation method combines all the assumptions of the simplified method and provides, with additional assumptions for specific types of heating systems, values for annual electrical energy demand. National Annexes providing tabulated values for this method may be elaborated. The simplified calculation method shall form the basis for determination of tabulated values at a national level and the tables should follow the same structure as in A.2.1. The necessary boundary conditions which can be changed on national requirements are given in A.2.1. also.

A.2.1 Tabulated calculation of annual electrical auxiliary energy demand

Annual electrical auxiliary energy demand is given in Table A.3. The values have been calculated from the simplified method (see A.1) with some additional assumptions:

— mean part load of distribution = 0,4

— heating hours = 5000 per year

— design heat load per m² = 40 W/m² (new buildings)

— hight of a level = 3 m

— length of the zone depending on the heated floor area: $L = 11,4 + 0,0059 \cdot A$,

— width of the zone depending at the heated floor area: $B = 2,72 \cdot \ln(A) + 6,62$

— number of levels in the zone: $n_G = A \; /(L \cdot B)$

— A = m² of the zone (one pump for a maximum of 1000 m² per zone)

Table A.3 — Annual electrical auxiliary energy demand

Annual electrical auxiliary energy demand [kWh/year] (5000 heating hours)					
	Generators with standard water volume			Generators with small water volume		
A [m²]	Two-pipe-system with radiators					
	not controlled	dpconst	dpvariabel	not controlled	dpconst	dpvariabel
100	99	64	53	105	68	57
150	126	82	68	151	98	82
200	151	98	82	206	134	112
300	196	127	106	349	226	189
400	238	154	129	544	352	294
500	278	180	150	799	517	432
600	316	205	171	915	592	495
700	354	229	192	1021	661	553
800	391	253	211	1125	728	609
900	427	276	231	1226	794	664
1000	463	299	250	1326	858	718
A [m²]	Two-pipe-system with floor-heating					
	not controlled	dpconst	dpvariabel	not controlled	dpconst	dpvariabel
100	193	125	105	198	128	107
150	246	159	133	263	170	142
200	294	190	159	333	215	180
300	379	245	205	497	322	269
400	458	296	248	709	459	384
500	532	344	288	979	634	530
600	602	390	326	1122	726	607
700	671	434	363	1254	812	679
800	738	477	399	1384	895	749
900	803	520	435	1510	977	817
1000	867	561	469	1635	1058	885
A [m²]	One-pipe-system with radiators					
	not controlled			not controlled		
100	109			115		
150	141			164		
200	170			222		
300	224			369		
400	274			568		
500	323			827		
600	370			950		
700	417			1063		
800	463			1174		
900	509			1283		

	Annual electrical auxiliary energy demand [kWh/year] (5000 heating hours)			
	Generators with standard water volume		Generators with small water volume	
1000	554		1390	

For a different number of heating hours than 5000 per year, the tabulated values can be corrected by multiplication with a factor $f = \dfrac{heating\_hours}{5000}$

For intermittent heating, the tabulated values can be corrected by multiplication with the factor f_{int} :

Regular mode 06:00 – 22:00 h every day and set back mode for the remaining time: $f_{int} = 0,87$;

If the pump is turned off during the set back mode: $f_{int} = 0,69$

Regular mode 06:00 – 22:00 h on Monday – Friday and set back mode for the remaining time: $f_{int} = 0,87$;

If the pump is turned off during the set back mode: $f_{int} = 0,60$

Recovered energy to the water: $Q_{d,r,w} = 0,75 \cdot W_{d,e}$

Recoverable energy to the surrounding air: $Q_{d,r,a} = 0,25 \cdot W_{d,e}$

(Note: similar table can be created for existing buildings)

A.3 Simplified Calculation Method of heat emission

For the simplified calculation method, some assumptions are made for the most relevant cases, reducing the required input data (e.g. the length of pipes are calculated by approximations depending on the outer dimensions of the building). This method may be applied if only few data are available (in general at an early stage of design). The assumptions in A.3.2 and A.3.3 can be changed on national requirements but the calculation method must be used as described in 6.2 of the standard.

A.3.1 Input- / Output data

The input data for the simplified calculation method are listed below. These are all part of the detailed project data:

L length of the zone
B width of the zone
h_G height of the storey in the zone
n_G number of storeys in the zone
U' tabulated U-Values per length in W/mK for each part of the distribution system in the zone
ϑ_m mean medium temperature in the zone in °C

ϑ_a surrounding temperature in the zone (unheated and heated space) in °C

t_H heating hours in the time step in h/(time step)
        Number of valves and hangers taken into account

The output data are:

Q_D Total heat emission of the distribution system in the zone [kWh/year]

$Q_{d,r}$ Recoverable energy in the zone [kWh/timstep]

$Q_{d,u}$ Unrecoverable energy in the zone [kWh/timstep]

A.3.2 Approximation of the length of pipes per zone in distribution systems

For the simplified calculation method, approximations of the length of the pipes in a building or a zone (see Figure 6) are made, based on the length (L) and width (B) of the building or zone, the storey height (h_G) and the number of storeys (n_G), see Table A.4 and Table A.5.

L_V Pipe length between generator and vertical shafts. These (horizontal) pipes could be in unheated space (basement, attic) or in heated space.

L_S Pipe length in shafts (e.g. vertical). These pipes are either in heated space, in outside-walls or in the inside of the building. The heating medium is always circulating.

L_A Connection pipes. These pipes are flow controlled by the emission system in heated spaces.
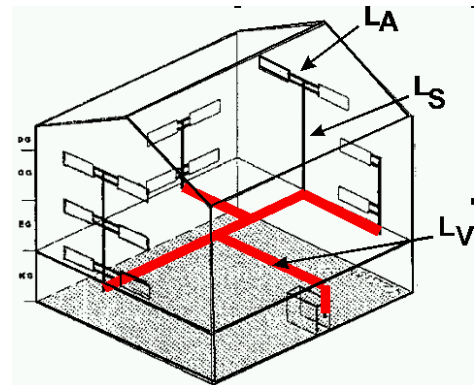

Figure A.1 — Type of A.A.pipes in a distribution system

Table A.A.4 —A.Approximation of pipe lengths (two-pipe heating systems)

Values	result	unit	part V distribution to the shafts	part S Vertical shafts	part A connection pipes
Mean surrounding temperature		°C	13 respectively 20	20	20
Pipe length in case of shafts in outside walls	L_i	m	$2 \cdot L + 0,01625 \cdot L \cdot B^2$	$0,025 \cdot L \cdot B \cdot h_G \cdot n_G$	$0,55 \cdot L \cdot B \cdot n_G$
Pipe length in case of shafts inside the building	L_i	m	$2 \cdot L + 0,0325 \cdot L \cdot B + 6$	$0,025 \cdot L \cdot B \cdot h_G \cdot n_G$	$0,55 \cdot L \cdot B \cdot n_G$

Table A.A.5 — A.A.Approximation of pipe length (one-pipe heating systems)

Pipe length in case of shafts inside of the building	L	m	$2 \cdot L + 0{,}0325 \cdot L \cdot B + 6$	$0{,}025 \cdot L \cdot B \cdot h_G \cdot n_G + 2 \cdot (L + B) \cdot n_G$	$0{,}1 \cdot L \cdot B \cdot n_G$

A.3.3 Approximation of U-Values

For the simplified calculation method, approximations of the U-Values are made for the different types of pipes (see Table A.6). These should be constant values.

Table A.A.6 — A.Typical Values of linear thermal transmittance [W/mK] for new and existing buildings

Age class of building	Distribution		
	V	S	SL
From 1995 – assumed that insulation thickness approximately equals to pipe external diameter	0,2	0,3	0,3
1980 to 1995 - assumed that insulation thickness approximately equals to half of pipe external diameter	0,3	0,4	0,4
Up to 1980	0,4	0,4	0,4
Non-insulated pipes			
A <=200 m²	1,0	1,0	1,0
200 m² < A <=500 m²	2,0	2,0	2,0
A > 500 m²	3,0	3,0	3,0
Laid in external walls		total / usable *	
External wall non-insulated		1,35 / 0,80	
External wall external insulated		1,00 / 0,90	
External wall without insulation, but low thermal transmittance (U=0,4 W/m²K)		0,75 / 0,55	

* (total = total heat emission of the pipe, usable = recoverable heat emission)

A.3.4 Equivalent length of valves

Table A.7 gives the equivalent length of valves including flanges depending on the kind of insulation:

Table A.A.7 — A.A.Equivalent length of valves

Valves incl. flanges	equivalent length in m d <= 100 mm	equivalent length in m d > 100 mm
not insulated	4,0	6,0
insulated	1,5	2,5

A.4 Tabulated Calculation Method of annual heat emission

The input data for the tabulated calculation method are listed below. These are all part of the detailed project data:

A Heated floor area in the zone [m²]

ϑ_m mean medium temperature in the zone in °C (supply/return temperature)

t_H heating hours in the time step in h/(time step)

The output data are:

Q_D Total heat emission of the distribution system in the zone [kWh/year]

$Q_{d,r}$ Recoverable energy in the zone [kWh/timstep]

$Q_{d,u}$ Unrecoverable energy in the zone [kWh/timstep]

The tabulated calculation method combines all the assumptions of the simplified method and provides, with additional assumptions regarding the design system temperature, values for annual heat emission. National Annexes providing tabulated values for this method may be elaborated. The simplified calculation method shall form the basis for determination of tabulated values at a national level and the tables should follow the same structure as in A.5.

A.5 Tabulated calculation of annual heat emission

Annual heat emission is given in Table A.8 for two-pipe heating systems. The values have been calculated from the simplified method (see 4.6) with some additional assumptions:

— mean part load of distribution = 0,4

— heating hours = 5000 per year

— length of the zone depending on the heated floor area: $L = 11,4 + 0,0059 \cdot A$,

— width of the zone depending on the heated floor area : $B = 2,72 \cdot \ln(A) + 6,62$

— number of levels in the zone: $n_G = A /(L \cdot B)$

— A = m² of the zone

— U-value for pipes of part V of the distribution system, in unheated spaces U = 0,2 W/mK

— U-value for shafts and connecting pipes of the distribution system, in heated spaces U = 0,255 W/mK

— shafts inside the zone

— floor height = 3,0 m

Table A.8 — Annual heat emission in kWh/year at design temperature

	Annual heat emission in kWh/year at design temperature (5000 heating hours)							
Heated Area	90 / 70 °C		70 / 55 °C		55 / 45 °C		35 / 28 °C	
	unheated space	heated space	unheated space	heated space	unheated space	heated space	unheated space	heated space
A [m²]	$Q_{D,u}$	$Q_{D,r}$	$Q_{D,u}$	$Q_{D,r}$	$Q_{D,u}$	$Q_{D,r}$	$Q_{D,u}$	$Q_{D,r}$
100	1133	2375	865	1681	674	1187	388	446
150	1265	3562	966	2522	753	1781	433	669
200	1383	4749	1056	3363	823	2375	473	893
300	1592	7124	1216	5044	948	3562	545	1339
400	1783	9499	1362	6726	1061	4749	611	1785
500	1964	11873	1499	8407	1169	5937	672	2231
600	2138	14248	1632	10088	1272	7124	732	2678
700	2308	16623	1762	11770	1373	8311	790	3124
800	2475	18998	1890	13451	1473	9499	847	3570
900	2641	21372	2016	15133	1572	10686	904	4016
1000	2805	23747	2142	16814	1669	11873	961	4463

Note: The values have to be checked

For a different number of heating hours than 5000 per year, the tabulated values can be corrected by multiplication with a factor $f = \dfrac{heating\_hours}{5000}$

A similar table could be created for one-pipe heating systems.

A.6 Example

In this example, application of the simplified calculation method is shown.

Given:

Building: Length: 10 m, Width: 8 m,   Number of floors: 2, floor height: 3 m, Heated floor: 160 m²

Design heat load: QN = 8000 W

Mean part load of distribution ß$_D$ = 0,4, Heating hours = 5000 h/year,

Design supply temperature: ϑ_{sa} = 55 °C, Design return temperature: ϑ_{ra} = 45 °C

Two-pipe heating system -> f$_{sch}$ = 1, Hydraulic balanced -> f$_{Abg}$ = 1, l$_c$ = 10 m

Heat emitters: standard radiators -> Δp_{FH} = 0 , Generator -> Δp_G = 1 kPa, New building : b = 1

Pump controlled: Δp_{var} -> Cp1 = 0.90; Cp2 = 0.10

Calculations:

Electrical energy demand:

$$L_{\max} = 2 \cdot \left(L + \frac{B}{2} + n_G \cdot h_G + l_c \right) \qquad \text{-> } L_{\max} = 60 \text{ m}$$

$$\Delta p = 0.13 \cdot L_{\max} + 2 + \Delta p_{FBH} + \Delta p_{WE} \quad \text{-> } \Delta p = 10,8 \text{ kPa}$$

$$\dot{V} = 0{,}713 \text{ m}^3/\text{h}$$

$$P_{hydr} = 2{,}141 \text{ W}$$

$$W_{d,hydr} = 4{,}282 \text{ kWh/year}$$

$$f_e = 16{,}373$$

$$e_{d,e} = 18{,}829$$

$$W_{d,e} = \underline{80{,}6 \text{ kWh/year}}$$

Intermittent Operation: regular mode: 15 h/day, boost mode: 3 % -> $\alpha_r = 0{,}625$, $\alpha_b = 0{,}03$, $\alpha_{setb} = 0{,}345$

$$W_{d,e,\text{int }erm} = 69{,}5 \text{ kWh/year}$$

Monthly energy demand:

Example: January: mean part load of distribution $\beta_{D,J} = 0{,}8$, Heating hours = 744 h/month

$W_{d,e,Jan} = 24{,}0$ kWh/month, in intermittent operation: $W_{d,e,\text{int }erm,Jan} = 20{,}7$ kWh/month

Recoverable energy:

$$f_{P,rec} = 0{,}75 \text{ (not insulated pump)}$$

Recovered energy to the water: $Q_{d,r,w} = 0{,}75 \cdot W_{d,e} = 60{,}4$ kWh/year

Recoverable energy to the surrounding air: $Q_{d,r,a} = (1 - 0{,}75) \cdot W_{d,e} = 20{,}2$ kWh/year

Heat emission:

Given:

U-Values: In heated space: 0,255 W/mK, unheated space: 0,200 W/mK

With the outer dimensions of the building:

Lv = 28,6 m

Ls = 12 m

La = 88 m

Mean temperature of the distribution: ϑ_m = 35,06 °C

Temperature in heated space = 20 °C and temperature in unheated space = 13 °C

Calculations:

$q_{D,u}$ = 4,413 W/m, $q_{D,h}$ = 3,841 W/m,

Lu = Lv = 28,6 m,   Lh = Ls + La = 100 m

$Q_{D,u}$ = 631 kWh/year, $Q_{D,h}$ = 1921 kWh/year,

Total heat emission:

Q_D = 2552 kWh/year

Recoverable energy:

$Q_{D,r} = Q_{D,h}$ = 1921 kWh/year