BRITISH STANDARD

BS EN 15450:2007

Heating systems in buildings — Design of heat pump heating systems

The European Standard EN 15450:2007 has the status of a British Standard

ICS 27.080

British Standards

National foreword

This British Standard is the UK implementation of EN 15450:2007.

The UK participation in its preparation was entrusted to Technical Committee RHE/24, Central heating installations.

Throughout this standard, the term “tapping patterns” is used to describe the draw-off demands on Domestic Hot Water supply systems. In the UK, the term “demand profile” has similar meaning and is more commonly used.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 November 2007

ISBN 978 0 580 56385 0

Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 15450

October 2007

ICS 27.080

English Version

Heating systems in buildings - Design of heat pump heating systems

Systèmes de chauffage dans les bâtiments - Conception des systèmes de chauffage par pompe à chaleur

Heizungsanlagen in Gebäuden - Planung von Heizungsanlagen mit Wärmepumpen

This European Standard was approved by CEN on 26 August 2007.

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Ref. No. EN 15450:2007: E

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Foreword

This document (EN 15450:2007) has been prepared by Technical Committee CEN/TC 228 “Heating systems in buildings”, the secretariat of which is held by DS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2008, and conflicting national standards shall be withdrawn at the latest by April 2008.

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.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

This standard provides design criteria for heating systems with integrated heat pump systems with respect to:

— heat source;

— electrical supply;

— strategy;

— positioning;

— noise level;

— heat supply;

— sizing.

Energy performance design criteria are dealt with in another document of this technical committee.

1 Scope

This standard specifies design criteria for heating systems in buildings using electrically driven heat pumps alone or in combination with other heat generators. Heat pump systems considered include (see Table 1):

- water – water;
- water – air;
- brine – water;
- refrigerant – water (direct expansion systems);
- refrigerant – refrigerant;
- air – air;
- air – water.

This standard takes into account the heating requirements of attached systems (e.g. domestic hot water) in the design of heat supply, but does not cover the design of these systems. This standard covers only the aspects dealing with the heat pump, the interface with the heat distribution system and heat emission system (e.g. buffering system), the control of the whole system and the aspects dealing with energy source of the system.

Systems designed primarily for cooling and systems which can operate simultaneously in cooling and heating mode are not within the scope of this standard.

Table 1 — Heat pump systems (within the scope)

<table>
<tr><th colspan="2">source-system
(energy extraction)</th><th colspan="2">sink-system
(energy rejection)</th></tr>
<tr><th>energy source [a]</th><th>medium [b]</th><th>medium</th><th>energy sink [c]</th></tr>
<tr><td rowspan="2">exhaust air
outdoor air</td><td rowspan="2">air</td><td>air</td><td>indoor air</td></tr>
<tr><td>water</td><td>indoor air
water</td></tr>
<tr><td rowspan="2">surface water
ground water</td><td rowspan="2">water</td><td>water</td><td>indoor air
water</td></tr>
<tr><td>air</td><td>indoor air</td></tr>
<tr><td rowspan="4">ground</td><td rowspan="2">brine
(water)</td><td>air</td><td>indoor air</td></tr>
<tr><td>water</td><td>indoor air
water</td></tr>
<tr><td rowspan="2">refrigerant</td><td>water</td><td>indoor air
water</td></tr>
<tr><td>refrigerant</td><td>indoor air</td></tr>
<tr><td colspan="4">a Energy source is the location where the energy is extracted.
b Medium is the fluid transported in the corresponding distribution system.
c Energy sink is the location where the energy is used; this can be the heated space or water in case of domestic hot water production.</td></tr>
</table>

2 Normative references

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

EN 378-1, *Refrigerating systems and heat pumps – Safety and environmental requirements – Part 1: Basic requirements, definitions, classification and selection criteria*

EN 12828:2003, *Heating systems in buildings – Design for water-based heating systems*

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

EN 14336, *Heating systems in buildings – Installation and commissioning of water based heating systems*

EN 14511-1:2004, *Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling – Part 1: Terms and definitions*

prEN 15316-4-2, *Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-2: Space heating generation systems, heat pump systems*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12828:2003 and the following apply.

3.1.1
coefficient of performance (COP)
ratio of the heating capacity to the effective power input of the unit, expressed in Watt/Watt

[EN 14511-1:2004]

3.1.2
seasonal performance factor (SPF)
ratio of the total annual energy Q_{HP} delivered by the heat pump to the distribution subsystem for space heating and/or other attached systems (e.g. domestic hot water) to the total annual input of electrical energy consumed, including the total annual input of auxiliary energy

NOTE See also Annex C.

3.1.3
balance point temperature
lowest design external air temperature at which the heat pump output capacity and the building heating demand (heat load) are equal

NOTE At lower external air temperatures, a second heat generator is employed to cover the entire or part of the building heating demand.

3.1.4
bivalent-alternative mode
operational mode in which a second heat generator (e.g. gas boiler) completely accounts for the heat demand of the heating system if the external temperature falls below the balance point temperature

3.1.5
bivalent-parallel mode
operational mode in which a second heat generator (e.g. gas boiler) accounts for the remaining heat demand of the heating system, which cannot be supplied by the heat pump when the external temperature falls below the balance point temperature

3.1.6
monovalent mode
operational mode in which the heat pump is designed to cover the entire heat demand of the heating system alone

NOTE The heat pump output capacity is at least equal to the design heat load calculated according to EN 12831.

3.1.7
backup heater
supplementary heating which is used to supply heat when the capacity of the heat pump is inadequate

3.2 Symbols, units and abbreviations

For the purposes of this document, the following symbols and units (Table 2) and abbreviations (Table 3) apply.

Table 2 — Symbols and units

Symbol	Description	Unit
C_{ih}	Effective internal heating capacity of the building elements	Wh/m³K
$COP_{\theta set}$	coefficient of performance of the heat pump for domestic hot water demand at the set buffer storage temperature θ_{set}	–
f_{AS}	design factor for attached systems	–
f_{DHW}	design factor for domestic hot water systems	–
f_{HL}	design factor for the heat load	–
$\Phi_{hp,el,\theta set}$	electrical power of the heat pump for domestic hot water demand at θ_{set}	kW
P_{el}	effective electrical power input	kW
Q	energy	kWh
Q_{daily}	total hot water energy demand per day	kWh
Q_S	energy stored in the buffer storage	kWh
Q_{DP}	energy demand during the defined period	kWh
$Q_{l,s}$	heat losses of the buffer storage in a defined time period	kWh
$Q_{s,eff}$	effective (useful) amount of energy in the buffer storage	kWh
$q_{l,s}$	specific daily thermal losses of the buffer storage	kWh/(24h·l)
t_{DP}	duration of the defined period	h
$t_{Energy,HP}$	duration of period when energy is available for the heat pump	h
V_S	volume of buffer storage	l
V_{DP60}	volume delivered during the defined period at 60 °C	l
$V_{l,s}$	volume amounting to the thermal losses of the buffer storage	l
$V_{\Phi set}$	volume of hot water at θ_{set} that has the same enthalpy as QDP	L
Φ_{AS}	heating capacity of attached systems	kW
Φ_{DHW}	heating capacity of the heat pump for domestic hot water use	kW
Φ_{HL}	heat load capacity	kW
$\Phi_{hp,\theta set}$	heating capacity of the heat pump at θ_{set}	kW
Φ_{hp}	heating capacity of the heat pump	kW
Φ_{SU}	heating capacity of the heat supply system	kW
λ	thermal conductivity	W/(mK)
θ_{CW}	inlet temperature (cold water)	°C
θ_{DPset}	set point for temperature in the buffer storage	°C
θ_e	design external air temperature	°C
$\theta_{m,e}$	local mean external air temperature	°C
θ_{min}	minimum value for domestic hot water draught off	°C
θ_{set}	set temperature	°C

Table 3 — Abbreviations

Abbreviation	Description
COP	coefficient of performance
DHW	domestic hot water
GWP	global warming potential
ODP	ozone depletion potential
SPF	seasonal performance factor

4 System design requirements

4.1 General

4.1.1 Basic consideration

The heating system shall be designed according to the requirements stated in 4.1 of EN 12828:2003. The following additional aspects shall be taken into account.

4.1.2 Heat source

4.1.2.1 General design aspects

For each type of heat source, the following design aspects shall be taken into consideration:

— availability of the heat source;

— temperature level of the heat source;

— available heat extraction rate;

— quality of the heat source.

4.1.2.2 Air as heat source

The minimum air flow declared by the manufacturer has to be taken into account when designing the system.

The efficiency and the capacity of the heat pump increases with increasing external air temperature. For monovalent systems, the required capacity of the heat pump shall be determined by using the design external air temperature θ_e in the heat load calculation according to EN 12831. For bivalent systems, a suitable balance point temperature shall be set depending on the selected operational mode (bivalent-alternative or bivalent-parallel mode).

The air entering the evaporator of the heat pump (outdoor air or exhaust air), shall be clean according to the manufacturer's specifications.

4.1.2.3 Water as heat source (e.g. groundwater, seawater, lake, river)

The required water flow rate for the heat pump unit shall be made available, taking into account local regulations which may place limits on availability and flow rates.

The average groundwater temperature can be obtained from local authorities, a test borehole or (in the case of dwellings) by qualified assumption (i.e. the annual mean external temperature at the location).

The water source shall enable a continuous extraction of the design flow rate of the attached heat pumps. The possible extraction flow rate is dependant on local geological factors and can be ascertained by continuously extracting the nominal flow rate in a test run of sufficient duration to attain quasi-steady-state conditions. For larger systems, hydrogeological investigations (e.g. well test) may be necessary.

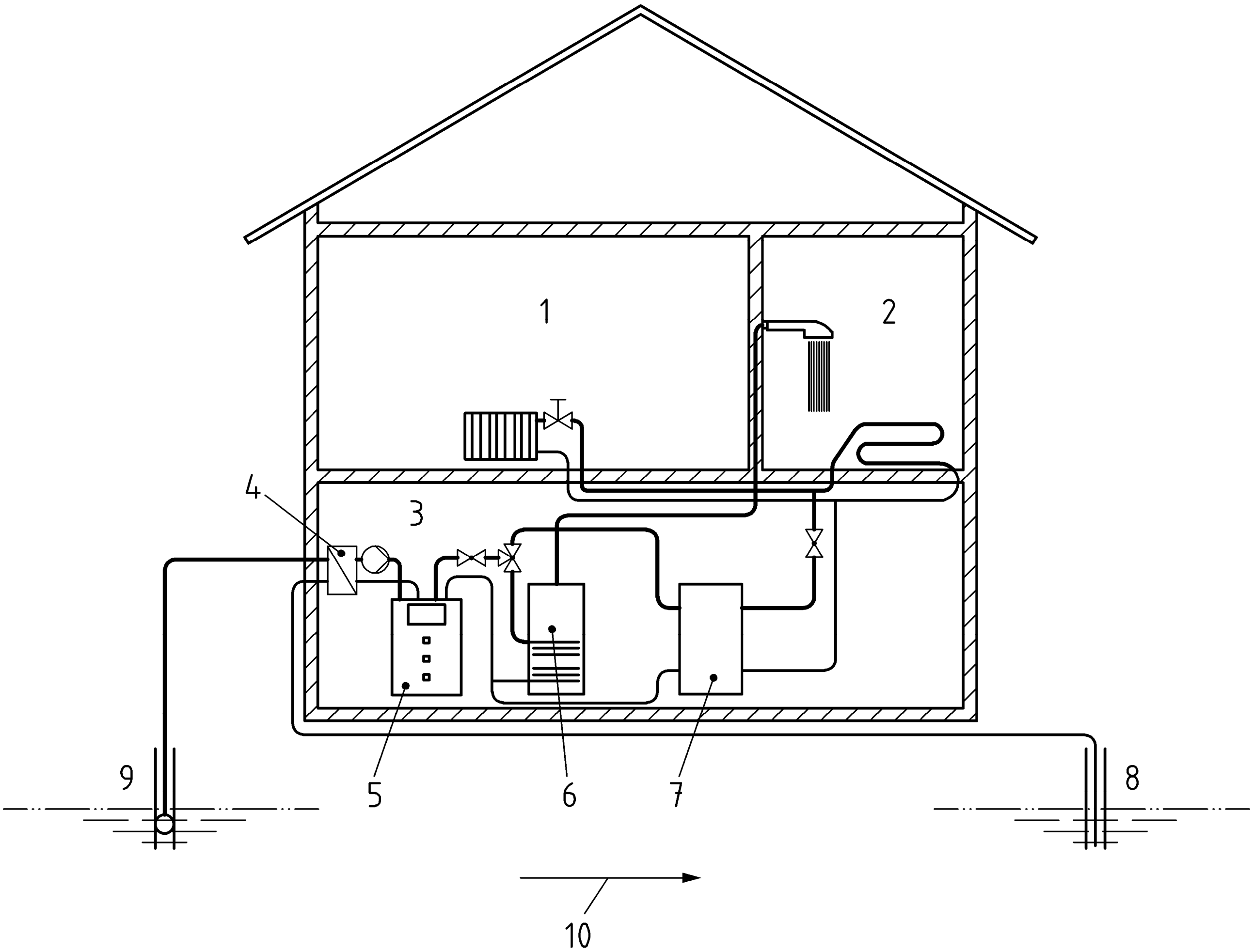
The water should be free of impurities and aggressive substances so as to prevent clogging of the injection well. Care should be taken not to allow oxygen to enter the system, in particular in case iron and manganese are present in the water. The manufacturer's specifications shall be adhered to. If no manufacturer's specifications are available, guidance values for the water quality are given in Annex A.

If the above requirements cannot be achieved (e.g. in case of sea-water), a secondary circuit or a water treatment shall be considered.

The water shall be returned to the environment as clean as possible and in accordance with local regulations.

Provisions for returning the water shall be provided for. The direction of the ground water flow shall be taken into account when selecting the position of the injection well. The extraction well shall be situated upstream of the injection well if the heat pump is only used for heating purposes (see Figure 1).

The heat extraction system shall be designed and controlled so as to avoid the risk of freezing.



Key

1 living room,
2 bathroom,
3 cellar,
4 heat exchanger,
5 heat pump,
6 storage water heater,
7 buffer storage,
8 injection well,
9 extraction well,
10 ground water flow direction

Figure 1 — Arrangement of a heat pump heating system with ground water flow

4.1.2.4 Ground as heat source

The heat supply from the ground can be obtained by using either horizontal ground heat exchangers situated below the surface (horizontal loops) or vertical borehole heat exchangers (vertical loops).

The minimum temperature of the ground at the appropriate depth shall be taken into account when designing the heat pump system. Information on typical temperature profiles is given in Annex A.

The temperature reduction of the ground, as a result of heat extraction over the heating period, as well as the long term temperature drop, due to consecutive years of heat pump operation, shall be taken into account so as never to jeopardize the operation of the heat pump and also to ensure economical - as well as reasonable environmental operating conditions.

Local thermal properties of the ground, undisturbed ground temperature and system design have to be considered in the design of the heat exchanger.

Information on neighbouring drillings, where available, shall be considered.

Local regulations may limit the availability of ground as a heat source (e.g. drilling depths, presence of ground water).

4.1.3 Electrical supply

Availability of a suitable electrical supply shall be ensured (power and amperage).

National regulations may require that the local energy supplier shall be informed prior to installation.

The operation time, the tariff and the cut-out time have to be taken into account.

Maximum current drawn during start-up phase shall be considered.

4.1.4 Strategy

The strategy for the design of a heat pump system shall consider the following aspects:

— The heat pump system shall be designed so as to achieve the highest seasonal performance factor (SPF) with respect to the selected heat source. The SPF increases with decreasing temperature difference between the source temperature and the sink temperature. High source temperatures and low sink temperatures are desirable (reducing the sink temperature by 1 K leads to an increase in the COP of about 2 %).

— The heat pump system shall be designed so that its seasonal performance factor is equal to or higher than the minimum values given in an according national annex. In case no national annex has been published, default minimum values are given in Annex C.

NOTE Additionally, target-values for the seasonal performance factor are given in an according national annex. In case no national annex has been published, default target-values are given in Annex C.

— The heat pump system shall be designed and controlled so as to avoid excessive start-up cycles (e.g. three start-up cycles per hour). The maximum number of start-up cycles per hour (or other time unit) shall comply with the regulations stated by the local utility and shall be in accordance with specifications by the manufacturer of the heat pump.

— The environmental impact due to heat pump operation shall be minimised. The selected refrigerant of the heat pump shall have an ozone depletion potential (ODP) of zero and a low global warming potential (GWP) (see also EN 378-1). Care shall be taken not to emit the refrigerant into the atmosphere due to leakages during operation as well as during maintenance.

— The heat pump system shall be designed so as to be user-friendly and require limited maintenance.

4.1.5 Positioning

When positioning the heat pump, the following should be considered:

— location of the heat pump, e.g. outside the building, within the heated space or in an unheated space;

— allowable temperature range of the environment surrounding the heat pump (given by the manufacturer);

— possibility of damaging the unit or the components due to freezing;

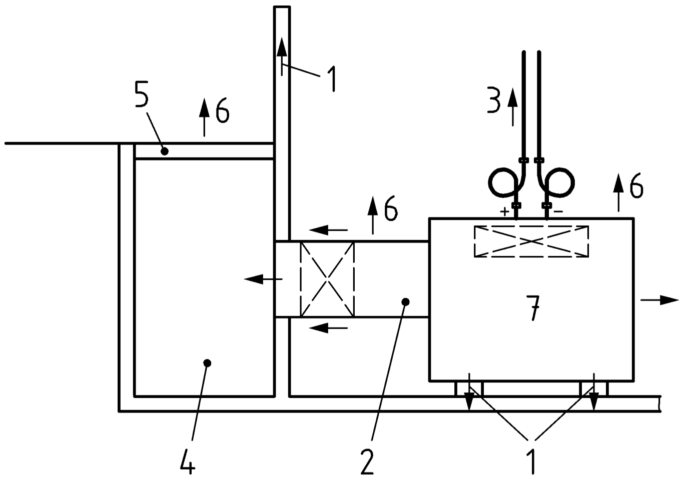
— accessibility for installation and maintenance purposes.

4.1.6 Noise level

Noise immission (i.e. sound pressure) caused by the heat pump unit and its auxiliary components shall not exceed the maximum values required by national authorities.

Recommended maximum noise-levels are given in Annex D.

Heat pumps using air as a heat source are prone to cause noise problems resulting from sound conducted through solids and transmitted through air. Figure 2 shows critical sound transmission points of such heat pump installations. Care should be taken to acoustically insulate these points when designing and installing the heat pump system.



Key

1 sound conducted through solids;
2 channel for air intake or air extraction;
3 heating pipes;
4 air shaft;
5 grid cover;
6 sound conducted through air;
7 heat pump.

Figure 2 — Critical sound transmission points in air-source heat pumps

The room acoustics also have an important impact on the noise propagation and the noise level. This should be taken into consideration in the design phase.

4.2 Heat supply

The heat supply system shall be designed to satisfy the design heat load of the building and the requirements of any attached system (e.g. domestic hot water production). The design heat load shall be calculated in accordance with EN 12831.

NOTE The heating capacity of the heat pump can be kept low by avoiding the additional heat load caused by intermittent heating (e.g. avoiding night setback).

The heat supply to serve the system shall be sized according to 4.2.2 of EN 12828:2003:

$$\Phi_{SU} = f_{HL} \cdot \Phi_{HL} + f_{DHW} \cdot \Phi_{DHW} + f_{AS} \cdot \Phi_{AS} \quad \text{KW} \qquad (1)$$

where:

Φ_{SU} capacity of the heat supply system in kW;
f_{HL} design factor for the heat load;
Φ_{HL} heat load capacity in kW;
f_{DHW} design factor for domestic hot water systems;
Φ_{DHW} domestic hot water capacity in kW;
f_{AS} design factor for attached systems;
Φ_{AS} capacity of attached systems in kW;

The domestic hot water capacity Φ_{DHW} is determined in 4.4.

For heat pump systems, the design factors for Equation (1) are given in Table 4.

Table 4 — Heat pump systems design factors

Load	Heat pump design factor	Design criteria	Values for design factors
heat load	f_{HL}	low building mass (suspended ceilings and raised floors and light walls); C_{ih} ≤ 20 Wh/m³K	1,00
		medium building mass (concrete floors and ceilings, and light walls); 20 Wh/m³K < C_{ih} < 40 Wh/m³K	0,95
		high building mass (concrete floors and ceilings combined with brick or concrete walls); C_{ih} ≥ 40 Wh/m³K	0,90
domestic hot water	f_{DHW}	standard class of sanitary equipment	1
attached systems	f_{AS}		1

where:

C_{ih} Effective internal heating capacity of the building elements in Wh/m³K;

4.3 Additional backup heater

Heat pumps incorporating an additional backup heater shall be selected such that the energy supplied by the backup system is reduced to a minimum (e.g. less than 5 % of the total energy supplied by the heat pump if the energy source of the backup heater is not renewable).

In order to secure sufficient domestic hot water production, the designer shall calculate and document the daily quantity of hot water which can be delivered by the backup system alone.

4.4 Domestic hot water production or other attached systems

4.4.1 Hot water demand

The maximum daily hot water demand and relevant tapping pattern shall be identified to size the system.

The hot water demand can differ considerably depending on the type of building, its usage and the region or country. The mandate M324 and SAVE report on domestic hot water demand provide data to identify the daily hot water demand for residential areas. National values on the daily hot water demand shall therefore preferably be used.

In the absence of national values, an average daily hot water demand of 1,45 kWh, corresponding to 25 l at 60 °C per person per day, can be considered as a default value for sizing domestic hot water systems. This corresponds to the average daily hot water consumption (Mandate M324 from the European Commission). Daily tapping patterns in residential buildings assume typically that the domestic hot water demand is required in the morning (35 %), at noon (20 %) and in the evening (45 %).

4.4.2 Heat pump data

Data should be obtained from the manufacturer's specifications, which shall be based on test data according to EN 255-3.

4.4.3 Sizing (heat pump capacity, DHW storage volume, auxiliary source capacity)

4.4.3.1 Identify the hot water demand for sizing the system

The designer shall identify the critical value Q_{DP} of the daily hot water energy demand during a defined period and the duration of this corresponding period t_{DP}.

Annex E provides information on domestic hot water demand for the residential sector.

Different strategies are available depending on electrical tariff, space available and cost effectiveness of the design solutions.

Solution 1 — Accumulation:
This solution results in a larger volume of the DHW storage, which is sized on the maximum daily demand. The selected thermal capacity of the heat pump allows the DHW storage to be heated up during low cost tariff.

Solution 2 — Semi accumulation:
This is the most general solution and requires that the heat pump is always available for hot water production.

The designer shall check which period is the most critical for maintaining the DHW storage at hot conditions. The tables given in Annex E provide guidance to define the total hot water energy demand Q_{daily}, the critical value Q_{DP} and the duration of the corresponding period t_{DP}.

4.4.3.2 Definition of the DHW storage volume V_S

The size of the DHW storage and the thermal capacity needed to heat up and maintain enough DHW to fulfil the demand are closely related.

The simplest way to design the DHW storage is to define a volume and subsequently check whether or not the thermal power of the heat pump is sufficient to meet the requirements for DHW demand alone as well as during the heating period. If the thermal power of the heat pump is not sufficient, the volume of the DHW storage shall be adapted.

Solution 1 — Accumulation
As a basis, the average daily consumption given in 4.4.1 is doubled (e.g. from 25 to 50 l at 60 °C per person) and this value is considered for sizing the system. Larger values may be used if large bathrooms and use of DHW are considered.

The daily thermal losses of the DHW storage ($Q_{l,s}$) shall be integrated in this calculation as an added volume corresponding to the set temperature.

Solution 2 — Semi-accumulation
As a basis, volume should be considered to match the daily average consumption of DHW given in 4.4.1. Smaller volumes may be used if the thermal heating capacity of the heat pump is sufficient to reload the DHW storage to the set temperature after critical sequences such as 2 consecutive baths.

NOTE The critical value Q_{DP} of the daily hot water energy demand is conventionally expressed as a corresponding volume V_{DP60} delivered at 60 °C. The volume of hot water has to be corrected according to the set temperature of the DHW in the DHW storage tank.

The DHW storage volume is determined as the volume of hot water $V_{\theta set}$ delivered at θ_{set} and is obtained as follows:

$$V_S = V_{\theta set} = V_{DP60} \times \frac{(60 - \theta_{cw})}{(\theta_{set} - \theta_{cw})} \quad \text{l} \qquad (2)$$

where:

V_S volume of the DHW storage in l

$V_{\theta set}$ volume of hot water at θ_{set} corresponding to Q_{DP} in l

V_{DP60} volume of hot water at 60 °C corresponding to Q_{DP} in l

θ_{set} set temperature of the hot water in the DHW storage in °C

θ_{cw} temperature of the cold water in °C.

4.4.3.3 Energy balance of the DHW storage

The energy stored in the DHW storage is expressed as follows:

$$Q_s = 0{,}00116\ (\theta_{set} - \theta_{cw}) \cdot V_s \quad \text{kWh} \qquad (3)$$

The extraction temperature in the DHW storage shall not fall below θ_{min} = 40 °C during any draw off period. The effective amount of energy available in the storage is therefore:

$$Q_{s,eff} = Q_s \cdot (\theta_{set} - 40) / (\theta_{set} - \theta_{cw}) \quad \text{kWh} \qquad (4)$$

The energy demand during the defined period is:

$$Q_{DP} = 0{,}00116\ (60 - \theta_{cw}) \cdot V_{DP60} \quad \text{kWh (as energy demand is expressed at 60 °C)} \qquad (5)$$

4.4.3.4 Calculation of the minimum thermal heating capacity needed to fulfil domestic hot water requirements

Solution 1 — Accumulation systems

The thermal heating capacity of the heat pump for DHW production is sized to heat up the storage when electrical energy is available.

$$\Phi_{hp,\theta set} = \frac{Q_S}{t_{Energy,hp}} \quad \text{kW} \qquad (6)$$

where

$\Phi_{hp,\theta set}$ thermal heating capacity of the heat pump at θ_{set} in kW

Q_S energy stored in the DHW storage in kWh

$t_{Energy,hp}$ time period where electrical energy is available for DHW production in h

The corresponding electrical power is determined as

$$P_{hp,el,\theta set} = \frac{\Phi_{hp,\theta set}}{COP_{\theta set}} \quad \text{kW} \qquad (7)$$

where

$P_{hp,el,\theta set}$ electrical power of the heat pump for domestic hot water use in kW

$\Phi_{hp,\theta set}$ thermal heating capacity of the heat pump at θ_{set} in kW

$COP_{\theta set}$ coefficient of performance at θ_{set} (as obtained from the manufacturer's specifications)

Solution 2 — Semi- accumulation system

Considering the energy drawn off during the critical period Q_{DP}, the thermal capacity of the heat pump is determined so as to reload the DHW storage to the same status (θ_{set}) before the next draw off occurs.

This signifies, that during the defined period (e.g. as presented in Annex E), the heat pump power is sufficient to maintain the DHW storage at a minimum value (40 °C as a minimum).

Equation (8) indicates the energy balance of the system.

Energy input = Energy used – Useful energy stored + energy losses of DHW storage

↓ ↓ ↓ ↓

$$\Phi_{hp,\theta set} \cdot t_{DP} = Q_{DP} - Q_S \cdot (\theta_{set} - 40) / (\theta_{set} - \theta_{cw}) + Q_{l,s} \qquad (8)$$

$$\Phi_{hp,\theta set} = \frac{Q_{DP} - Q_S \cdot \frac{(\theta_{set} - 40)}{(\theta_{set} - \theta_{cw})}}{t_{DP}} + \frac{Q_{l,s}}{t_{DP}} \qquad (9)$$

where:

t_{DP} duration of the defined period in h

$Q_{l,s}$ thermal losses of the DHW storage in the considered time period kWh

The corresponding electrical power can be determined according to Equation 7.

An example calculation is given in Annex E.

4.4.3.5 Additional heating requirements and sizing of backup heater

Equation (2) given in 4.4.3.2 provides the relationship between output capacity of the heat pump and volume of the DHW storage.

The designer should choose the DHW storage volume taking into consideration, that the total output capacity of the heat pump should be sufficient to fulfil the demand for space heating and domestic hot water, and if this is not the case, the volume of the DHW storage shall be changed.

The backup heater (usually electrical) should be sized to cover at least the demand for DHW of the system as calculated above.

4.4.4 Specific control requirement for DHW production

The system shall be sized and supplied with a control system so as to assure that a temperature of 60 °C may be reached once a day, if required. If the heat pump is not able to reach 60 °C on its own, the auxiliary system shall ensure that 60 °C may be reached.

In case of combined systems (space heating and domestic hot water), the control system should be designed to prioritize DHW production when simultaneous need of space heating and DHW occur.

Care should be taken to ensure that the control of the backup heater is properly integrated with those of the heat pump. This should avoid both operating at the same time, where the return water temperature to the condenser could rise to such a level, that the high pressure cut-out shuts down the heat pump.

4.4.5 Other specifications

Good thermal insulation of the DHW storage and the connection points is important for the performance of the system.

$$q_{l,s} = \frac{Q_{l,s}}{V_S} \quad \text{kWh / (24h·l)} \qquad (10)$$

The daily thermal losses of the DHW storage $q_{l,s}$ are expressed in kWh/(24h·l) for a defined temperature difference of 45 K. Typical values for $q_{l,s}$ are between 0,005 and 0,015 kWh/(24h·l).

DHW storage vessels (domestic water heaters, hot water and DHW storage vessels) with a storage volume between 30 l and 2 000 l, which are equipped with manufacturer provided prefabricated insulation, underlie an energy related testing method. The energy loss shall not exceed the values given in Table 5. More stringent national regulations may apply.

Table 5 — Proposed maximum energy losses of DHW storage vessels

nominal volume l	**max. heat loss** kWh/24h	**nominal volume** l	**max. heat loss** kWh/24h
30	0,75	600	3,8
50	0,90	700	4,1
80	1,1	800	4,3
100	1,3	900	4,5
120	1,4	1 000	4,7
150	1,6	1 100	4,8
200	2,1	1 200	4,9
300	2,6	1 300	5,0
400	3,1	1 500	5,1
500	3,5	2 000	5,2

Intermediate sizes are to be interpolated linearly; the actual volume may fall below the nominal volume by max. 5 %.

The above heat losses are valid for installations and equipment with up to 2 water-containing pipe connections. Each additional pipe connection increases the permitted heat loss by 0,1 kWh in 24 h, up to maximal 0,3 kWh in 24 h.

If the DHW storage is installed in an unheated room, additional insulation should be considered.

4.5 Hydraulic integration

In order to minimize cycling, it shall be assured that the heating capacity delivered by the heat pump is completely transferred to the heating system.

NOTE This can be achieved by setting a sufficient constant volume flow rate at the heat sink side of the heat pump. A higher inertia (capacity) can be achieved with a surface heating system or by installing a buffer storage (in parallel or series). A buffer storage connected in parallel with the heat pump serves additionally as a means of hydraulic decoupling. A guidance value for sizing the buffer storage volume is 12 to 35 l per kW maximum heat pump capacity.

4.6 Control of the system

The output capacity of the heat pump shall be adapted to the building heat demand. It can be accomplished by different methods, which are given in Annex F.

4.7 Safety arrangements

The safety requirements listed in 4.6 of EN 12828:2003 also apply to this standard (nominal heat output < 300 kW) if the medium on the heat sink side of a heat pump system is water.

All heat pump systems shall be equipped with appropriate controls that prevent a major leakage of refrigerant in case of accident. Refrigerant systems shall be in accordance with EN 378-1.

NOTE Local regulations may require that heat pump systems using the ground as heat source shall be equipped with appropriate equipment to detect a leakage of brine or water.

4.8 Operational requirements

4.8.1 General

Operational parameters shall be controlled during commissioning and be periodically monitored in the normal running phase of the heating system. In addition, measurement and recording of operational parameters can be used to calculate the energy performance of the heat pump in operation during a certain period of time. These respective parameters are the feed and return temperatures of the heat source and heat sink, the electrical power consumption and the volume flow rate (or heat meter readings).

4.8.2 Provisions for monitoring operational conditions (e.g. temperature, power consumption)

4.8.2.1 General requirements

In order to facilitate monitoring and recording of operational and energy related parameters, provisions in the piping (water systems) or ducting (air systems) shall be made at operating locations, provided they have not already been integrated in the heat pump unit as supplied by the manufacturer.

4.8.2.2 Fluid systems

If the source side and/or the sink side of the heat pump system is served by water, brine or refrigerant as a medium, the following operational requirements in these types of circuits apply:

— provisions for directly measuring the feed and return temperatures of the circuit shall be provided;

— pipe sleeve on the feed or return pipe of the circuit shall be installed in such a way, that a volume flow-meter can be easily installed for measurement (external method). Alternatively, a refrigerant heat balance method may be used (internal method);

— electrical power consumption of the heat pump unit should be measured by a power meter.

4.8.2.3 Air based systems

If the source side and/or the sink side of the heat pump system is served by air as a medium, the following operational requirements in these types of circuits apply:

- provisions for directly measuring the feed and return temperatures of the air in the circuit shall be provided;

- provisions shall be taken to leave enough room around the supply or return air ducts in order to introduce an air velocity or an air flow-meter probe into the duct (external method). Alternatively, a refrigerant heat balance method may be used (internal method);

- electrical power consumption of the heat pump unit should be measured by a power meter.

5 Installation requirements

The manufacturer's installation instructions shall be adhered to when installing the system.

National regulations concerning the installation of vertical and horizontal ground collectors shall be adhered to. This also applies to the creation of injection and extraction wells in water-based systems.

6 Commissioning of the system

6.1 Overview

Basic recommendations for commissioning of the heat distribution system are given in EN 14336.

The objective of the commissioning according to this standard is:

— to check that the system as a whole is in a satisfactory and safe condition for operation;

— to check that all components of the system can operate in accordance with the design conditions;

— to tune the control system parameters in order to meet the operation conditions according to the design;

— to balance the heat distribution system.

Commissioning shall be carried out after the installation of the heat pump heating system has been completed.

Commissioning is done in steps as follows:

— Preparation of commissioning:

  — distribution system;

  — storage;

  — heat source;

- heat pump unit;
- electrical installation;

— Commissioning:

- heat pump;
- heating system;

— Handing over:

- owner's instructions;
- documentation.

Optimization (if requested or necessary).

6.2 Preparation of commissioning

6.2.1 Heat distribution circuit

Heat distribution circuits of water based systems should be cleaned and flushed. This includes heat exchangers, tanks and other hydraulic components.

Water tightness of the circuit shall be tested.

NOTE A possible method for controlling water tightness is given in EN 14336.

6.2.2 Ground loop

The ground loop circuit (horizontal or vertical) shall be cleaned and flushed.

Tightness of the circuit shall be checked. The ground loop circuit shall be pressure tested with an appropriate method, e.g. to a pressure of 4 bar during at least 30 min (for metal pipes). The testing method for plastic pipes shall take into account the expansion of the material. The values may vary depending on the selected pipe material and pipe dimensions.

Refrigerant tubing shall be tested in accordance with EN 378-1.

6.2.3 Filling and venting

The heat distribution system shall be filled with water and be vented. Venting is particularly important in circuits using brine as a medium so as to minimize the effect of foam generation.

After filling the system, the filling source connection shall be disconnected from the water supply.

When necessary, anti-freeze products shall be added to the water according to the heat pump manufacturer's specifications (brine).

The same considerations shall be taken when filling up the ground loop.

6.2.4 Switch box and electrical wiring

Tightening of the electrical connections of the heat pump and the other components of the installation (e.g. fans, pumps, electrical valves) to the energy supply shall be carefully checked.

Connections of the ground potential wiring shall be checked.

Cut-out current value of the cut-out switches shall be checked.

6.3 Commissioning

6.3.1 Functional performance tests

6.3.1.1 General

The functional performance tests given in the following sub-clauses shall be carried out.

6.3.1.2 Water based systems

- operation of electrical valves;
- operation of manual valves;
- operation of circulation pumps;
- operation of control valves.

6.3.1.3 Air based systems

- operation of fans (direction of rotation).

6.3.1.4 Start-up procedure for all systems – start-up of the heat pump unit

Start-up procedure shall be checked and the heat pump shall be held in operation for a few minutes.

Shut-down procedure shall be followed and checked to stop the unit.

6.3.2 Operation performance tests

6.3.2.1 General

Operation performance tests allow verification that the heat pump has been set up properly with other components and meets the design objectives.

6.3.2.2 Heat pump unit

The following parameters shall be checked:

- set points for the controller (e.g. temperatures, heating curve);
- temperature difference between feed and return on the source side and the sink side of the heat pump;
- maximum attainable hot water temperature;
- function and position of the external temperature sensor.

6.3.2.3 Heat distribution system

Supply and return temperatures of the water loop shall be checked. For air based systems, outgoing and return temperatures of the air duct system shall be measured and compared to the design values.

6.3.2.4 Heat source system

Supply and return temperatures of the earth loop coming from the heat source system shall be measured and compared with the design values. Where this is not possible, due to high external temperature conditions, the temperature difference between the feed and supply of the heat source shall be measured.

6.3.2.5 Control system tuning

Control systems and devices (central control, thermostat) shall be adjusted to the design values.

6.3.3 Balancing

6.3.3.1 General

The heat distribution circuit and, if existing, the earth loop circuit shall be balanced. Methods of balancing are given in EN 14336.

6.3.3.2 Water based systems

The water flow rates of the heat distribution system shall be balanced to meet the design requirements.

6.3.3.3 Air based systems

The air mass flow rates of the heat distribution system shall be balanced, or the airflow shall be controlled by appropriate means, to meet the design requirements.

6.3.3.4 Ground loop

The water (or brine) mass flow rates of the ground collector circuit shall be balanced.

The mass flow rates in the different loops of the ground collector system shall be adjusted in accordance with design considerations (vertical and horizontal ground loops).

6.4 Handing over

After the commissioning procedure has been finalised for the entire installation, the installer shall hand over to the contractor the following documents:

— final plans of the installation, including ducting and piping;

— final electrical circuits wiring schemes;

— manufacturer’s data sheets for all components;

— user’s manuals;

— commissioning report;

— maintenance instructions.

Additionally, the contractor is to be instructed on how to operate the system.

Annex A
(informative)

Guidelines for determining design parameters

A.1 Design parameters for heat pumps using water as a heat source

A.1.1 Water quality

In order to prevent damage of the heat pump system (i.e resulting from precipitation or corrosion), the water quality of the heat source should follow the values given by the manufacturer or, if this is not the case, follow the values listed in Table A.1. If in doubt, an analysis of the water source is recommended.

Table A.1 — Requirements for the quality of extraction water as a heat source

components / units of measurement	value
organic material (possibility of sedimentation)	none
ph – value	6,5 to 9
electrical conductivity (µS/cm)	50 to 1 000
chloride (mg/litre)	< 300
iron and manganese (mg/litre)	< 1
sulfate (mg/litre)	0 to 150
O_2 – content (mg/litre)	< 2
chlorine (mg/litre)	0 to 5
nitrate (mg/litre)	0 to 100

A.1.2 Water temperature

For systems with a thermal heating capacity less than 30 kW, the average temperature of the extracted water can be assumed as the local mean external air temperature $\theta_{m,e}$, provided the extraction well is situated at least 10 m below ground surface. This value ($\theta_{m,e}$) may be increased by up to 3 °C in urban areas or regions with large snow covering.

A.1.3 Water quantity

The yield of the well shall guarantee permanent production of the nominal flow rate of the attached heat pumps. If no other data is available, a water flow rate of 0,25 m³/h per kilowatt capacity of the heat pump evaporator can be used as a design parameter. The temperature difference between supply and return temperature is typically between 3 K and 4 K for small systems. Larger systems may operate with larger temperature differences.

A.2 Design parameters for heat pumps using ground as a heat source

A.2.1 General

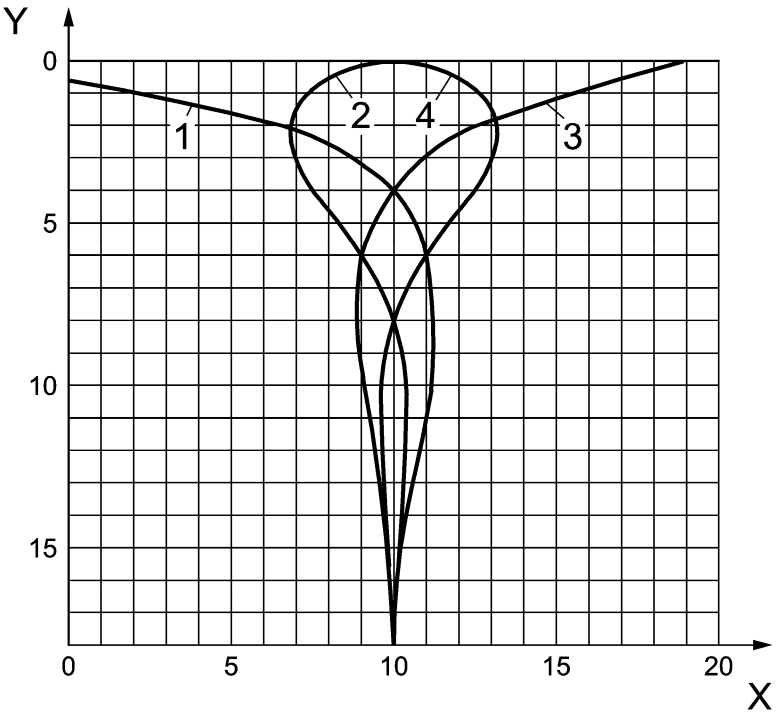
For heat pumps using the ground as a heat source, the heat extraction can be obtained by using either horizontal heat exchangers positioned between 0,8 and 2,0 m underneath the ground level (depending on the region) or by drilling vertical bore holes.

A.2.2 Ground temperature

The seasonal variation of the ground temperature decreases with increasing depth. Typical values of undisturbed ground temperatures are given in Figure A.1 below. For the purpose of designing the system (heat load calculation), the lowest ground temperatures should be used (typically 0 °C).

Ground loop circuits shall be installed (laid) in an appropriate depth and in such a manner, that freezing of the medium is avoided in extreme conditions (design external temperature).

For vertical bore-hole-heat exchangers, the annual mean external temperature $\theta_{m,e}$ can be used as a design value.



Key

Y depth in m;
X temperature of the surrounding earth at horizontal level
1 temperature curve of 1st of February;
2 temperature curve of 1st of May;
3 temperature curve of 1st of August;
4 temperature curve of 1st of November.

Figure A.1 — Theoretical temperature distribution versus depth for a location with 10 °C annual mean external temperature

A.2.3 Heat extraction rates

A.2.3.1 Horizontal ground heat exchangers

In simple cases (i.e. domestic buildings), the average specific values for the heat extraction rate can be obtained by determining an extraction rate per square metre ground collector area in W/m². The extraction rate depends upon the quality of the ground and the duration of heat extraction (operation period of the heat pump in hours per year). The values given in Table A.2 assume operation periods of the heat pump of 1 800 and 2 400 h per year for the heating system only. Additional heat production for domestic hot water can be considered in the table by prolonging the operation period. Horizontal ground collectors should not be built over.

An example of a horizontal ground heat exchanger is given in Figure A.2

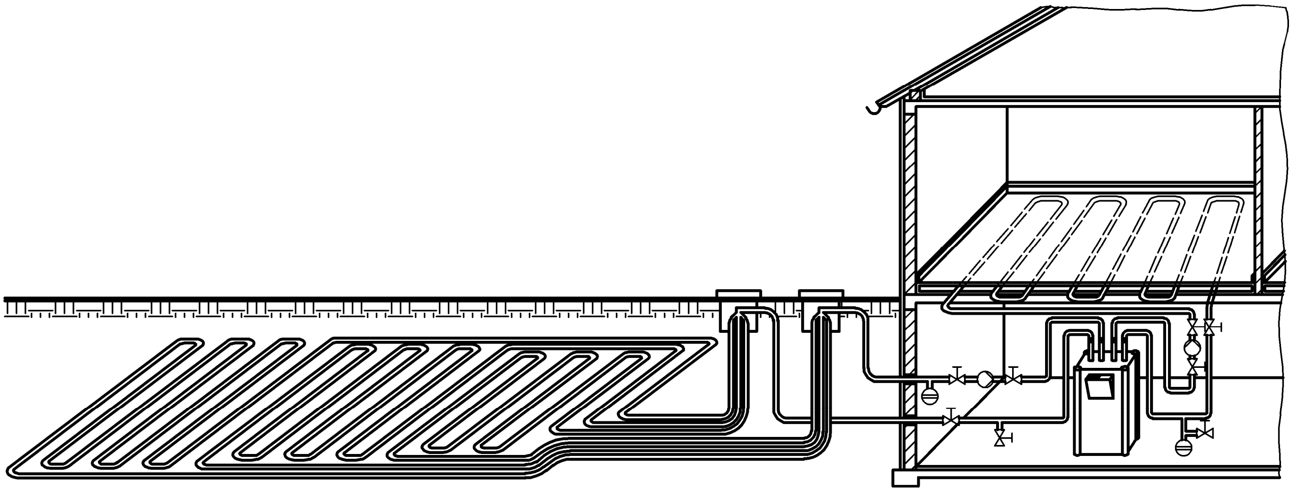


Figure A.2 — Heat pump heating system with horizontal located heat exchanger

Table A.2 — Example of requirements for ground quality in Central Europe[1)]

Ground quality	**Specific heat extraction flow rate**	
	operation period 1 800 h per year	operation period 2 400 h per year
dry, non cohesive soil	10 W/m²	8 W/m²
moist cohesive soil	20 to 30 W/m²	16 to 24 W/m²
water saturated sand or gravel	40 W/m²	32 W/m²

For longer operation periods, the annual heat extracted per square meter collector area (in kWh/m² per year) shall additionally be taken into account when designing the system, since this value reflects the long term effect of continuous heat extraction. The value should be between 50 and 70 kWh/m² per year for heating operation only.

The temperature drop between the return temperature of the heat exchange medium and the undisturbed ground temperature, during continuous operation, shall not be of such extent that technical problems arise during operation. A typical value for Central Europe is 12 K.

A.2.4 Vertical bore heat exchanger

For smaller heat pump systems up to a heating capacity of 30 kW, the average specific values for the heat extraction rate can be obtained by determining an extraction rate per metre bore hole length in W/m. The extraction rate depends upon the quality of the ground and the duration of heat extraction (operation period of the heat pump in hours per year). The values given in Table A.3 below assume operation periods of the heat pump of 1 800 and 2 400 h per year for the heating system only. Additional heat production for domestic hot water shall be considered in the table by prolonging the operation period. Table A.3 also assumes an annual mean external temperature range between 9 and 11 °C and is valid for single heating systems with up to 5

1) The values are taken from VDI 4640, part 2.

bore holes. If the quality of the ground varies significantly during drilling procedure, the length of the bore holes and/or number of bore holes should be adapted so as to compensate for the deviation in maximum heat flux extraction.

An example of a vertical bore heat exchanger is given in Figure A.3.

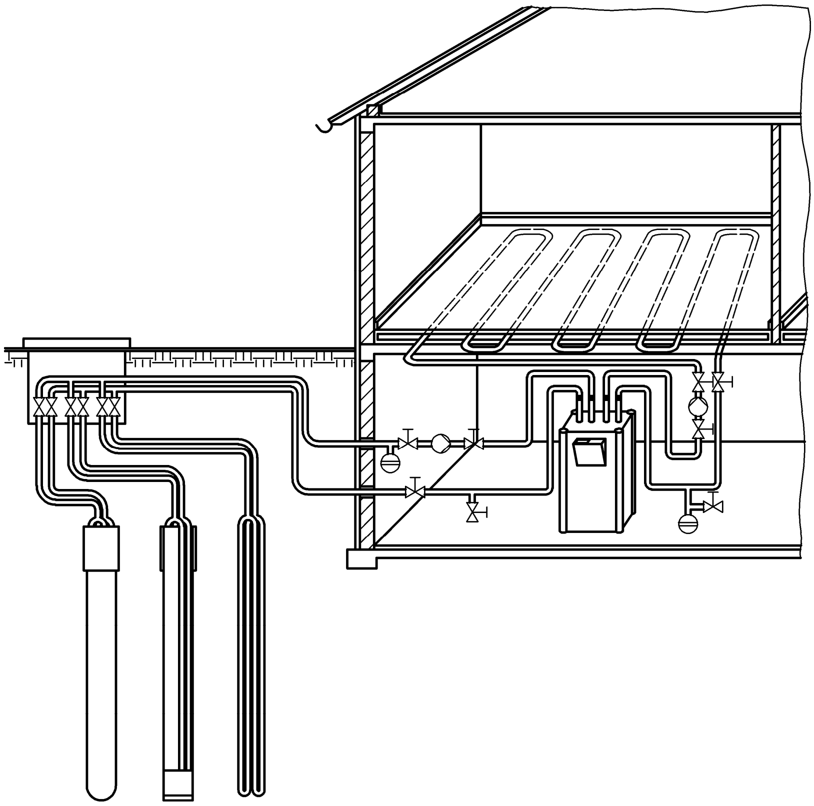


Figure A.3 — Heat pump heating system with bore hole heat exchanging by extraction

For longer operation periods, the annual heat energy per metre bore hole depth (in kWh/m per year) shall additionally be taken into account when designing the system, since this value reflects the long term effect of continuous heat extraction. The value should be between 100 kWh/m per year and 150 kWh/m per year for heating operation only.

The temperature drop between the return temperature of the heat exchange medium and the undisturbed ground temperature (i.e. 10 m depth), during continuous operation, shall not be of such extent that technical problems arise during operation. A typical value for Central Europe is 11 K.

Table A.3 — Specific heat extraction rate for various ground types in Central Europe[2)]

Ground type	Specific heat extraction rate	
	operation period 1 800 h	operation period 2 400 h
General guidance values:		
poor underground (dry sediment and λ < 1,5 W/(m K)	25 W/m	20 W/m
normal underground and water-saturated sediment 1,5 < λ < 3,0 W/(m K)	60 W/m	50 W/m
consolidated rock with high thermal conductivity λ > 3,0 W/(m K)	84 W/m	70 W/m
Individual ground types:		
dry gravel or sand	< 25 W/m	< 20 W/m
gravel or sand saturated with water	65 to 80 W/m	55 to 65 W/m
gravel or sand and strong ground water flow	80 to 100 W/m	80 to 100 W/m
moist clay	35 to 50 W/m	30 to 40 W/m
massive limestone	55 to 70 W/m	45 to 60 W/m
sandstone	65 to 80 W/m	55 to 65 W/m
siliceous magmatite (e.g.granite)	65 to 85 W/m	55 to 70 W/m
basic magmatite (e.g. basalt)	40 to 65 W/m	35 to 55 W/m
diorite	70 to 85 W/m	60 to 70 W/m
NOTE values valid for heat pump systems with a heating output up to 30 kW		

For larger ground source heat pump systems, specific calculations using analytical solutions or numerical simulation methods are required.

Filling and grouting of the bore holes could be necessary; separation distances between bore holes must be adequate and according to local regulations.

2) The values are taken from VDI 4640, part 2.

Annex B
(informative)

Standard hydraulic circuits

The most frequently used hydraulic circuits for integrating the components of the heating system are depicted in Figures B.1 to B.7.

These systems are:

— Standard system 1: Without buffer storage tank, without DHW, space heating only (given in Figure B.1);

— Standard system 2: Without buffer storage tank, with space heating and DHW (given in Figure B.2);

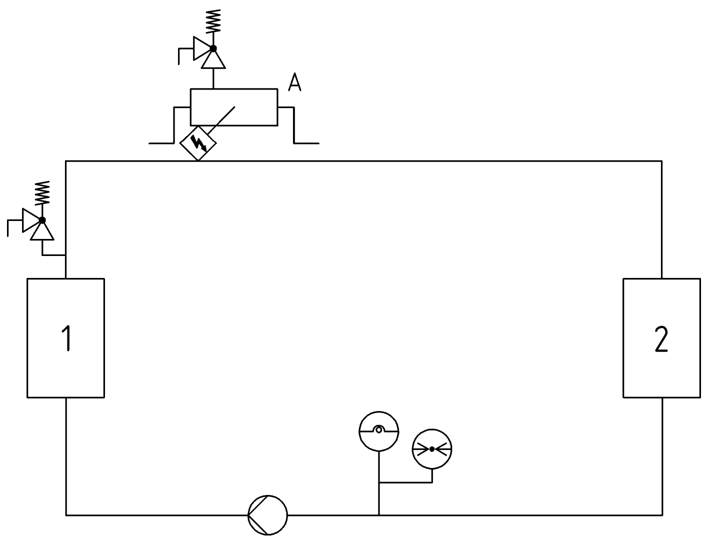
— Standard system 3: With buffer storage tank connected in series, space heating only (given in Figure B.3);

— Standard system 4: With buffer storage tank connected in series, with space heating and DHW (given in Figure B.4);

— Standard system 5: With buffer storage tank connected in parallel, space heating only (given in Figure B.5);

— Standard system 6: With buffer storage tank connected in parallel, with space heating and DHW (given in Figure B.6);

— Standard system 7: With combination storage tank and solar collectors, with space heating and DHW (given in Figure B.7).



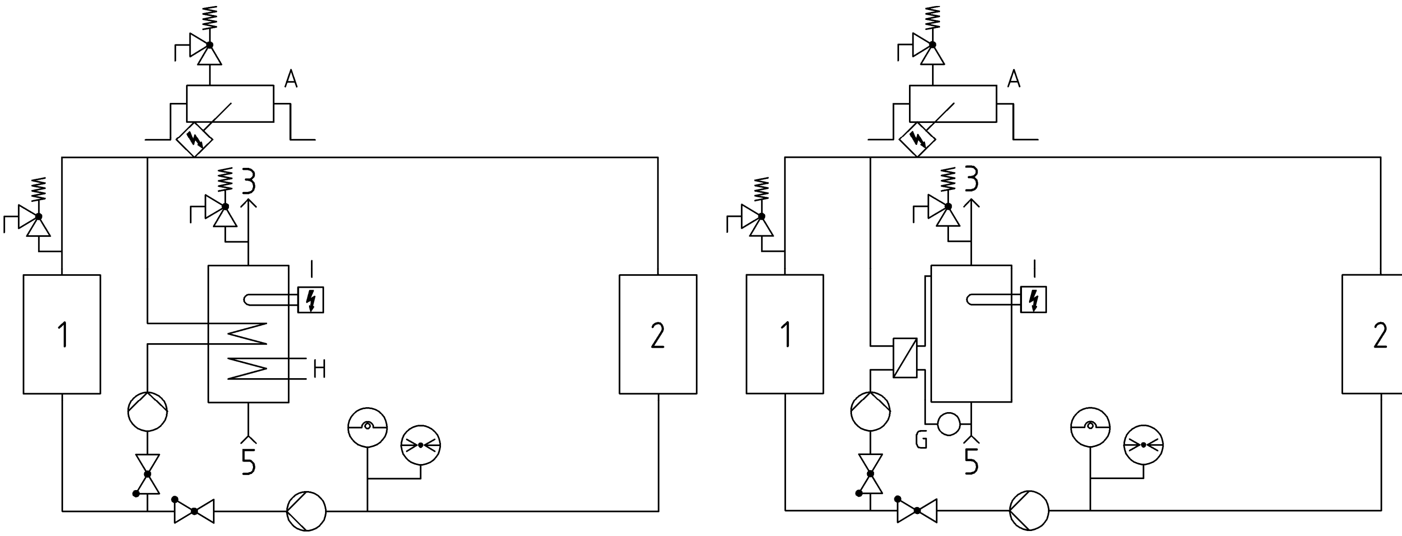
Key

1 heat pump using outdoor air or ground (bore hole heat exchanger) as heat source

2 heat distribution, emission system

A optional electrical backup heating with safety valve

Figure B.1 — Heat pump installation without buffer storage tank, without domestic hot water production, space heating only

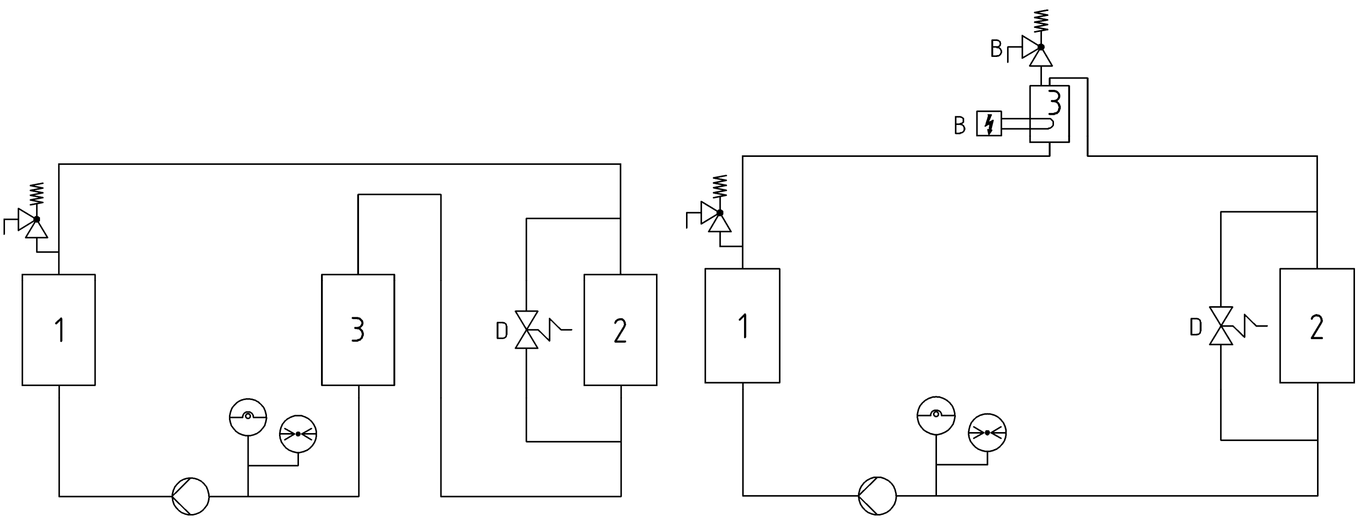


a) DHW with internal heat exchanger **b) DHW with external heat exchanger**

Key

1 heat pump using outdoor air or ground (bore hole heat exchanger) as heat source
2 heat distribution, emission system
3 domestic hot water storage
5 cold water supply
A: optional electrical backup heating with safety valve
G optional external heat exchanger for domestic hot water production
H optional solar collector (only with Figure B.2.a)
I optional electrical backup heating for domestic hot water production

Figure B.2 — Different alternatives of heat pump installation without buffer storage tank, with space heating and domestic hot water production

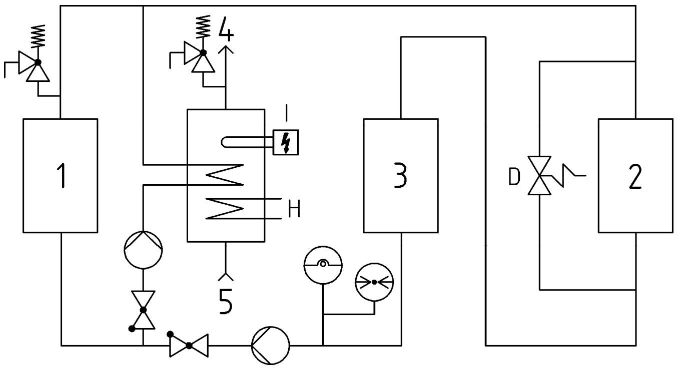


a) buffer storage in return line **b) buffer storage in supply line**

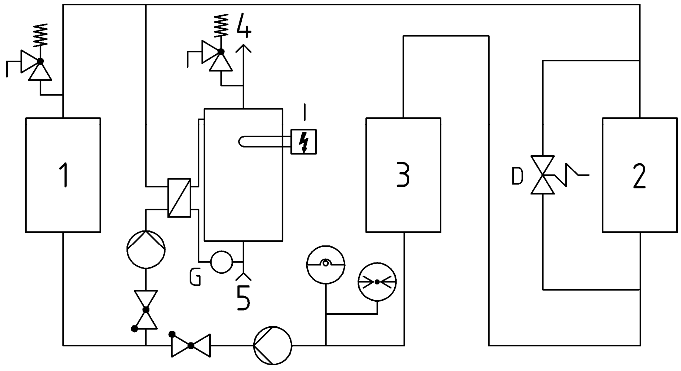
Key

1 heat pump using outdoor air or ground (bore hole heat exchanger) as heat source
2 heat distribution, emission system
3 water buffer storage for space heating
B optional electrical backup heating with safety valve (only with Figure B.3.b)
D optional overflow valve to use with thermostatic valves in heat emission system

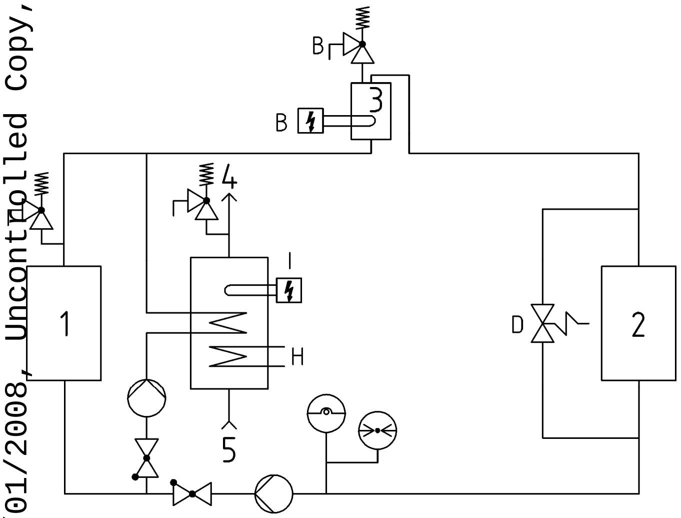
Figure B.3 — Different alternatives of heat pump installation with buffer storage tank connected in series, without domestic hot water production, space heating only



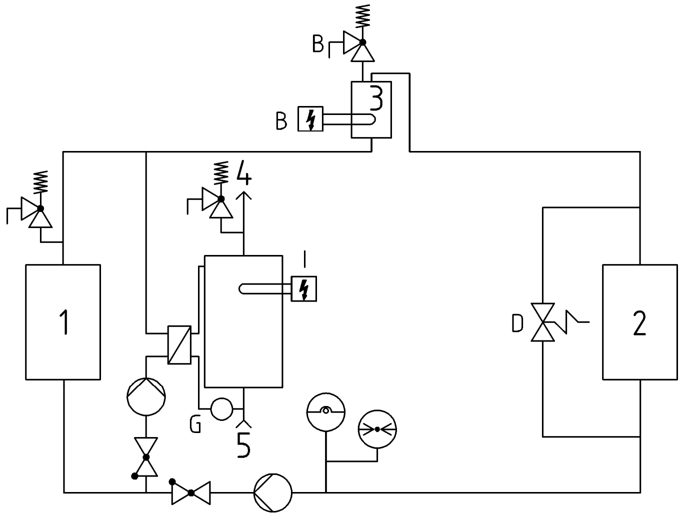
a) buffer storage in return line, internal DHW HX



b) buffer storage in return line, external DHW HX



c) buffer storage in supply line, internal DHW HX

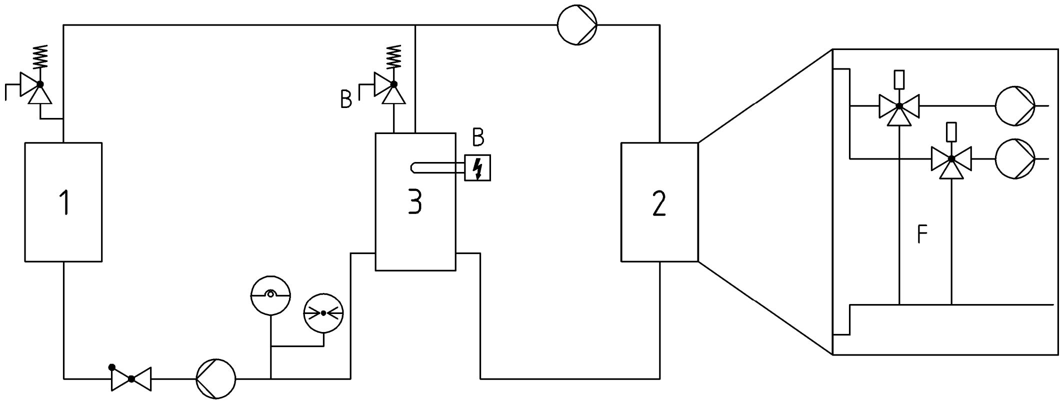


d) buffer storage in supply line, external DHW HX

Key:

1 heat pump using outdoor air or ground (bore hole heat exchanger) as heat source
2 heat distribution, emission system
3 water buffer storage for space heating
4 domestic hot water storage
5 cold water supply
B optional electrical backup heating with safety valve (only with Figures B.4.c and B.4.d)
D optional overflow valve to use with thermostatic valves in heat emission system
G optional external heat exchanger for domestic hot water production
H optional solar collector (only with Figures B.4.a and B.4.c)
I optional electrical backup heating for domestic hot water production

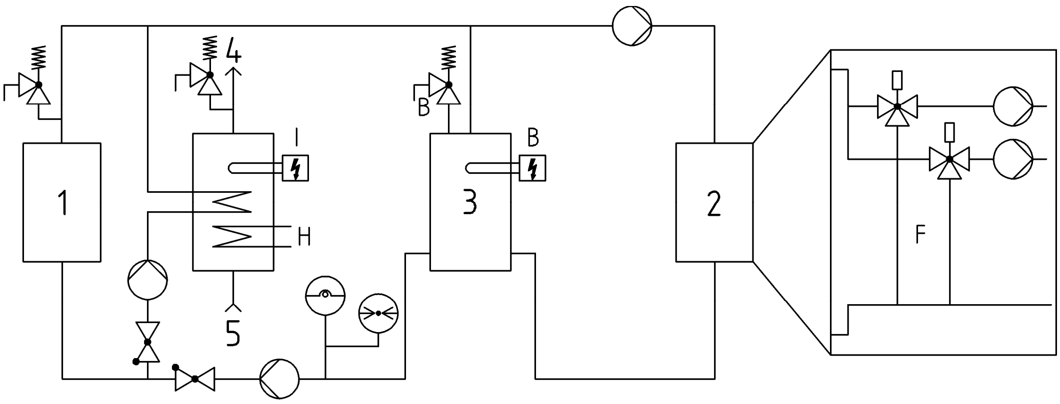
Figure B.4 — Different alternatives of heat pump installation with buffer storage tank connected in series, with space heating and domestic hot water production



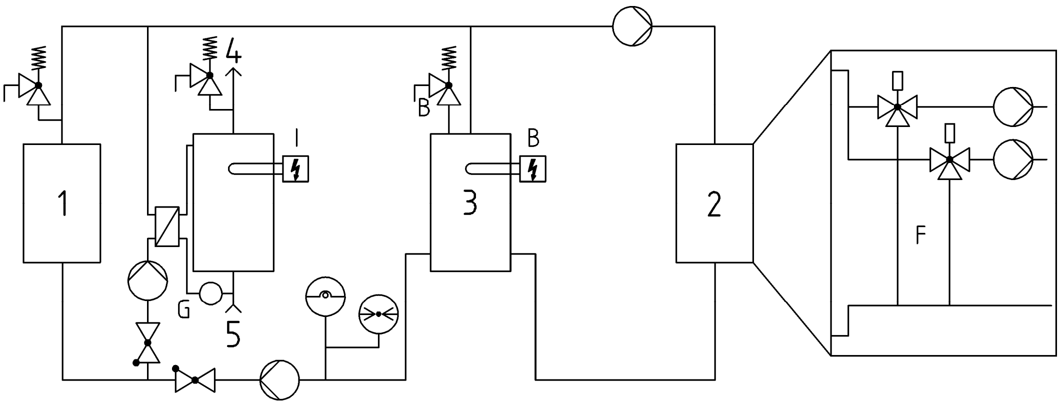
Key

1 heat pump using outdoor air or ground (bore hole heat exchanger) as heat source
2 heat distribution, emission system
3 water buffer storage for space heating
B optional electrical backup heating with safety valve
F optional additional groups of heating circuits with mixing valves

Figure B.5 — Different alternatives of heat pump installation with buffer storage tank connected in parallel, without domestic hot water production, space heating only



a) buffer storage in parallel, internal DHW HX

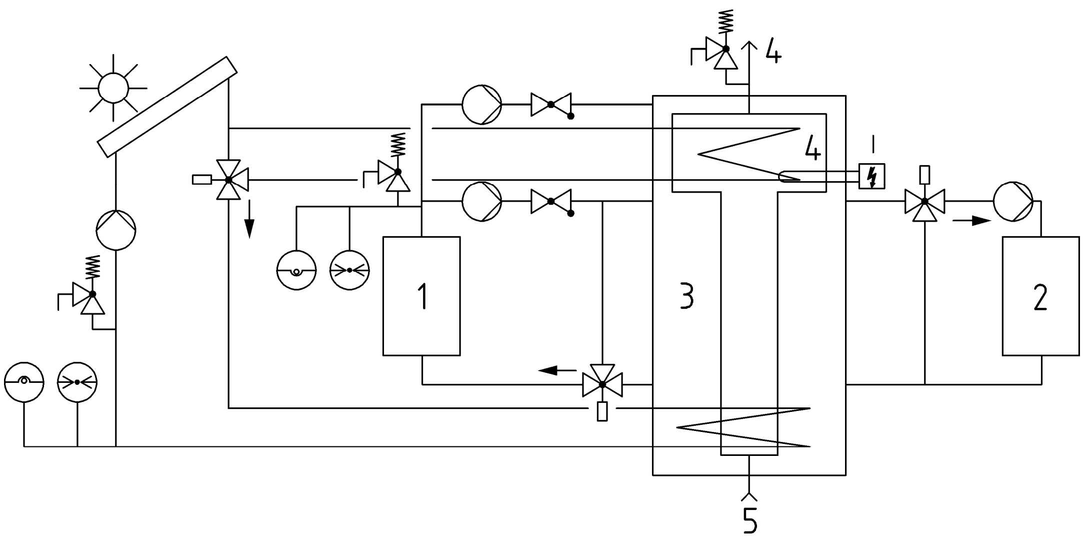


b) buffer storage in parallel, external DHW HX

Key:

1 heat pump using outdoor air or ground (bore hole heat exchanger) as heat source
2 heat distribution, emission system
3 water buffer storage for space heating
4 domestic hot water storage
5 cold water supply
B optional electrical backup heating with safety valve
F optional additional groups of heating circuits with mixing valves
G optional external heat exchanger for domestic hot water production (not compatible with H)
H optional solar collector (only with Figure B.6.a)
I optional electrical backup heating for hot water production

Figure B.6 — Different alternatives of heat pump installation with buffer storage tank connected in parallel, with space heating and domestic hot water production



Key

1 heat pump using outdoor air or ground (bore hole heat exchanger) as heat source
2 heat distribution, emission system
3 water buffer storage for space heating
4 domestic hot water storage
5 cold water supply
I optional electrical backup heating for domestic hot water production

Figure B.7 — Heat pump installation with combination storage tank and additional solar heating for domestic hot water production

NOTE 1 The logical position for a back-up heater, if installed, is always in the supply line of the heat pump.

NOTE 2 As an alternative to using two pumps for changing between space heating and domestic hot water mode, a switching valve may be used in Figures B.2, B.4 and B.6.

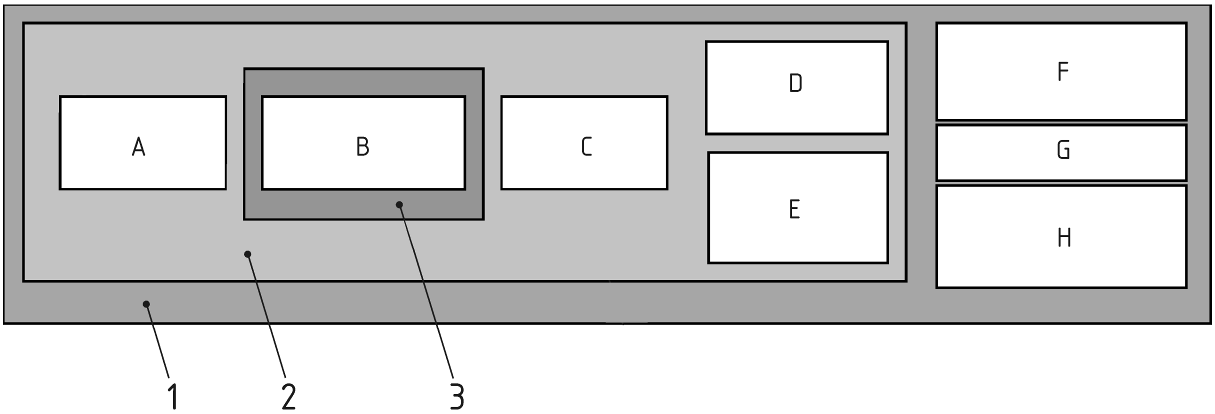
Annex C
(normative)

Calculation and requirements for Seasonal Performance Factors (SPF)

C.1 Definitions

Key values and system boundaries

Possible system boundaries are shown in Figure C.1.



Key

A heat source
B heat pump
C buffer storage (space heating)
D buffer storage (domestic hot water)
E electrical backup heater
F distribution (ventilation and heating)
G heat recovery
H distribution

1 overall seasonal performance of the space heating and DHW system, SPF_{sys}
2 overall seasonal performance factor of the generation subsystem according to prEN 15316-4-2, $SPF_{g,t}$
3 coefficient of performance of heat pump according to EN 14511-1, *COP*

Figure C.1 — System boundaries for COP and SPF

C.2 Calculations

Key values are used to evaluate the efficiency of various heating systems with heat pump and heat recovery. The most important key values are shown in the following.

Coefficient of Performance (*COP*)

The *COP* is intended to evaluate the efficiency of a heat pump at certain operation points.

$$COP = \frac{\Phi_{\mathrm{HP,hw}}}{P_{\mathrm{HP}} + P_{\mathrm{HP,aux}}} \tag{C.1}$$

with the heating capacity $\Phi_{\mathrm{HP,hw}}$ for space heating and, if applicable, domestic hot water production, the power consumption of the compressor P_{HP} and the extra power $P_{\mathrm{HP,aux}}$ to overcome the pressure drop in the evaporator and condenser, for defrosting and controls of the heat pump according to EN 14511-1.

Extract of prEN 15316-4-2

The total seasonal performance factor of the generation subsystem (incl. the heat pump and the electrical back-up heater) can be calculated according to:

$$SPF_{g,t} = \frac{Q_{out,g,h} + Q_{out,g,DHW}}{E_{in,g} + W_g} \tag{C.2}$$

where:

$SPF_{g,t}$	total seasonal performance factor of generation subsystem	(-)
$Q_{out,g,h}$	heat energy requirement of the space heating distribution subsystem	(J)
$Q_{out,g,DHW}$	heat energy requirement of the DHW distribution subsystem	(J)
$E_{in,g}$	total electrical energy input to heat pump and back-up heater	(J)
W_g	total auxiliary energy input	(J)

C.3 Minimum and target SPF-values for heat pumps

The heat pump system shall be designed to achieve a high seasonal performance factor (SPF).

Minimum values for SPF (for space heating and domestic hot water production) as well as target values for SPF for good design practice may be given in national annexes. The same applies for domestic hot water production only.

In case no national annex with such values has been published, default values are given in Table C.1, Table C.2 and Table C.3 below.

System boundaries are described in C.1. The calculation method for estimating SPF shall be taken from prEN 15316–4–2.

Table C.1 — Default minimum and target values for SPF for heat pump systems employed for space heating and domestic hot water production in new buildings (typical for Central Europe)

energy source / sink	minimum value for SPF	target value for SPF
air / water	2,7	3,0
ground / water	3,5	4,0
water / water	3,8	4,5

Table C.2 — Default minimum and target values for SPF for heat pump systems employed for space heating and domestic hot water production in retrofit buildings (typical for Central Europe)

energy source / sink	minimum value for SPF	target value for SPF
air / water	2,5	2,8
ground / water	3,3	3,7
water / water	3,5	4,2

Table C.3 — Default minimum and target values for SPF for heat pump systems employed for domestic hot water production only (typical for Central Europe)

energy source / sink	minimum value for SPF	target value for SPF
air / water	2,3	2,8
ground / water	3,0	3,5
water / water	3,2	3,8

Annex D
(informative)

Noise levels in the vicinity

In many countries, noise immisions are regulated by directives, in which determination and evaluation of maximum allowable values for noise levels are defined. For fixed installed heat pumps or retrofit installations, the design values given in Table D.1 shall be authoritative if no national regulations apply.

Table D.1 — Maximum noise immission from residential and mixed zones (residential and commerce)

Design values L_r in dB(A)	
	night (9 pm to 7 am)
residential zone (SL II)	45
mixed zone (SL III)	50

Sensitivity Level (SL) II is valid for zones, where no disturbing undertakings are permitted, notably in residential zones and zones for public buildings and constructions.

Sensitivity Level III is valid for zones, where moderately disturbing undertakings are permitted, notably in residential and trade zones.

Requirements on the noise protection for spaces with occupants (e.g. sitting and sleeping rooms, offices) concerning building automation equipment are given in Table D.2.

Table D.2 — Requirements on the noise protection towards noise from building automation equipment in multi-residential and office buildings

Evaluation level $L_{r,H}$ in dB(A)	
	night (10pm to 6am)
minimum requirement	30
increased requirement	25

Annex E
(informative)

Average daily tapping patterns for domestic hot water production

E.1 Average daily tapping patterns

Average daily tapping patterns are given in Tables E.2, E.3 and E.4, and each kind of tapping used in these tables are based on the assumptions for volumes given in Table E.1.

Cold water temperature is assumed to be at 10 °C.

Table E.1 — Assumptions for volumes

Type of draw-off	Energy kWh	Volume l	$\Delta\theta$ desired K	Draw-off time at flow rate indicated min			
				at flow rate 3,5 l/min	at flow rate 5,5 l/min	at flow rate 7,5 l/min	at flow rate 9 l/min
small	0,105	3	30	0,9	0,5	0,4	0,3
floor	0,105	3	30	0,9	0,5	0,4	0,3
clean	0,105	2	45	0,6	0,4	0,3	0,2
small dishwash	0,315	6	45	1,7	1,1	0,8	0,7
medium dishwash	0,420	8	45	2,3	1,5	1,1	0,9
larger dishwash	0,735	14	45	4,0	2,5	1,9	1,6
“large”	0,525	15	30	4,3	2,7	2,0	1,7
shower	1,400	40	30	11,4	7,3	5,3	4,4
bath	3,605	103	30	29,4	18,7	13,7	11,4

Table E.2 — Average daily tapping pattern for a single person (36 l at 60 °C)

No	Time of the day hh/mm	Energy initial pattern kWh	Reference period for semi accumulation systems		Kind of tapping	$\Delta\theta$ desired (to be reached during draw-off) K	Minimal θ for start of counting useful energy °C
1	07.00	0,105			small		25
2	07.30	0,105			small		25
3	08.30	0,105			small		25
4	09.30	0,105			small		25
5	11.30	0,105			small		25
6	11.45	0,105			small		25
7	12.45	0,315			dishwashing	50	0
8	18.00	0,105			small		25
9	18.15	0,105			clean		45
10	20.30	0,420			dishwashing	50	0
11	21.30	0,525			large		45
	Q_{DP} [kWh]	**2,1**	**1,78**	**0,945**			
	t_{DP} [hh:mm]	**14:30**	**9:00**	**1:00**			
					36 l at 60 °C		

Table E.3 — Average daily tapping pattern for a family with shower use (100 l at 60 °C)

No	Time of the day hh/mm	Energy initial pattern kWh	Reference period for semi accumulation systems		Kind of tapping	$\Delta\theta$ desired (to be reached during draw-off) K	Minimal θ for start of counting useful energy °C
1	07.00	0,105			small		25
2	07.15	1,400			shower		40
3	07.30	0,105			small		25
4	08.01	0,105			small		25
5	08.15	0,105			small		25
6	08.30	0,105			small		25
7	08.45	0,105			small		25
8	09.00	0,105			small		25
9	09.30	0,105			small		25
10	10.30	0,105			floor	30	10
11	11.30	0,105			small		25
12	11.45	0,105			small		25
13	12.45	0,315			dishwashing	45	10
14	14.30	0,105			small		25
15	15.30	0,105			small		25
16	16.30	0,105			small		25
17	18.00	0,105			small		25
18	18.15	0,105			cleaning		40
19	18.30	0,105			cleaning		40
20	19.00	0,105			small		25
21	20.30	0,735			dishwashing	45	10
22	21.15	0,105			small		25
23	21.30	1,400			shower		40
	Q_{DP} [kWh]	**5,845**	**5,740**	**2,24**			
	t_{DP} [hh:mm]	**14:30**	**14:15**	**1:00**			
					100,2 l at 60 °C		

Table E.4 — Average daily tapping pattern for a family of 3 persons with bath and shower use (200 l at 60 °C)

No	Time of the day hh/mm	Energy initial pattern kWh	Reference period for semi accumulation systems		Kind of tapping	$\Delta\theta$ desired (to be reached during draw-off) K	Minimal θ for start of counting useful energy °C
1	07.00	0,105			small		25
2	07.05	1,400			shower		40
3	07.30	0,105			small		25
4	07.45	0,105			small		25
5	08.05	3,605			bath	30	10
6	08.25	0,105			small		25
7	08.30	0,105			small		25
8	08.45	0,105			small		25
9	09.00	0,105			small		25
10	09.30	0,105			small		25
11	10.30	0,105			floor	30	10
12	11.30	0,105			small		25
13	11.45	0,105			small		25
14	12.45	0,315			dishwashing	45	10
15	14.30	0,105			small		25
16	15.30	0,105			small		25
17	16.30	0,105			small		25
18	18.00	0,105			small		25
19	18.15	0,105			cleaning		40
20	18.30	0,105			cleaning		40
21	19.00	0,105			small		25
22	20.30	0,735			dishwashing	45	10
23	21.00	3,605			bath	30	10
24	21.30	0,105			small		25
	Q_{DP} [kWh]	**11,655**	**11,445**	**4,445**			
	t_{DP} [hh:mm]	**14:30**	**13:55**	**1:00**			
					199,8 l at 60 °C		

E.2 Example calculation

The heat pump and DHW storage is to be sized for a single family dwelling with 3 persons at a set DHW temperature of 50 °C.

In absence of national values, the average daily DHW consumption amounts to 25 l at 60 °C per person.

Solution 1 — Accumulation solution

The daily DHW consumption is doubled (50 l per person per day) and the initial sizing value of the DHW storage is 150 l.

Design values:

t_{DP} = 24 h
$Q_{l,s}$ = 2,2 kWh/d (daily thermal losses of the selected DHW storage at $\Delta\theta = 50$ °C)
θ_{DPset} = 50 °C

The volume amounting to the thermal losses of the DHW storage is:

$$V_{l,s} = \frac{Q_{l,s}}{0{,}001\,16 \cdot (\theta_{DP,60} - \theta_{cw})} = 38 \text{ l.}$$

V_{DP60} = 188 l at 60 °C (including consideration of thermal losses)
$V_{\Theta set}$ = 235 l at 50 °C (including consideration of thermal losses)

The selected DHW storage volume is 250 l. The energy stored in the DHW storage is:

Q_S = 0,00116 · 250 · (50 – 10) + 2,2 = 13,8 kWh

With $t_{Energy,HP}$ = 8 h, the minimum thermal power dedicated to domestic hot water should be greater than 1,7 kW.

Solution 2 — Semi-accumulation solution

The daily DHW consumption is 25 l per person per day and the initial sizing value of the DHW storage is 75 l.

t_{DP} = 1 h (see Table E.3)
Q_{DP} = 4,445 kWh (see Table E.3)
θ_{DPset} = 50 °C
$Q_{l,s}$ = 0,3 kWh/h (thermal losses of the selected DHW storage per hour at $\Delta\theta = 50$ °C)
$V_{l,s}$ = 6,4 l
V_{DP60} = 82 l at 60 °C (including consideration of thermal losses)
$V_{\theta set}$ = 103 l at 50 °C (including consideration of thermal losses)

The selected DHW storage volume is 120 l. The energy stored in the DHW storage is:

Q_S = 0,00116 · 120 · (50 – 10) + 0,3 = 5,9 kWh.

The effective amount of energy available in the storage is:

$Q_{s,eff}$ = 1,5 kWh

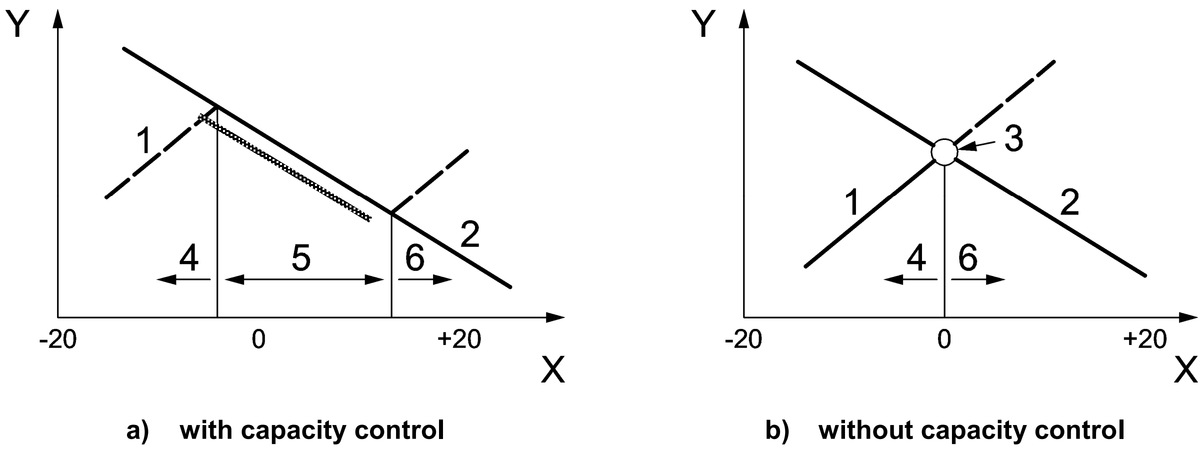
Thermal energy needed is (4,445 – 1,5) + 0,3 = 3,25 kWh and the minimum thermal heating capacity of the heat pump is 3,25 kWh / 1h = 3,25 kW.

Annex F
(informative)

Capacity control

F.1 General control strategy

Examples for control strategy are given in Figure F.1.



Key

Y heat load and heating capacity
1 heating capacity
2 heat load
3 balance point
4 backup heater
5 working area
6 cycling
X outside temperature °C.

Figure F.1 —Capacity control with and without variable speed

F.2 Capacity control of the heat pump

Capacity control can be accomplished by different methods.

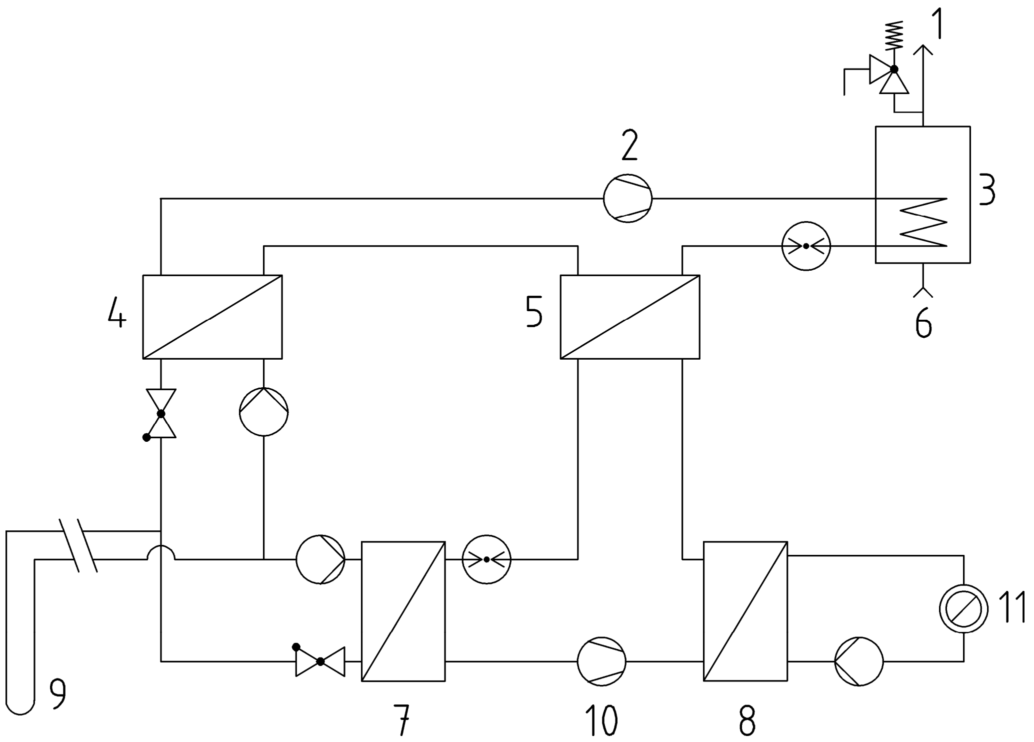
The simplest method is the ON/OFF control of the compressor. In cases, where the inertia of the distribution system is not sufficient, additional buffer storage is required to avoid excessive cycling.

A better method to be used is stepwise or continuous capacity control with a variable-speed controlled compressor. It has to be ascertained, that the compressor is suitable for this type of control. This type of control may allow an increase of the seasonal efficiency of the heat pump by adjusting its heating capacity to the heat load.

F.3 Enhanced Cycle Systems

Some heat pumps incorporate advanced cycles, such as economised vapour (injected) compression cycle and cascaded vapour compression cycle, which may offer better performance.

Capacity control can be accomplished in a cascade, where two heat pump cycles are arranged in such a way, that the condenser of the lower stage is the evaporator of the upper stage. The cascade is especially suitable if high supply temperatures are required, e.g. in the retrofit case or for domestic hot water (see Figure F.2).



Key

1 domestic hot water
2 compressor upper stage
3 condenser of upper stage
4 evaporator upper stage connected to ground source
5 evaporator upper stage connected to condensate sub-cooler lower stage
6 cold water supply
7 evaporator lower stage
8 condenser lower stage
9 U-tube ground heat exchanger
10 compressor lower stage
11 heat emission system

Figure F.2 — Configuration of a cascade type heat pump for space heating and domestic hot water with vertical borehole heat exchanger as heat source

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