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Heating and cooling systems in buildings — Method for calculation of the system performance and system design for heat pump systems —

Part 1: **Design and dimensioning**

Systèmes de chauffage et de refroissement dans les bâtiments — Méthode de calcul de la performance du système et de la conception du système pour les systèmes de pompes à chaleur —

Partie 1: Conception et dimensionnement

Reference number
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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 205, *Building environment design*.

ISO 13612 consists of the following parts, under the general title *Heating and cooling systems in buildings — Method for calculation of the system performance and system design for heat pump systems*:

— *Part 1: Design and dimensioning*

— *Part 2: Energy calculation*

Introduction

This International Standard will be part of a series of standards on the method for the calculation of heating system energy requirements and heating and cooling system efficiencies.

— ISO 13612-1 deals with the design and sizing of heat pump systems.

— ISO 13612-2 presents the energy calculation method.

Heating and cooling systems in buildings — Method for calculation of the system performance and system design for heat pump systems —

Part 1: Design and dimensioning

1 Scope

This International Standard is applicable to heat pumps for space heating and cooling, heat pump water heaters (HPWH), and heat pumps with combined space heating and cooling and domestic hot water production, in alternate or simultaneous operation, where the same heat pump is used for space heating and cooling and domestic hot water heating.

This part of ISO 13612 establishes the required inputs, calculation methods, and required outputs for heat generation for space heating and domestic hot water production and control of the following heat pump systems:

— electrically driven vapour compression cycle (VCC) heat pumps;

— combustion engine-driven VCC heat pumps;

— thermally-driven vapour absorption cycle (VAC) heat pumps.

This part of ISO 13612 specifies the design and dimensioning criteria for the heating and cooling systems in buildings using heat pumps alone or in combination with other heat generators. These include the following:

— water–water;

— brine–water;

— refrigerant–water (direct expansion systems);

— air–air;

— air–water;

— combined;

— systems driven by electricity or gas.

This part of ISO 13612 takes into account the heating requirements of attached systems (e.g. domestic hot water, process heat) in the design of heat supply, but does not cover the design of these systems. This part of ISO 13612 covers only the aspects dealing with the heat pump, the interface with the heat distribution and emission system (e.g. buffering system), the control of the whole system, and the aspects dealing with the energy source of the system.

Table 1 — Heat pump systems (within this scope)

Source system (energy extraction)		Sink system (energy rejection)	
Energy source[a]	**Medium[b]**	**Medium**	**Energy sink[c]**
Exhaust air Outdoor air	Refrigerant	Refrigerant	Air
	Air	Air	Air
		Water	Indoor air Water
Surface water Ground water	Water	Water	Indoor air Water
		Air	Indoor air
Ground	Brine (Water)	Air	Water
		Water	Indoor air Water
	Refrigerant (Direct expansion)	Water	Indoor air Water
		Refrigerant	Indoor air

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 air-conditioned space or water in case of domestic hot water (DHW) production.

2 Normative references

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

ISO 16818, *Building environment design — Energy efficiency — Terminology*

ISO 13790, *Energy performance of buildings — Calculation of energy use for space heating and cooling*

EN 15243, *Ventilation for buildings — Calculation of room temperatures and of load and energy for buildings with room conditioning systems*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16818 and the following apply.

3.1
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 1 to entry: At lower external air temperatures, a second heat generator is employed to cover the entire or part of the building heating demand.

3.2
bivalent alternative mode
low-temperature cut out
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

3.3
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

3.4
coefficient of performance
COP
momentary ratio of the thermal heat flux (Θ_{HP}) of the heat pump to the electrical power input of the unit

Note 1 to entry: The electrical power of the unit includes auxiliary power requirements, but not the additional power requirements for circulation pumps (heat sink and heat source).

3.5
minimum operating temperature
$\boldsymbol{\theta}_{\mathbf{MOT}}$
minimum recommended value of the external temperature to operate the heat pump

3.6
monovalent mode
operational mode in which the heat pump is designed to cover the entire energy demand of the heating and cooling system alone

Note 1 to entry: The heat pump output capacity is equal to the design heat load.

3.7
seasonal performance factor
ratio of the annual heat Q_{HP} supplied by the heat pump to the total electrical energy consumed (including all auxiliary sources)

3.8
source (heat–cool)
source of energy extracted to the heat pump system

4 Symbols and abbreviations

The symbols and units and abbreviations used in this part of ISO 13612 are listed in Tables 2 and 3.

Table 2 — Symbols and units

Symbol	Description	Unit
Φ_{supply}	Heating capacity of the supply system	kW
θ_{MOT}	Minimum operating temperature (external)	°C
$\theta_{e,h}$	Design external temperature (heating)	°C
$\theta_{min,h}$	Minimal operating temperature of the heat pump (heating)	°C

Table 3 — Abbreviations and subscripts

Abbreviation	Description
H	Heating
C	Cooling
DWH	Domestic hot water

5 System design requirements

5.1 General

The heat pump system shall be designed to satisfy the design heating and cooling load of the building and the requirements of any attached system.

Any other recognized energy load calculation method shall only be used if accepted by the client.

The heating supply system and/or the cooling supply system shall be designed and dimensioned taking into account the type of energy source.

General consideration shall be given to the energy efficiency of the heat pump system.

5.2 Heating/cooling source

5.2.1 Air as heat source

The minimum air flow declared by the manufacturer shall be taken into account when designing the system. For monovalent systems, the required capacity of the heat pump shall be determined by using the design external air temperature. For bivalent systems, a suitable balance point temperature shall be set depending on the selected operational mode (bivalent-alternative or bivalent-parallel mode) and the minimum air flow entering the system. The air quality shall be checked and airborne salinity (a function of the distance from seawater) shall be taken into consideration.

5.2.2 Water as heat source

Water sourced from groundwater, seawater, a lake, or a river can be used as a heat source.

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

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

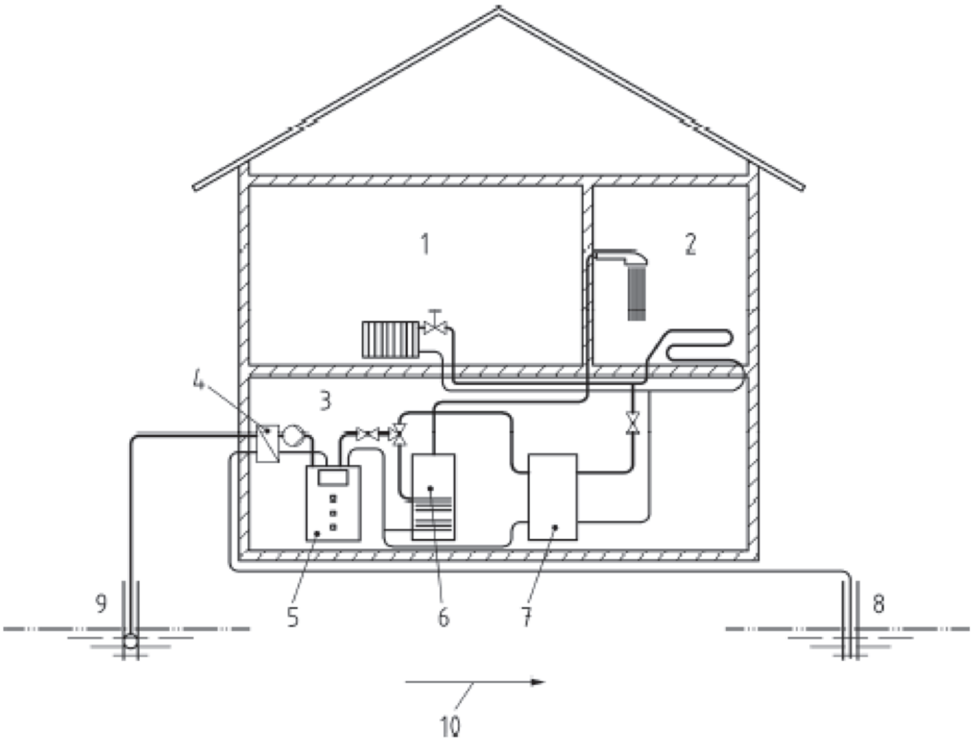
The water source shall enable a continuous extraction of the design flow rate of the attached heat pumps. The possible extraction flow rate is dependent on local geological factors and can be ascertained by continuously extracting the nominal flow rate in a test run of sufficient duration to attain quasi-steady-state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

The quality of the water shall match the manufacturer's requirements. If the manufacturer's requirements cannot be achieved (e.g. in the case of seawater), a secondary circuit or water treatment shall be considered (see Annex B).

Provisions for returning the water shall be provided. 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.

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



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 (including pump)
10 ground-water flow direction

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

5.2.3 Ground as heat source

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

The temperature reduction of the ground, as a result of the 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 to never jeopardize the operation of the heat pump and also to ensure economical as well as reasonable environmental operating conditions.

5.3 Electrical supply

The availability of a suitable electrical supply (both power and amperage) shall be ensured.

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

The maximum current withdrawn during the start-up phase shall be considered, especially for single-phase electrically driven heat pumps.

5.4 Heat pump system design

The design of a heat pump system shall consider the following aspects.

— The heat pump system shall be designed to achieve the highest seasonal performance factor with respect to the selected heat source. The seasonal energy efficiency ratio (or seasonal energy performance) increases with decreasing temperature difference between the source temperature and the sink temperature. High source temperatures and low sink temperatures are desirable in the heating period (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 a corresponding national annex. In case no national values have been published, the default minimum values are given in Annex C.

NOTE 1 Additionally, the target values for the seasonal performance factor are given in a corresponding national data set. In case no national annex has been published, the default target values are given in Annex C.

— The environmental impact due to the heat pump operation shall be minimized. Care shall be taken in order not to emit the refrigerant into the atmosphere due to leakages during operation as well as during maintenance.

NOTE 2 Monoblock systems are hermetically sealed and the leakage rate is under 1 %.

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

5.5 Positioning

The positioning of a heat pump shall consider the following aspects:

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

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

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

— the accessibility for installation and maintenance purposes.

5.6 Noise level

Heat pumps using air as a heat source are prone to cause noise problems resulting from the sound conducted through solids and transmitted through air. The noise levels and information regarding the installation shall be provided in the technical documents provided by the manufacturer.

6 Dimensioning of the heat pump system

6.1 General

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 heating and cooling loads shall be calculated in accordance with the rules given in the accepted methodologies.

NOTE 1 ISO 15265 provides benchmark results for the validation of the building simulation model used for the calculation of the design heating and cooling loads.

NOTE 2 Information on the design scheme is presented in Annex A.

6.2 Methodology for sizing

The method for dimensioning the heat pump is provided in Figure 2.

The maximum power supply required for any period of activity (heating or cooling) shall be calculated and the heat pump system shall be designed to satisfy the energy demand in any case.

Designers shall take into account the energy uses required by any combination of heating, domestic hot water production, and cooling.

The priority given to the energy used to satisfy the demand shall also be identified.

For a heat pump system sized below this maximum value, a supply system shall be attached to satisfy the energy demand. For a bivalent system, the minimum operating temperature shall be identified as the thermal load is calculated for this value of the minimum operating temperature. The temperature operating limit and the bivalent temperature shall be identified by the designer.

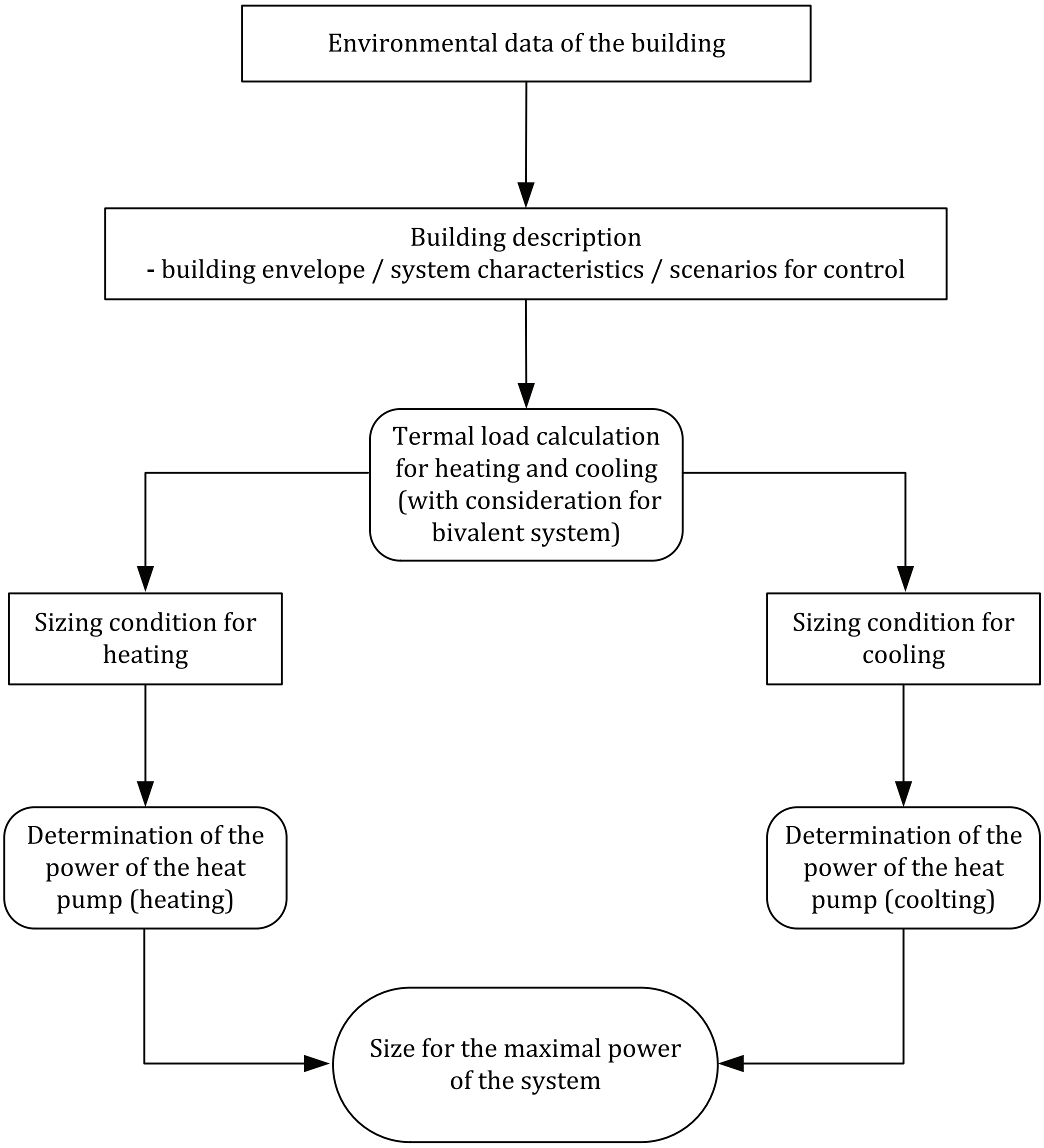


Figure 2 — Flowchart for dimensioning the heat pump system

6.3 Dimensioning the heat pump system for the heating period

6.3.1 Heat supply conditions

The heat supply to serve the system shall be sized according to EN 15243. For the heat pump systems, the design factors in Formula (1) are:

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

where

Φ_{SU} is the capacity of the heat supply system, in kW;

f_{HL} is the design factor for the heat load;

Φ_{HL} is the heat load capacity, in kW;

f_{DHW} is the design factor for the domestic hot water systems;

Φ_{DHW} is the domestic hot water capacity, in kW;

f_{AS} is the design factor for the attached systems;

Φ_{AS} is the capacity of the attached systems, in kW.

Table 4 — Heat pump systems design factor (informative)

Load	Heat pump design factor	Design criteria	Default value for the design factor
Heat load	f_{HL}	Low building mass (suspended ceilings and raised floors and light walls) C_{th} < 20 Wh/m^2	1,00
		Medium building mass (concrete floors and ceilings and light walls) 20 Wh/m^2 < C_{th} < 40 Wh/m^2	0,95
		High building mass (concrete floors and ceilings combined with bricks or concrete walls) C_{th} > 20 Wh/m^2	0,90
Domestic hot water	f_{DHW}	Standard class of sanitary systems	1
Attached systems	f_{AS}		1

NOTE C_{th} is the effective internal heating capacity of the building element.

6.3.1.1 Incorporated additional backup heater

Heat pumps incorporating an additional backup heater shall be selected so that the energy supplied by the backup system is reduced to a minimum, particularly 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.

6.3.1.2 Domestic hot water production or other attached systems

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

Annex A presents the information on the alternative requirements for domestic hot water use.

Annex E presents the basic data, based on a European survey in the domestic sector, to specify the energy use for domestic hot water and the energy performance of domestic hot water appliances.

6.3.1.3 Heat pump data

The data shall be obtained from the manufacturer's specifications, which shall be based on the test data according to the product standards (see Bibliography).

6.3.2 Dimensioning for space heating

The maximum heat load, Φ_{HL}, for space heating is obtained from the rules given in the accepted methodologies.

The design values are based on the regional set of data or accepted methodologies.

NOTE EN 12831 can be used for the dimensioning for space heating.

6.3.3 Dimensioning for DHW

6.3.3.1 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 A and Annex E provide the information on the domestic hot water demand for the residential sector. Different strategies are available depending on the electrical tariff and the cost-reflective messages for energy management, the space available for the heat pump system and energy collectors, and the cost effectiveness of the design solutions.

The accumulation system 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 during the defined period to restore the storage at set temperature conditions.

The defined period corresponds as a maximum to the low-cost period tariff for the electrically driven heat pump.

The volume of the storage shall be reduced accordingly with the availability of the corresponding energy output from the heat pump. The tables given in Annex D and 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}).

6.3.3.2 Definition of the DHW storage volume V_s

The size of the DHW storage and the thermal capacity needed to heat 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 the 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.

6.3.3.2.1 Accumulation

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

Annex A provides an alternative guidance for dimensioning the capacity of the storage, depending on a specific domestic hot water use.

The daily thermal losses of the DHW storage ($Q_{1,\,s}$) shall be integrated in this calculation as an added volume corresponding to the set temperature.

6.3.3.2.2 Semi-accumulation

As a basis, the volume should be considered to match the daily average consumption of the DHW.

Smaller volumes can 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 two 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, $V_{T\text{set}}$, delivered at T_{set} and is obtained using Formula (2).

$$V_{T\text{set}} = V_{\text{P60}} \times \frac{(60 - T_{\text{c}})}{(T_{\text{set}} - T_{\text{c}})} \tag{2}$$

where

$V_{T\text{set}}$ is the volume of the hot water at T_{set} corresponding to QDP, in l;

V_{DP60} is the volume of the hot water at 60 °C corresponding to QDP, in l;

T_{set} is the set temperature of the hot water in the DHW storage, in °C;

T_{c} is the temperature of the cold water, in °C.

6.3.3.3 Energy balance of the DHW storage

The energy stored in the DHW storage is expressed using Formula (3).

$$Q_{\text{s}} = 0{,}001\ 16\ (\theta_{\text{set}} - \theta_{\text{cw}}) \cdot V_{\text{s}}\ [\text{kWh}] \tag{3}$$

The extraction temperature in the DHW storage shall not fall below ⎝ min = 40 °C during any draw-off period.

The effective amount of energy available in the storage is therefore calculated using Formula (4).

$$Q_{\text{s, eff}} = Q_{\text{s}} \cdot (\theta_{\text{set}} - 40) / (\theta_{\text{set}} - \theta_{\text{cw}})\ [\text{kWh}] \tag{4}$$

The energy demand during the defined period is calculated using Formula (5).

$$Q_{\text{DP}} = 0{,}001\ 16\ (60 - \theta_{\text{cw}}) \cdot V_{\text{DP60}}\ [\text{kWh}] \tag{5}$$

as the energy demand is expressed at 60 °C.

6.3.3.4 Minimum thermal heating capacity needed to fulfil the DHW requirements

6.3.3.4.1 Accumulation systems

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

$$\Phi_{hp,\theta set} = \frac{Q_s}{t_{Energy,hp}} [kW] \tag{6}$$

where

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

Q_S is the energy stored in the DHW storage, in kWh;

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

The corresponding electrical power is determined using Formula (7).

$$P_{hp,el,\theta set} = \frac{\Phi_{hp,\theta set}}{COP_{\theta set}} \tag{7}$$

where

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

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

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

6.3.3.4.2 Semi-accumulation systems

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).

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

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

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

$$\Phi_{hp,\theta set} = \frac{Q_{DP} - Q_s \dfrac{(\theta_{set} - 40)}{(\theta_{set} - \theta_{cw})}}{t_{DP}} + \frac{Q_{ts}}{t_{DP}} \tag{9}$$

where

t_{DP} is the duration of the defined period, in h;

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

The corresponding electrical power can be determined according to Formula (7).

6.3.3.5 Additional heating requirements and sizing of the backup heater for DHW

Formula (2) given in 6.3.3.2.2 provides the relationship between the output capacity of the heat pump and the volume of the DHW storage. The designer shall choose the DHW storage volume so that the total output capacity of the heat pump is sufficient to fulfil the demand for space heating and domestic hot water. If this is 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 the DHW of the system as calculated above.

6.3.3.6 Specific control requirement for the DHW production

If containment of Legionella growth is required, the system shall be sized and supplied with a control system to ensure that a temperature of 60 °C is reached periodically (e.g. daily, weekly, etc.). If the heat pump is unable to reach 60 °C on its own, the auxiliary system shall ensure that a temperature of 60 °C can be reached.

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

The control of the backup heater shall be properly integrated with those of the heat pump. This is to 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.

6.3.4 Power of the heat pump system and additional supply system (backup system)

Additional heat supply is sometimes needed when

— the external reference temperature of the site location is lower than the minimum operating temperature of the heat pump, and

— the heat pump is doubled with another source for heating (boiler, etc.).

In this case, the power of the supply shall complete the capacity to provide heat to the building for the design conditions.

The difference between the types of source of energy shall be considered for the sizing as their availability is linked to the local temperature.

6.4 Determination of the power of the heat pump system for the cooling period

The cooling power to be installed is a function of

— the internal load (human occupancy, lighting, heat dissipated by appliances, heat transmitted from internal surfaces, and other sources such as processes),

— the external load due to climate conditions (transmission through facades and glazing and solar irradiation through glazing), and

— the set temperature of the building and acceptable range for temperature and humidity.

The cooling load is derived from ISO 13790 or alternative approved methodologies. Cooling does not correspond strictly to the sum of the maximum, but to the sum of the cooling for the different thermal zones. For large buildings with a centralized heat pump system, it is possible to introduce a simultaneity coefficient to reduce the heat load due to internal heat load.

The designer shall take into account the maximal heat load during seasons combining cooling demand due to temperature and humidity aspects.

If domestic hot water use is required during the cooling period, the designer shall consider if

— the system ensures both energy use (cooling and DWH) or if a separate system is needed for the DWH use, and

— the preheating of the DWH is considered in cooling mode.

6.5 Oversizing considerations

The supply system for a bivalent system will complete the heat pump system to provide sufficient heat.

The total thermal power of the system should match the requirements of the heat load calculation of the building. In case of bivalent systems there is no need of oversizing the heat generator heat pump.

7 Additional design information for heat pump system

7.1 Hydraulic integration

In order to minimize cycling, it shall be ensured 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 additionally serves as a means of hydraulic decoupling. A guidance value for sizing the buffer storage volume is 12 l/kW to 35 l/kW maximum heat pump capacity.

7.2 Control of the system

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

During the heating period, the control of the heat pump is linked to the temperature (external–internal). Humidity control shall be added (for large buildings) during the cooling period.

The control system shall identify which priority is given to the different energy uses such as

— domestic hot water,

— heating, and

— cooling.

7.3 Safety requirements

The safety requirements are provided in the national regulations.

EXAMPLE In Europe, EN 378–1 applies.

In principle, all heat pump systems shall be equipped with the appropriate controls that prevent a major leakage of refrigerant in case of an accident. Refrigerant systems shall be designed in accordance with the existing regulation or national guidance.

NOTE For Europe, the requirements listed in 4.6 of EN 12828:2003 also apply to this part of ISO 13612 (nominal heat output < 300 kW) if the medium on the heat-sink side of a heat pump system is water.

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

7.4 Operational requirements

7.4.1 General

Operational parameters shall be controlled during the commissioning and be periodically monitored in the normal running phase of the heating system. In addition, the measurement and recording of the 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).

7.4.2 Provisions for monitoring operational conditions

7.4.2.1 General requirements

Provisions shall be made in the piping (water systems) or ducting (air systems) to facilitate the monitoring and recording of the operational and energy-related parameters (e.g. temperature and power consumption), provided they have not already been integrated in the heat pump unit as supplied by the manufacturer.

7.4.2.2 Fluid systems

If the source side and/or the sink side of the heat pump system are 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.

— A 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 can be used (internal method).

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

7.4.2.3 Air-based systems

If the source side and/or the sink side of the heat pump system are 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 can be used (internal method).

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

8 Installation requirements

The manufacturer’s installation instructions shall be followed. The 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.

Annex A
(informative)

Heat pump technologies and design schemes

A.1 General

A.1.1 Design standard

The heat source systems are selected in consideration of the applications, scale, heat load trends, operation hours, etc. of the facilities.

The types of major heat source equipment and others are selected in consideration of the effective and efficient use of energy, levelling of electric power loads, utilization of natural energy, cost efficiency, reliability, durability, ease of maintenance and inspection, and necessity of qualified operators.

The refrigerants selected for the use in chillers and package type air-conditioners should be highly safe and should have an ozone depletion potential of zero and a global warming potential as small as possible.

A.1.2 Design data

For large equipment such as chillers, the load-carrying strength of the floor should be taken into consideration. A machine hatch and similar provisions should be made as necessary.

Measures against earthquakes should also be taken as necessary.

The following measures should be taken against the noise and vibration of air-conditioners.

— The adoption of low-noise equipment should be considered for places where quietness needs to be maintained.

— Measures against noise and vibration should be taken as necessary.

The heat-source capacity and thermal storage tank capacity of a thermal storage system should be determined in consideration of the daily heat loads, heat balance of the heat source capacity, and operating time. Noise reduction measures should be considered for the operation of thermal storage systems during nighttime hours.

Salt-resistant equipment should be adopted if regular exposure to saltwater or high airborne salinity is anticipated.

A.2 Design schemes for several kinds of heat pump systems

A.2.1 Heat pump water heater (with CO_2 refrigerant)

A.2.1.1 Design standard

The heat pump water heater with CO_2 refrigerant is sized in accordance with the number of residents as shown in Table A.1.

The operating hours of a heat pump unit should be determined by considering the hot water supply load characteristics and the tariff.

Table A.1 — Sizing of the heat pump water heater with CO_2 refrigerant

	Number of residents			
	1 to 2	**3 to 5**	**5 to 6**	**7 to 8**
DHW storage volume	185 l	300 l–370 l	460 l	560 l
Heat pump capacity	4,5 kW/6,0 kW	4,5 kW	6,0 kW	6,0 kW

A.2.2 Heat pump water heater (except for detached house)

A.2.2.1 Design standard

A.2.2.1.1 The heating capacity of a heat pump unit and the volume of a hot water storage unit should be determined based on the hot water supply load characteristics of a facility, the hot water supply load per day, and the operating hours.

A.2.2.1.2 The operating hours of a heat pump unit should be determined by considering the hot water supply load characteristics and the tariff.

A.2.2.2 Calculation for the heat pump hot water supply units

A.2.2.2.1 General

The calculation procedure for a heat pump hot water supply unit is as shown in Figure A.1.

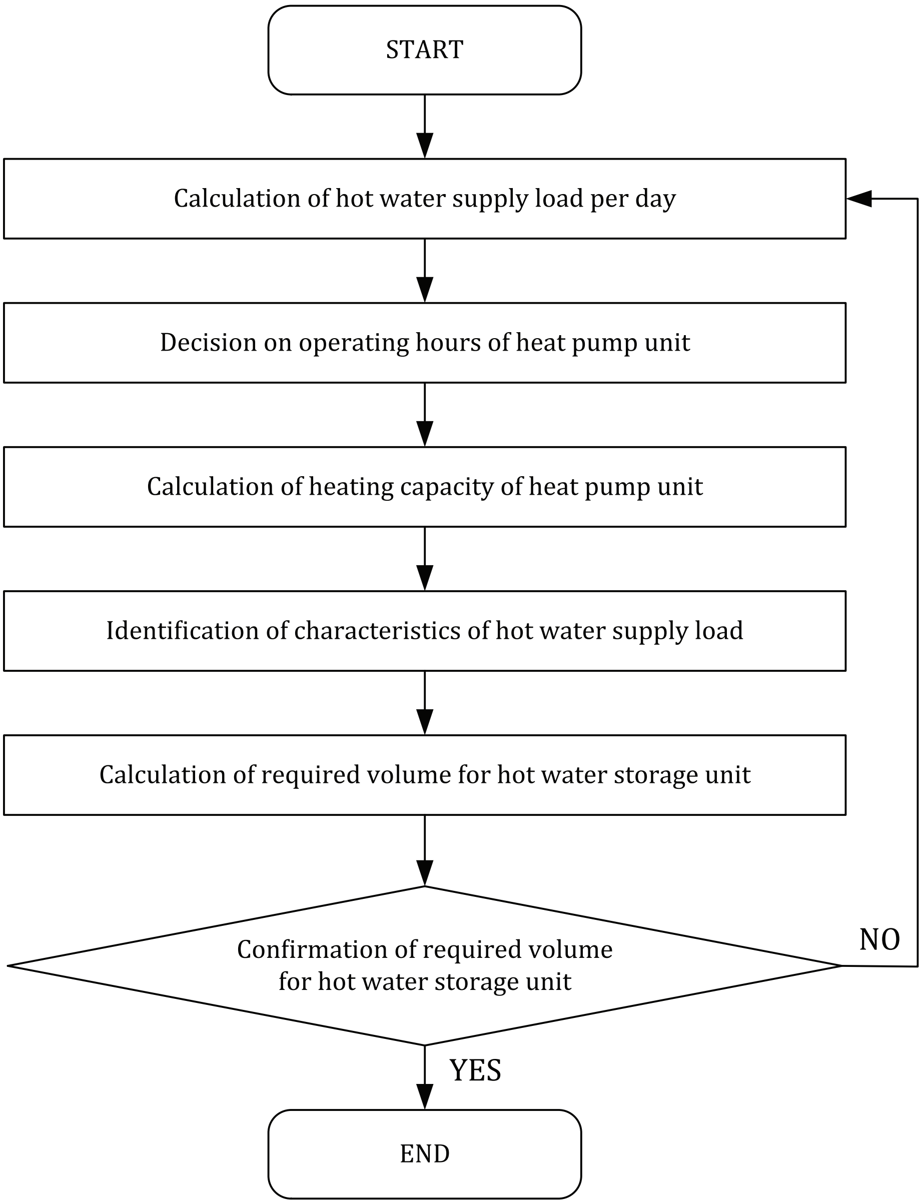


Figure A.1 — Heat pump hot water supply calculation method

Examples of the characteristics of the hot water supply load and the heat pump unit operation are shown in Figure A.2.

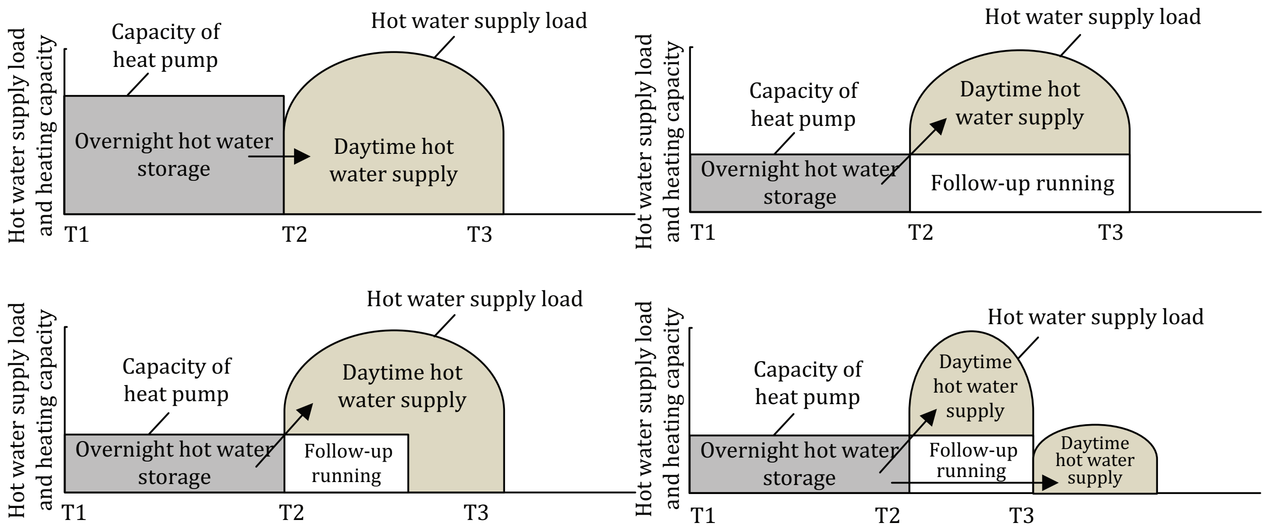


Figure A.2 — Examples of the hot water supply load and the heat pump unit operation

Formula (A.1) provides the calculation of the hot water supply load per day.

$$Q_{hwd} = 0{,}001\ 16 \cdot N \cdot q \cdot (T_{hw} - T_w) \quad (A.1)$$

where

Q_{hwd} is the hot water supply load per day, in kWh/day;

N is the number of users (man);

q is the yearly average hot water supply volume per day [l/(man · day)] (see Table A.2);

T_{hw} is the hot water supply temperature, in °C;

T_w is the water feed temperature, in °C.

Table A.2 — Hot water supply volume

Building type	Yearly average of hot water supply volume per day	Peak hot water supply volume	Peak continuous operating hours h
Apartment	150~250 l/(dwelling · day)	50~100 l/(dwelling · h)	2
Office	7~10 l/(man · day)	1,5~2,5 l/(man · h)	2
Hotel guest room	150~250 l/(man · day)	20~40 l/(man · h)	2
General hospital	2~4 l/(m^2 · day)	0,4~0,8 l/(m^2 · h)	1
	100~200 l/(bed · day)	20~40 l/(bed · h)	1
Restaurant	40~80 l/(m^2 · day)	10~20 l/(m^2 · h)	2
	60~120 l/(seat · day)	15~30 l/(seat · h)	2

The heating capacity of a heat pump unit is calculated by Formula A.2.

$$Q_{\text{hp}} = \frac{Q_{\text{hwd}} \cdot a_1 \cdot a_2 \cdot a_3}{n_1 + n_2} \tag{A.2}$$

where

Q_{hp} is the heating capacity of the heat pump unit, in kW;

Q_{hwd} is the hot water supply load per day, in kWh/day;

a_1 is the heat loss coefficient of the pipe lines, hot water storage unit, etc. (= 1,1);

a_2 is the aging coefficient (= 1,05);

a_3 is the capacity compensator coefficient (= 1,05);

n_1 is the operating hours of the overnight hot water storage for the heat pump unit, in h;

n_2 is the operating hours of the daytime follow-up running hours, in h.

The reduction in the capacity due to the outside temperature and defrosting in winter shall be determined, and if the heating capacity is not sufficient, it shall be increased.

A.2.2.2.2 Identification of hot water supply load characteristics

The temporal thermal balance should be investigated according to the hot water supply load characteristics and the heating capacity of the selected heat pump unit.

Formula (A.3) provides the calculation of the hot water storage unit volume.

$$V = \frac{860\left(Q_{hp} \cdot n_1 - Q_{hwn}\right)}{\Delta t \cdot n_s} \tag{A.3}$$

where

V is the hot water storage unit volume, in l;

Q_{hp} is the heating capacity of the heat pump unit, in kW;

n_1 is the operating hours of the overnight hot water storage for the heat pump unit, in h;

Q_{hwn} is the overnight hot water supply load, in kWh (= 0, if there is no overnight hot water supply load);

Δt is the temperature difference in the usage of the hot water storage unit, in °C (= the hot water storage temperature – the water feed temperature);

n_s is the effective volume of the hot water storage unit (= 0,8).

The factor values of the heat pump hot water supply units are shown in Table A.3.

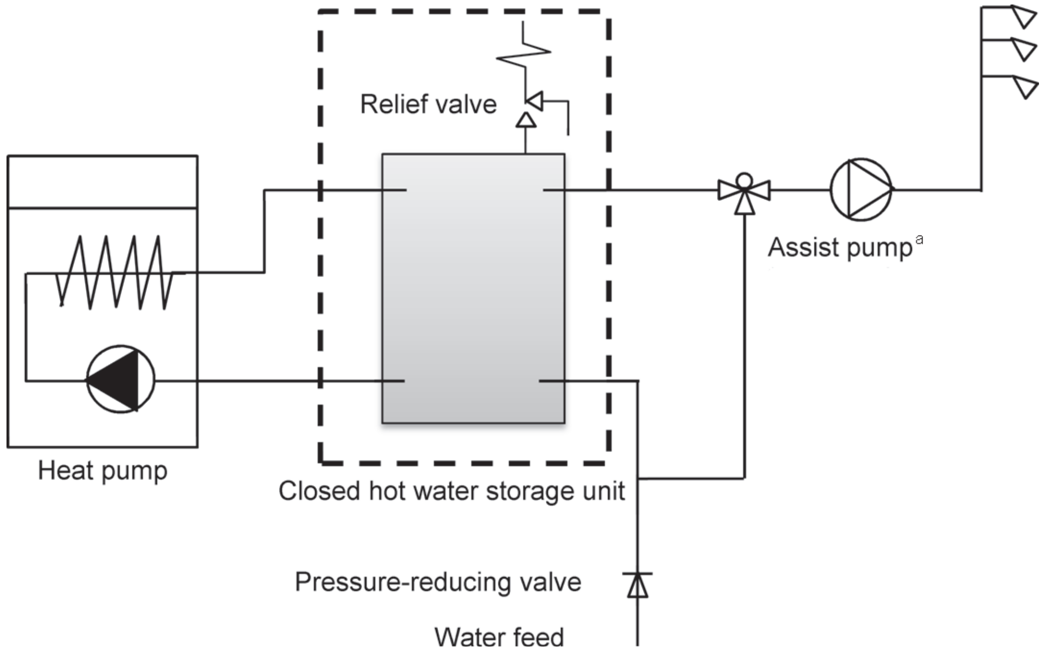
Table A.3 — Factors of the heat pump hot water supply units

Refrigerant		CO_2				HFC	
Hot water storage temperature (°C)		90				70	
Hot water supply system		Single pass				Single pass	Circulation
Specifications of the heat pump unit	Rated capacity (kW)	4,5	6	15	26,3	14	49,3
	Electricity consumption (kW)	1,1	1,25	3,69	6,9	3,14	15
	Coefficient of performance (COP)	4,1	4,8	4,1	3,8	4,5	3,3
	Mass (kg)	65	65	200	620	120	600
Specifications of the hot water storage unit	Type	Closed				Closed	
	Maximum volume (l)	370	370	1 680	3 000	1 680	6 000
	Operating mass (kg)	447	446	1 956	3 850	1 950	6 850
Hot water supply rate of the heat pump unit (5 °C to 60 °C) (per hour) (l/h)		70	94	235	411	219	771
Maximum hot water supply rate(5 °C to 60°C)	Per hour (l/h)	642	666	2 831	5 048	2 204	7 862
	Per three hours (l/3 h)	783	853	3 300	5 870	2 642	9 404
Instruction on the installation locations	Downstream supply	Measures to counter negative pressure are required.					
	Upstream supply	An assist pump is applicable.					

NOTE 1 Single-pass type means that no return pipe is installed in the hot water supply circuit.

NOTE 2 The maximum hot water supply rate is defined as the 60 °C hot water supply rate with the combination of the hot water storage unit and follow-up heating by the heat pump unit.

Piping examples of a heat pump unit for hot water supply are shown in Figures A.3 and A.4.



Key

a Not usually necessary for the second floor.

Figure A.3 — Piping of a ground installation of a heat pump unit for a hot water supply

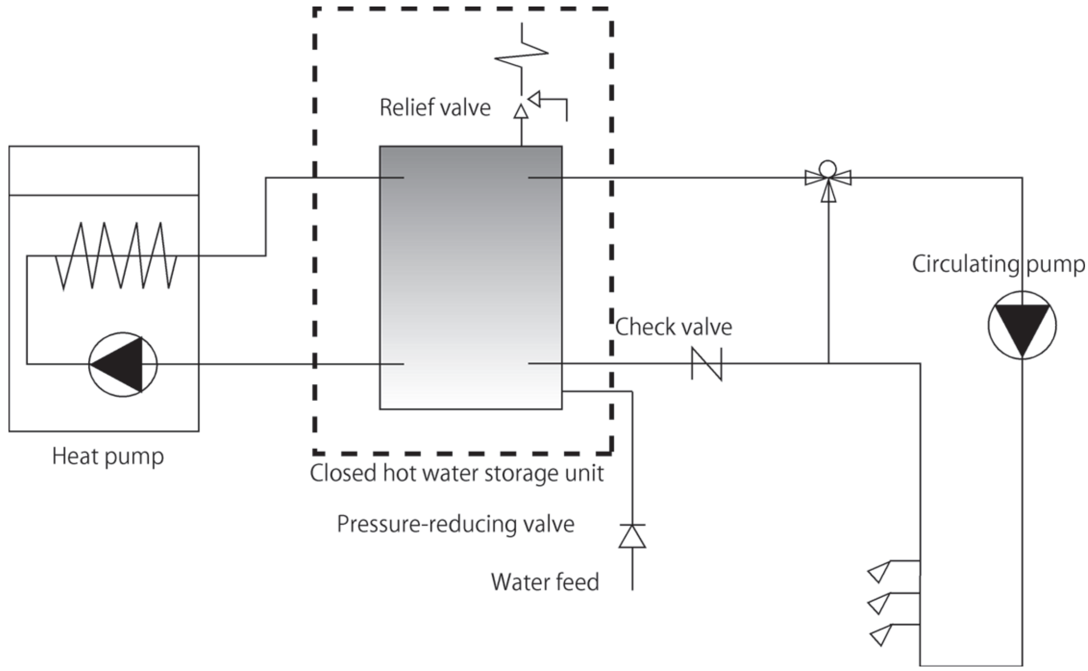


Figure A.4 — Piping of a roof installation of a heat pump unit for a hot water supply in case of a hot water circulation

A.2.3 VRF (variable refrigerant flow) system

A.2.3.1 General

The capacity of VRF system is selected according to the procedures shown in Figure A.5. A VRF system is temporarily decided by selecting the indoor units based on the total heat load required by the respective rooms and by correcting the capability based on the respective temperature conditions and others. Then, an outdoor unit that is connected to the indoor units is decided by calculating the capability at the time of use in combination with the indoor units.

As for given conditions, it is assumed that the interior design conditions (temperature and humidity) and the hourly heat loads required by the respective rooms (total heat load for cooling and total heat load for heating) are determined by calculation.

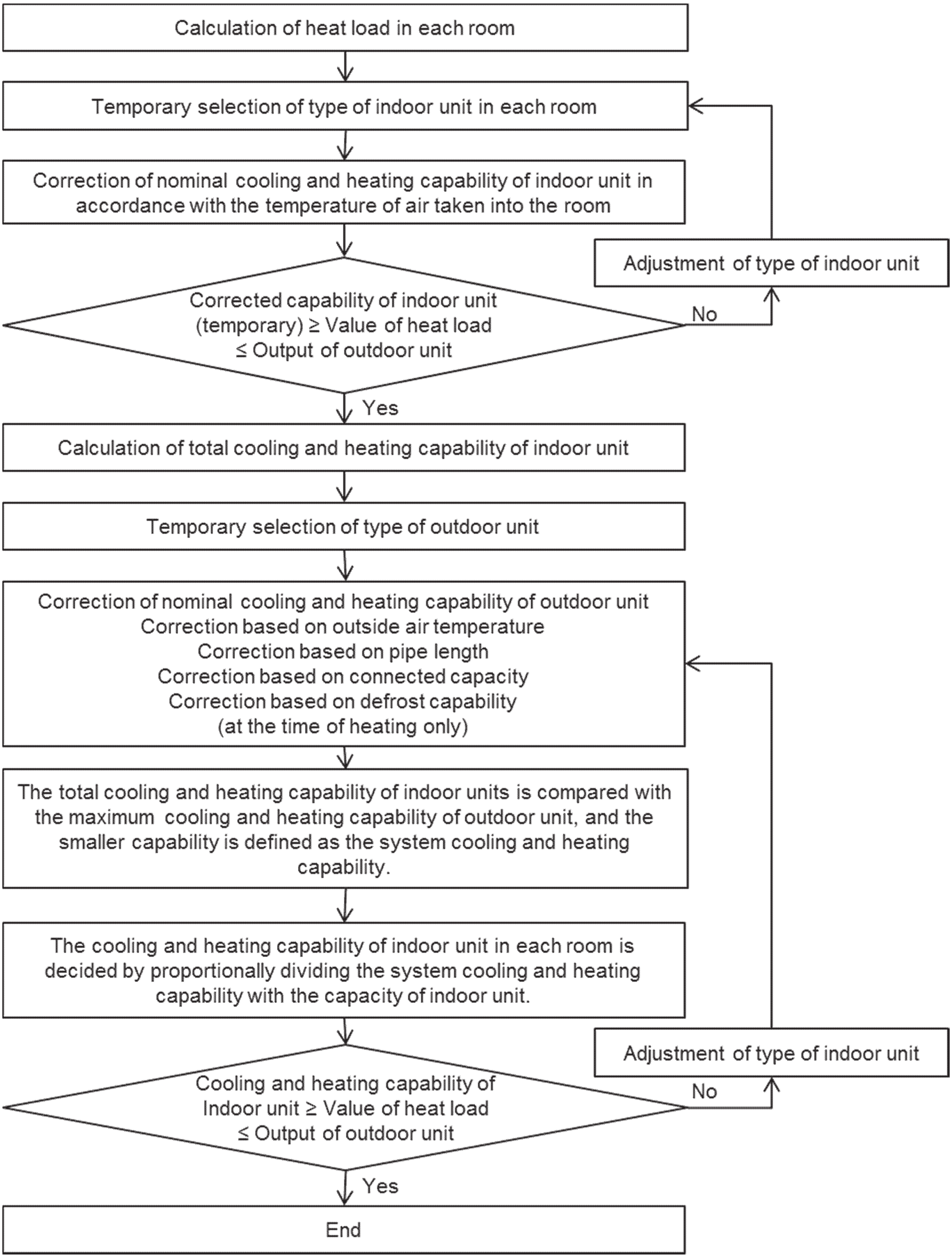


Figure A.5 — Procedures for the selection of the VRF system

A.2.3.2 Aggregation of heat loads in each room and zoning

The calculation results of the cooling and heating loads are aggregated and the loads are classified into respective zones. In zoning, attention should be given mainly to the following points:

a) each zone should be on the same floor level to the extent possible;

b) running time and load fluctuation should be similar;

c) in the case of duct types, air can be sent by a short duct;

d) return air should not be mixed into other zones;

e) the same conditions should be applied for the purpose of disaster prevention.

In the case of tenant buildings, it is necessary to plan the zoning by allowing for possible changes in partitions in the future.

A.2.3.3 Temporary selection of the type of indoor units in each room

The type of indoor units required to satisfy the cooling and heating loads in the respective rooms is temporarily selected. Attention should be given not to select the type of indoor units with excessive capacity in consideration of a margin.

The capability of the indoor unit type selected is greater than the cooling and heating loads.

A.2.3.4 Correction of the nominal cooling and heating capability of the indoor units

The nominal cooling and heating capability of the indoor units is corrected according to the temperature of the air taken into the rooms.

Based on the VRF system capacity tables provided by the manufacturers, correction is made according to the temperature of the air taken in by the indoor units.

A.2.3.5 Judgment of corrected capability of the indoor units

It should be checked that the corrected capability of the indoor units is higher than the cooling and heating loads. If the corrected capability is lower than the cooling and heating loads in the respective rooms, the type of the indoor unit should be selected again and the capability should be adjusted.

A.2.3.6 Decision on the grouping of the indoor units to be connected to the same outdoor unit

To select the outdoor unit that allows indoor units to sufficiently and rationally demonstrate their capability, the indoor units to be connected to the same outdoor unit should be grouped.

Grouping should be done in a manner that makes the distance of the refrigerant pipes and electrical works between the indoor units and the outdoor unit equal in the shortest possible length.

A.2.3.7 Calculation of the total cooling and heating capability of the indoor units

The total cooling and heating capability of the indoor units to be connected to the same outdoor unit should be calculated. The calculated total cooling and heating capability is considered to be the capability required for the outdoor unit.

A.2.3.8 Temporary selection of the type of the outdoor unit

The outdoor unit that is necessary to cope with the total cooling and heating capability of the indoor units should be temporarily selected. Attention should be given not to select the type of outdoor unit with an excessive capacity in consideration of a margin.

The capability of the outdoor unit type selected is greater than the total cooling and heating capability of the indoor units.

A.2.3.9 Correction of the nominal cooling and heating capability of the outdoor unit

Based on the VRF system capacity tables provided by the manufacturers, correction is made according to the outside air temperature, length of refrigerant pipes, difference of elevation between the indoor units and outdoor unit, and connected capacity ratio of the indoor units to the outdoor unit (in the case where the combined capacity of the indoor units is 100 % or higher).

If the VRF system is selected based on the heating capability, a correction is also made according to the defrost capability.

A.2.3.10 System cooling and heating capability

The total cooling and heating capability of the indoor units and the maximum cooling and heating capability of the outdoor unit are compared with each other, and the smaller capability should be defined as the system cooling and heating capability.

A.2.3.11 Indoor unit cooling and heating capability

The cooling and heating capability of each indoor unit is calculated by proportionally dividing the system cooling and heating capability with the capacity of the indoor units.

A.2.3.12 Judgment of indoor unit cooling and heating capability

It should be checked that the calculated cooling and heating capability of each indoor unit is larger than the heat load in each room. If the capability is smaller than the heat load, the type of outdoor unit should be selected again and the capability should be adjusted.

A.2.4 Cold heat source equipment and cooling towers

A.2.4.1 Cold heat source equipment

A.2.4.1.1 Design standard

The number of units of the cold heat source equipment is decided in consideration of the scale, applications, heat load trends, time-of-use periods, equipment efficiency and maintenance, inspection of facilities, and others.

The cold heat source equipment is installed by reasonably ensuring the space for maintenance and inspection.

A.2.4.1.2 Design data

The division of the number of units of the cold heat source equipment is decided in overall consideration of the maximum heat loads of the facilities, follow-up to fluctuation of the heat loads, and equipment efficiency.

The flow rate of the cold/hot water and cooling water of the cold heat source equipment should not be changed in principle. However, if energy-saving effects can be expected, variable flow systems can be adopted upon consideration of safety, reliability, and others.

The maintenance and inspection space of the cold heat source equipment is shown in Table A.4.

Table A.4 — Maintenance and inspection distance of chillers

Location	Distance
Front side Right side and left side Back side	1,2 m or longer 1,0 m or longer 1,0 m or longer
Height (from the floor)	2,0 m or longer
Clearance for tube cleaning	If needed

As for the circulating pumps to be installed in the primary circuits of the cold/hot water piping, each unit of the cold heat source equipment is equipped with one circulating pump in principle.

Air-source heat pump unit is designed as follows.

— The capacity of a heat pump unit is decided after the correction with the locally appropriate conditions of outside air temperatures and humidity.

— The noise, freezing, and corrosion resistance are considered.

— In the case where an air-source heat pump unit is used in snowy areas, it should be considered to install snow-shed hoods and others.

— In the case where two or more air-source heat pump units are installed or there are obstacles around the heat pump units such as advertising pillars, sound-insulating walls, and others, the space where the outside air flows into should be considered. Particularly, in the case where the heat pump units are surrounded by sound-insulating walls, it should be considered to install louvers or outlet ducts to allow the air to be ventilated at a specified outside air temperature. It should also be checked that sufficient separation distances from the stacks are ensured.

A.2.4.1.3 Calculation of capacity

A.2.4.1.3.1 Cold heat source equipment

A.2.4.1.3.1.1 Refrigeration capacity

The refrigeration capacity (H_{RC}, in W) of a compression chiller is decided by multiplying the maximum value (q_m) of the hourly cooling loads in the building by the pump load factor (K_1), piping loss factor (K_2), unit load factor (K_3), aging factor (K_4), and ability compensation factor (K_5).

$$H_{RC} = K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot K_5 \cdot q_m / 1\ 000 \qquad (A.4)$$

where

q_m is the maximum value of the aggregate hourly cooling loads in the building, in W;

K_1 is the pump load factor (= 1 to 1,05);

K_2 is the piping loss (= 1 to 1,05);

K_3 is the unit load (= 1 to 1,05);

K_4 is the aging factor (= 1,05);

K_5 is the ability compensation factor (= 1,05).

A.2.4.1.3.1.2 Heating capacity

The refrigeration capacity of an air-source heat pump unit is decided in accordance with A.2.4.1.3.1, and heating capacity (H_{Rh}, in kW) is decided by multiplying the total value of the heating loads (q_h) by the piping loss factor (K_2), unit load factor (K_3), aging factor (K_4), and ability compensation factor (K_5).

$$H_{Rh} = K_2 \cdot K_3 \cdot K_4 \cdot K_5 \cdot q_h / 1\ 000 \qquad (A.5)$$

where

q_h is the aggregate value of the heating loads, in W;

K_2 is the piping loss factor (= 1 to 1,05);

K_3 is the unit load factor (= 1 to 1,1);

K_4 is the aging factor (= 1,05);

K_5 is the ability compensation factor (= 1,05).

A.2.4.1.3.2 Package-type air-conditioner

A.2.4.1.3.2.1 Cooling capacity

The cooling capacity (H_c, in kW) is decided by multiplying the maximum value (q_m) of the aggregate hourly total heat load for the cooling of the system by the aging factor (K_4) and ability compensation factor (K_5).

$$H_C = K_4 \cdot K_5 \cdot q_m / 1\ 000 \tag{A.6}$$

where

K_4 is the aging factor (= 1,05);

K_5 is the ability compensation factor (= 1,05);

q_m is the maximum value of the aggregate hourly total heat load for cooling, in W.

A.2.4.1.3.2.2 Heating capacity (heat pump)

The heating capacity (H_h, in kW) is decided by multiplying aggregate value of the heating loads by the aging factor (K_4) and ability compensation factor (K_5).

$$H_h = K_4 \cdot K_5 \cdot q_h / 1\ 000 \tag{A.7}$$

where

K_4 is the aging factor (= 1,05);

K_5 is the ability compensation factor (= 1,05);

q_h is the total value of the heating loads, in W.

A.2.4.1.3.2.3 Capacity of the auxiliary space heater

The capacity of the auxiliary space heater (H_w, in kW) is calculated using Formula (A.8).

$$H_w = (H_h - H_{h0}) / 1\ 000 \tag{A.8}$$

where

H_h is the necessary heat capacity, in W;

H_{h0} is the heating capacity under the service conditions of the selected air-source heat pump package-type air-conditioner, in W.

A.2.4.1.3.3 Thermal heat source equipment

A.2.4.1.3.3.1 Rated output of the thermal heat source equipment

The rated output (H, in kW) of the thermal heat source equipment is decided by multiplying the heating load (q_1), hot water supply load (q_2), and others by the piping loss factor (K_2), unit load factor (K_3), aging factor (K_4), and ability compensation factor (K_5).

In the case of the absence of the heat exchanger:

$$H = K_2 \cdot K_3 \cdot K_4 \cdot K_5 (q_1 + q_2) / 1\,000 \tag{A.9}$$

where

K_2 is the piping loss factor (= 1 to 1,05 for hot water, = 1 to 1,1 for steam);

K_3 is the unit load factor (= 1 to 1,1 for hot water, = 1 to 1,15 for steam);

K_4 is the aging factor (= 1,05);

K_5 is the ability compensation factor (= 1,05);

q_1 is the heating load, in W (air-conditioning load);

q_2 is the hot water supply load, etc., in W.

In the case of the presence of the heat exchanger:

$$H = (H_E + K_2 \cdot K_3 \cdot K_4 \cdot q_3) \cdot K_5 / 1\,000 \tag{A.10}$$

where

H_E is the quantity of heat exchanged by the heat exchanger, in W;

q_3 is the load except for the heat exchanger, in W.

A.2.4.1.4 Calculation formula of the quantity of the cold/hot water

The quantity of the cold water, L_c (l/min), is calculated by Formula (A.11).

$$L_c = \frac{3\,600 \cdot H_{RC}}{60 \cdot C \cdot \rho \cdot (t_{wc1} - t_{wc2})} = \frac{14,3 \cdot H_{RC}}{\Delta t_{wc}} \tag{A.11}$$

where

H_{RC} is the refrigeration capacity, in kW;

t_{wc1} is the inlet temperature of the cold water, in °C;

t_{wc2} is the outlet temperature of the cold water, in °C;

Δt_{wc} is the difference in the temperature of the cold water between an outlet and an inlet, in °C

C is the specific heat of the water [kJ/(kg·K)] (= 4,19);

ρ is the density of the water, in kg/l (= 1,0).

The quantity of the hot water, L_w (l/min), is calculated by Formula (A.12).

$$L_w = \frac{14,3 \cdot H_{Rh}}{\Delta t_{wh}} \tag{A.12}$$

In the case where $L_c = L_w$,

$$\Delta t_{wh} = \frac{14,3 \cdot H_{Rh}}{L_c} \tag{A.13}$$

$$t_{wh1} = t_{wh2} - \frac{14,3 \cdot H_{Rh}}{L_c}$$

where

H_{Rh} is the heating capacity, in kW;

t_{wh1} is the inlet temperature of the hot water, in °C;

t_{wh2} is the outlet temperature of the hot water, in °C;

Δt_{wh} is the difference in the inlet temperature and outlet temperature of the hot water, in °C;

A.2.4.2 Cooling tower

A.2.4.2.1 Design standard

The determination of the cooling capacity of a cooling tower is based on the heat to be rejected from the equipment.

The cooling tower is installed at a place that ensures an ambient space where there is no harm in exchanging heat with outside air. In addition, measures should be taken as necessary to prevent noise, vibration, freezing, propagation of Legionella bacteria, and others.

The adoption of a cooling water temperature control is decided in consideration of the outside air temperature in the case when the cooling tower is operated between seasons or in the winter season.

The adoption of a closed-type cooling tower is decided in consideration of the quantity of dust and concentrations of pollutants such as sulfur dioxide at the place of installation.

A.2.4.2.2 Design data

One cooling tower is provided to one unit of cold heat source equipment in principle.

In the case when the cooling towers are separately installed for a cooling water system of one unit of cold heat source equipment, the diameter of the communicating tube, shape of the joint to the water tank, and height of the foundation are examined to make it possible to maintain the balance of the water level between the cooling towers.

A cooling tower is installed at a place located as far away as possible from the fresh-air inlets (to prevent Legionella bacteria from being taken in) and stacks.

In the case when two or more cooling towers are installed or there are surroundings such as walls, an ambient space and the height of the outlet duct are examined.

The water treatment equipment is selected by considering the cost efficiency and others, based on the problems to be assumed in proportion to the water quality of the makeup water of the cooling tower and the level of air pollution.

The freezing of the cooling water is prevented in principle by the electric heaters that have a device to stop the operation when water is lost.

Measures should be taken to prevent the noise and vibration of the cooling towers as necessary.

The cooling capacity of a cooling tower is decided by the refrigeration capacity of the cold heat source equipment as a standard.

Earthquake-proof measures for cooling towers should be taken as necessary.

A.2.4.2.3 Calculation formula

The cooling capacity (H_{ct}, in kW) is calculated by Formula (A.13).

$$H_{\mathrm{ct}} = K_6 \cdot H_{\mathrm{RC}} \tag{A.13}$$

where

H_{Rc} is the refrigeration capacity of the cold heat source equipment, in kW;

K_6 is the cooling coefficient (= 1,3).

The quantity of the cooling water is calculated by Formula A.14.

$$L_{\mathrm{ct}} = \frac{14{,}3 \cdot H_{\mathrm{ct}}}{\Delta t} \tag{A.14}$$

where

Δt is the difference in the temperature of the cooling water, in °C.

A.2.5 Air-to-air heat pump room air-conditioner and mini split

A.2.5.1 List of heating and cooling load

When selecting the capacity of the room air-conditioner (RAC), the heating or cooling load is calculated, taking into consideration the type of the room, area, structure type of the envelope (wooden, RC, etc.), the thermal performance of the envelope including glazing and openings, and the generated heat from the occupants, lighting, and other appliances.

However, the heat load calculation can be complicated for the designers or occupants for one residential building. In such a case, lists of the heating and cooling load per unit area as shown in Tables A.5 and A.6 can be used; these were prepared based on the heating load pre-calculation discussed in A.2.5.3. In addition to the table, the applicable conditions such as the climate, region, type of the structure, and direction of the openings of the room, the assumption of the pre-calculation can be described as in Table A.7.

The maximum heating and/or cooling load are also dependent on the operation schedule of the heating and/or cooling equipment (e.g. intermittent use or continuous use). Designers can decide which design value to use through the discussion with the occupants in the design phase.

Table A.5 — Example of the heating and cooling load per unit area in the Southern Hemisphere (intermittent use)

Type of room		Heating and cooling load and its assumption	
		Heating and cooling load per unit area W/m²	
		Cooling	Heating
Detached house	South facing	190	265
(wooden, one-story house)	North facing	230	265
Apartment house (RC construction)	Highest floor	185	250
South-facing room	Middle floor	145	220

Table A.6 — Example of the heating and cooling load per unit area in the Southern Hemisphere (continuous use)

Type of room		Heating and cooling load and its assumption	
		Heating and cooling load per unit area W/m²	
		Cooling	Heating
Detached house	South facing	140	205
(wooden, one story house)	North facing	185	205
Apartment house (RC construction)	Highest floor	125	190
South-facing room	Middle floor	105	180

Table A.7 — Example assumption of the calculation (Southern Hemisphere)

Simulation: SHASE-S112–2009 Simplified Calculation Methods of Cooling and Heating Loads Strategy of sizing:	
Cooling conditions: — Indoor room temperature — Outdoor temperature	27 °C 33 °C
Heating conditions: — Indoor room temperature — Outdoor temperature	20 °C 0 °C
Air change rate	1 (1 volume per hour)
Window area/floor area	30 %
Number of occupants per floor area	3 persons/10 m²
Lighting (fluorescent): — Detached house — Apartment house — Others	10 W/m² 10 W/m² Opening such as windows and doors are closed.
Heat generated for lighting and occupants for heating	Neglected
Others	The blinds are closed at the openings facing east, south, and west.

A.2.5.2 Calculation of the heating or cooling load

The heating or cooling load per unit area is selected based on Tables A.5 and A.6, taking into account the type of room heated or cooled and the operation schedule of the heating/cooling system.

The heating or cooling load can be calculated using Formula A.15.

$$L = U \times S \tag{A.15}$$

where

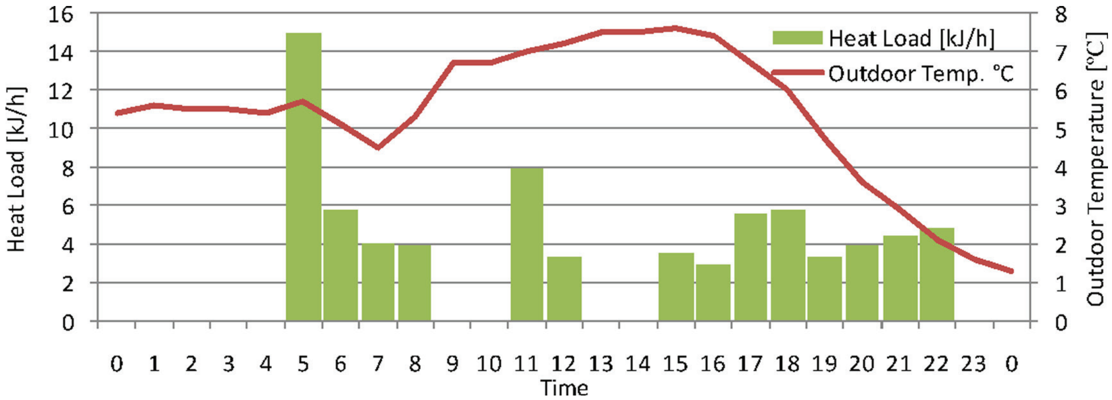
L is the designed heating or cooling load, in W;

U is the designed heating or cooling load per unit area selected from Tables A.5 and A.6, in W/m^2;

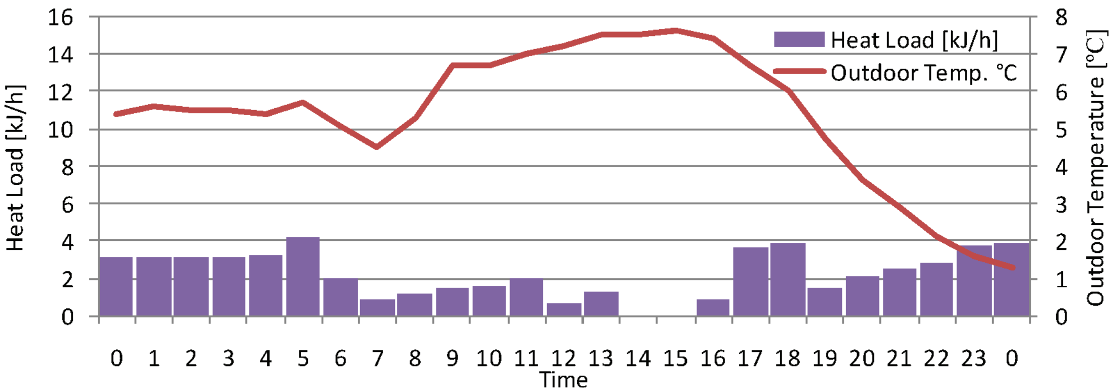
S is the floor area of the heated or cooled room, in m^2.

A.2.5.3 Heat load pre-calculation

In order to prepare the lists of the designed heating and cooling load per unit area as shown in Tables A.5 and A.6, a heat load calculation is carried out. It is important to classify the assumptions and results by the heating equipment's schedule of the intermittent use and continuous use, because the peak load is different between both operations (see Figure A.6). The peak load of the intermittent use is generally higher than that of the continuous use (see Figure A.7).



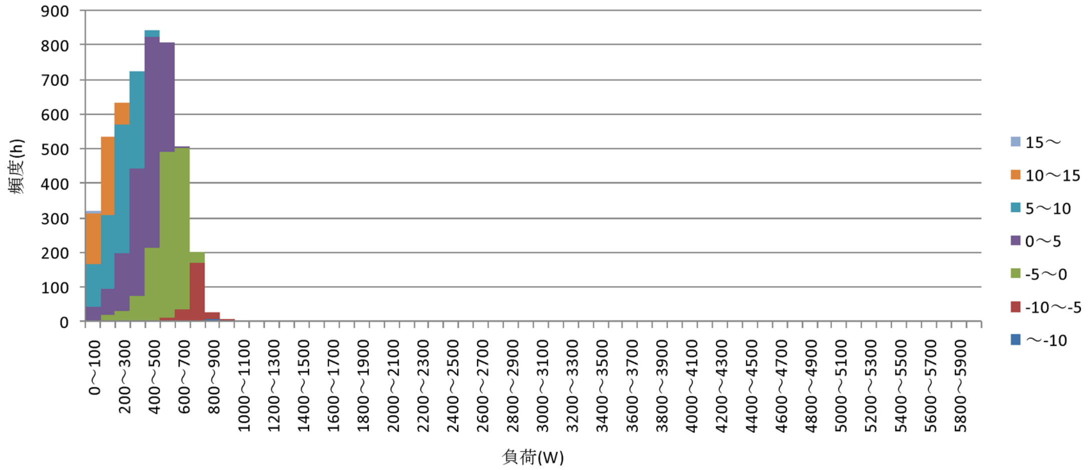
a) Intermittent use



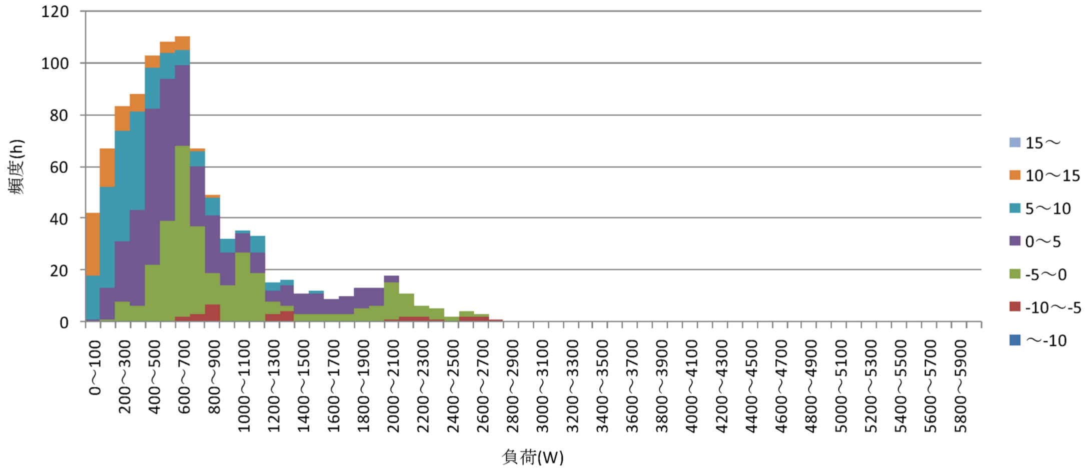
b) Continuous use

Figure A.6 — Example heating load and outdoor temperature

In the case of intermittent operation, the peak load mainly exists when the equipment is started up. Meanwhile, in the case of continuous operation, the peak load mainly exists when the outdoor temperature is lowest.



a) Intermittent use



b) Continuous use

Figure A.7 — Example frequency of equipment and distribution of heat load

A.2.6 Heat pump water heater (with CFC refrigerant)

A.2.6.1 Selection method of the air-conditioner and water heater combined systems

The combined systems of the air-conditioner and water heater generally have the configuration shown in Figure A.7. As for the systems on the secondary side, floor heating devices, fan coils, radiators, and others are used. The selection of the equipment of the air-conditioner and water heater combined systems is decided in consideration of the capacity of the equipment to cover the water heating loads and the capacity of the equipment to cover the heating loads in living space (or cooling loads for the region where the selection of the cooling loads is necessary). Air-conditioner and water heater combined systems give their basis of control to boil water for household use in the time zone when air-conditioning loads (heating and cooling) are not required, and the selection of the systems is not decided based on the total value of the air-conditioning loads and water-heating loads. As for the way of the hot water production, their tanks also have electric heaters and can keep the water hot and reheat the water. Some systems can also add optional heaters. For the energy calculation, it is necessary to consider the amount of energy consumed by optional heaters.

The point of selection of the equipment capacity is the comparison of the magnitude of the air-conditioning loads and water-heating loads. Usually, however, the capacity is selected based on air-conditioning loads because the air-conditioning loads are much larger as they are continuously used for long hours. It should be noted that the selection of the combined systems are different from that of the systems of the water heaters only.

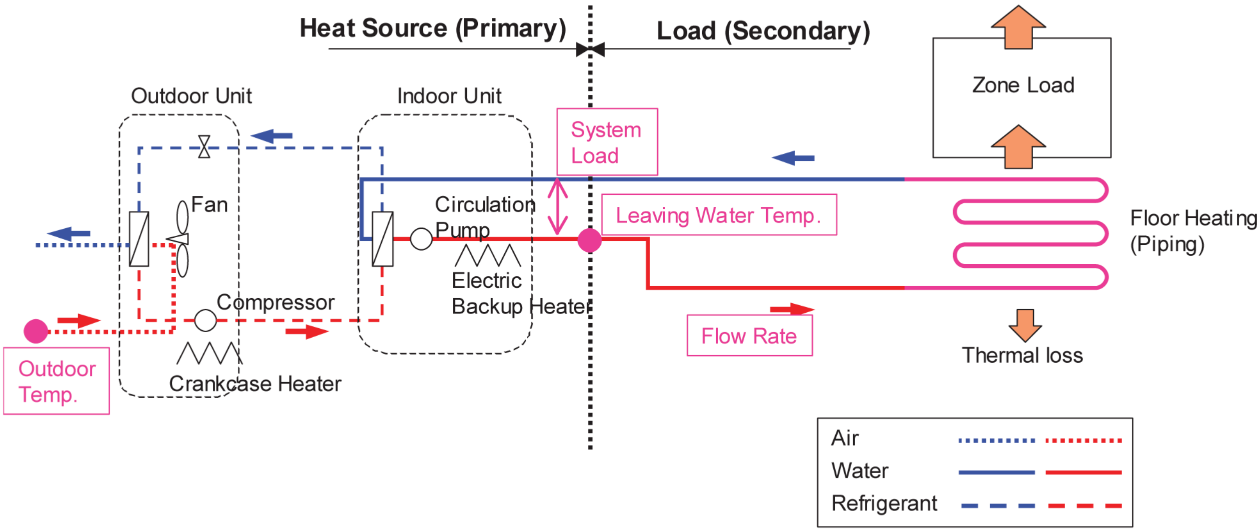


Figure A.8 — Configuration of the combined system

A.2.7 Heat recovery system

One of the heat pump system's major characteristics is the heat recovery system.

In the case of air-source heat pumps, the exhaust heat from cooling is recovered by another heat exchanger in the condenser, which is called a double-bundled condenser. However, the cooling load and heating load are not necessarily balanced, causing hourly deficiency and excess. Since it is also impossible to allocate the exhaust heat to the condenser for heat release and heat collection properly with sharing control, installation of both chilled water storage tank and hot water storage tank is necessary. Basically, the same concept applies to the water source types, but double-bundled condensers are not needed when the cooling water piping is used in combination as shown below:

a) when the switch between the heat release operation from the cooling tower and heat recovery operation is implemented per season, and there are no short-term switches such as by hour or day;

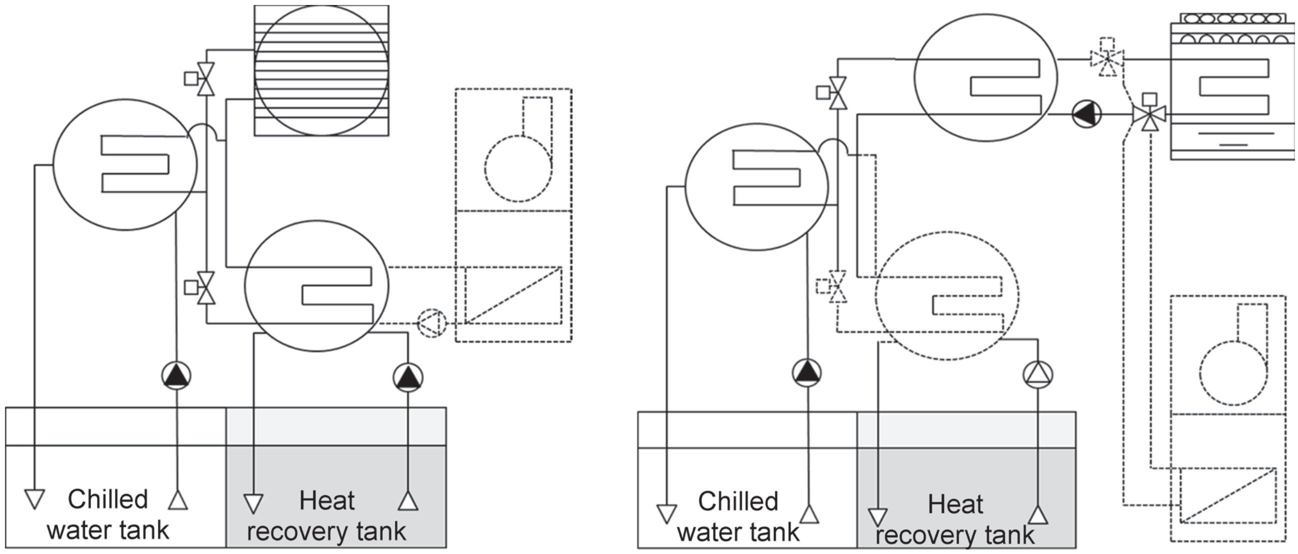
b) when the hot water temperature level out of the heat exchanger for heat recovery is allowed to be at the same level as the cooling water temperature.

The schematic diagram of the general heat recovery system is shown in Figure A.9.

An operational example of the heat recovery heat pump in winter using exhaust heat from space cooling for space heating with chilled water storage tank and hot water storage tank is shown in Figure A.9.

It uses a chilled water storage tank that contains thermal storage capacity which accounts for about 50 % of the peak daily cooling load in summer. It stores chilled water for two to three days of cooling demands, recovering exhaust heat equivalent to one day's of heating demands. The rest of the heating demands are covered by the storage operation of the air-source heat pump.

Thus, in the case of the heat recovery operation with heat pumps, it is necessary to install thermal storage tanks for both chilled and hot water sides in order to operate flexibly, overriding the time and demand difference between the cooling and heating demands.



a) Heat recovery by air source system **b) Heat recovery by water source system**

Figure A.9 — Schematic diagram of the waste heat recovery system

A.2.8 Water thermal storage system

A.2.8.1 Design standard

The capacities of the heat pump (chiller) and water thermal storage tank are decided based on the daily heat loads, heat balance, and operating time.

The operating time and stop time of the heat pump are decided in consideration of the characteristics of the daily heat loads.

A.2.8.2 Design data

A.2.8.2.1 General information

a) The capacity of the heat pump and thermal storage tank should cover the daily air-conditioning loads on the peak day.

b) The heat pump should conduct the thermal storage operation during the nighttime and the follow-up operation (running) during the daytime.

c) The thermal storage rate on the peak day and the annual rate of the heat load shift to the nighttime should be taken into account in deciding the capacity of a thermal storage tank, and the capacity should be decided in consideration of the economics of the thermal storage system. The rate of the heat load shift to the nighttime means a ratio of the heat loads stored by operating the heat pump during the nighttime to the daily heat loads.

d) A variable flow control system should be applied to the piping systems on the primary and secondary sides.

e) A connecting pipe type should be applied in principle in the case when underground double slabs are used for a thermal storage tank. If the effective depth of the water can be set at 2 m or deeper, a temperature stratification type should be considered based on the efficiency, economics, and other factors of the thermal storage tank.

f) The floor and walls in the thermal storage tank should be insulated and waterproofed all over the surface, and the ceiling should be insulated all over the surface to prevent dew condensation and heat loss.

g) The bore of the connecting pipe should be selected in accordance with Figure A.9 to set the difference in the water level between the lower temperature end tank and the higher temperature end tank at 200 mm or less and the flow rate through the connecting pipe at 0,1 m/s to 0,3 m/s (generally 0,2 m/s) at the maximum circulating water amount that can practically happen.

h) For the thermal storage tanks with the connecting pipe type, connecting pipes should be installed as the effective capacity of each tank becomes the largest. In addition to the connecting pipes, vent pipes (100 φ or larger), drain pipes (150 φ halved), overflow pipes (150 φ × 2 or more), and manholes (600 φ) should also be installed. Each pipe is installed in accordance with Figure A.10.

i) The lower connecting pipes should be installed practically as low as possible down to the slab surface in the case of thermal storage tanks with the connecting pipe type, and the upper connecting pipes should be installed to keep them always under the surface of the chilled and hot water. The opening of the connecting pipes should be chamfered to reduce resistance. The connecting pipes of the lower temperature end tank and higher temperature end tank should be installed in the upper part in principle. While preventing the operation with little water or no water due to a decrease in the water level at the start-up of the pumps, the capacity of the lower temperature end tank and that of the higher temperature end tank should be set at the same or larger than the capacity of the other intermediate tanks.

j) The pumping pipes of the heat pump and air-handling unit should be installed down to the lower depth of the water in the lower temperature end tank and higher temperature end tank. The return pipes should be installed down to the centre of the lower temperature end tank and higher temperature end tank, and the pipe ends should be elbowed for discharging in the horizontal direction.

k) The pumps should be installed in pits in the case when they are installed below the water surface. In the case when the pumps are installed above the water surface, they should be vertical types.

l) The manholes for inspection of the thermal storage tanks should be installed in every tank in principle. Moreover, measures for heat insulation such as double insulation and others should be taken as necessary.

m) The pipes for other applications should not be laid inside the thermal storage tanks.

n) The water meters and manual valves should be installed in the makeup water system, and ball taps should not be used. Makeup water should be put in a high-temperature tank (in the case of chilled water system) and its pipe position should be decided in consideration of the changes in the water level.

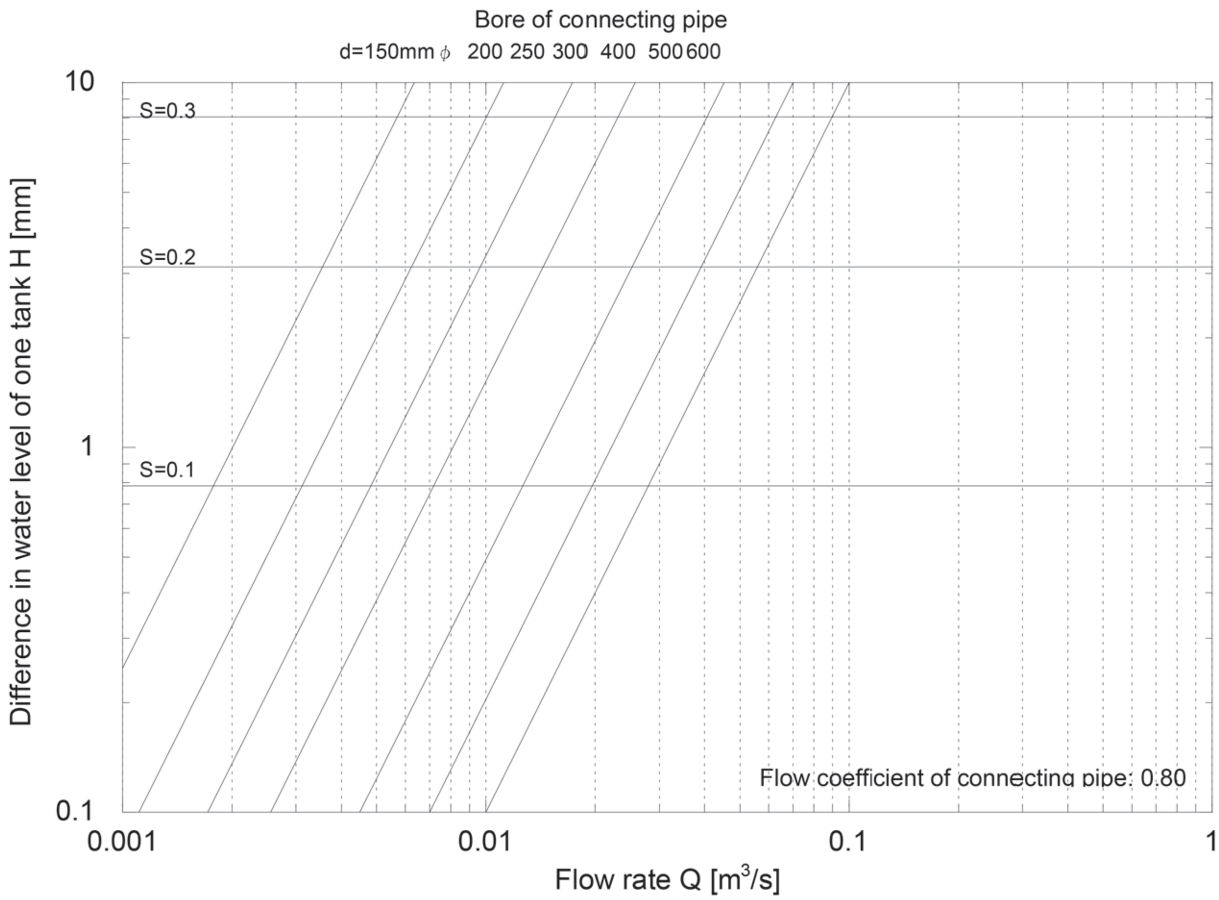


Figure A.10 — Table for the selection of the bore of connecting pipe

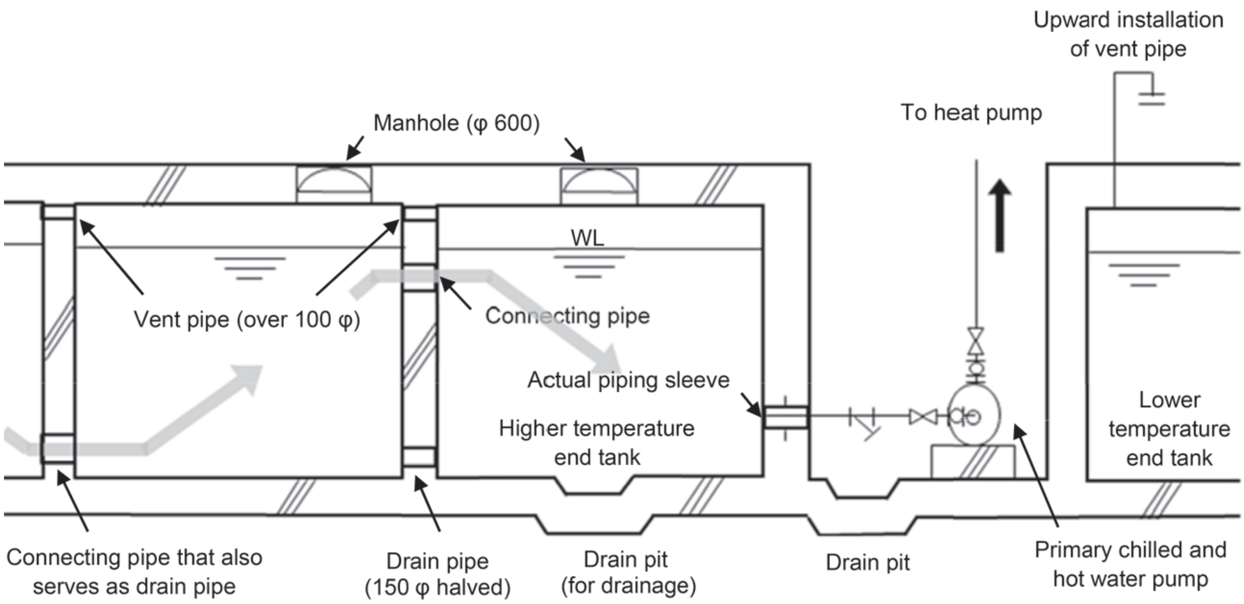


Figure A.11 — Example pipe installation in the connecting pipe type

A.2.8.3 Calculation of the water thermal storage tank

a) The capacities of the heat pump and thermal storage tank should be calculated in accordance with Figure A.12.

b) The hourly heat loads on one day should be calculated under the conditions of the air-conditioning design.

c) The amount of heat stored in the thermal storage tank should be decided based on the total effective volume of water stored in the water tanks and the calculation of the air-conditioning loads.

d) The examples of the thermal storage system diagrams are shown in Figure A.13.

e) The examples of the hourly heat balance and operation method of the heat pump are shown in Figure A.14.

f) The secondary system should use heat exchangers and should be a closed circuit.

g) The standard water temperatures of the heat pump and the secondary system are shown in Table A.8.

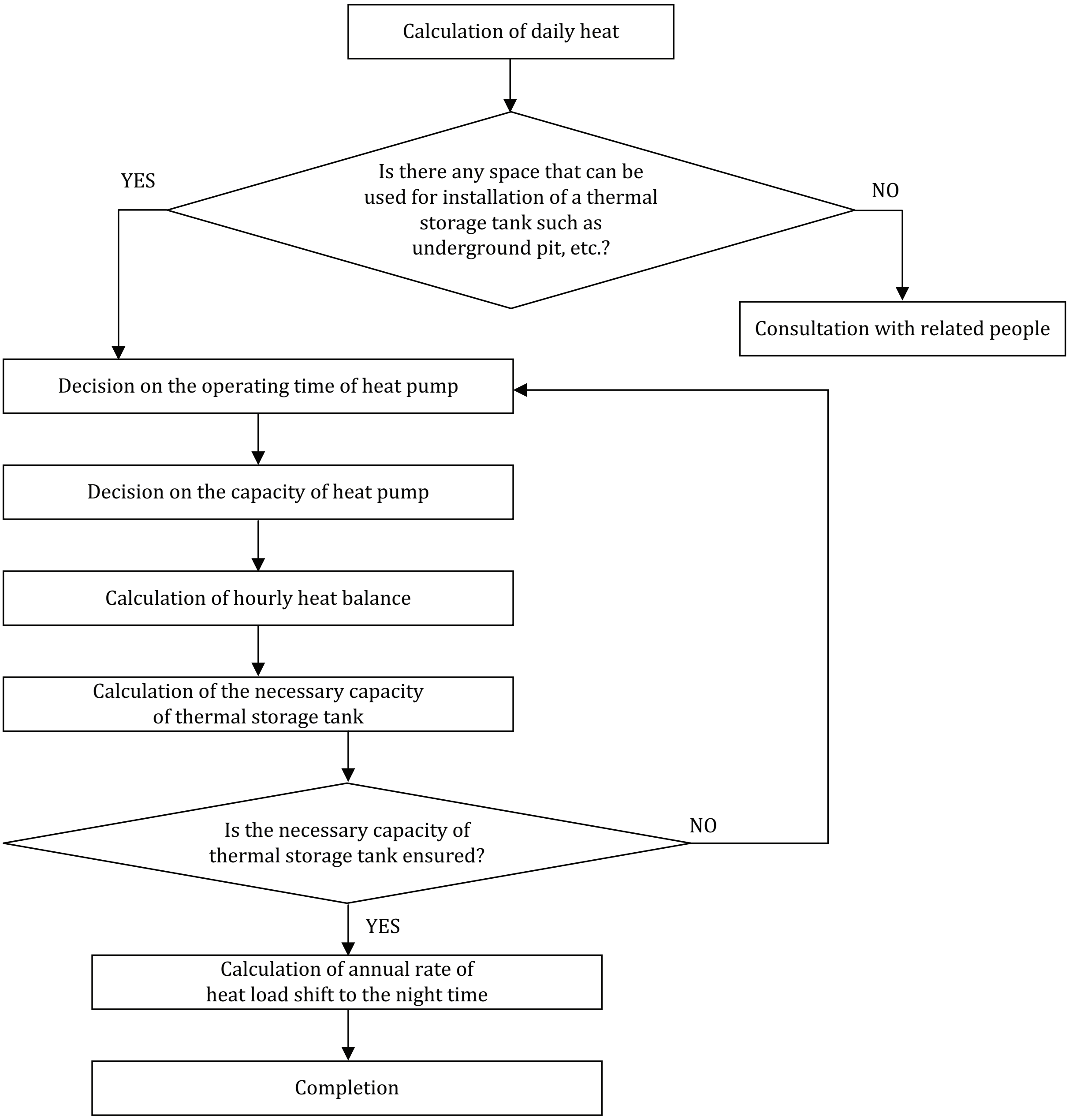


Figure A.12 — Procedures for calculating the capacities of the heat pump and thermal storage tank

Table A.8 — Standard water temperature conditions

	Heat pump	Equipment on the secondary system
Chilled water outlet	6 °C	15 °C
Chilled water inlet	14 °C	7 °C
Hot water outlet	46 °C	37 °C
Hot water inlet	38 °C	45 °C

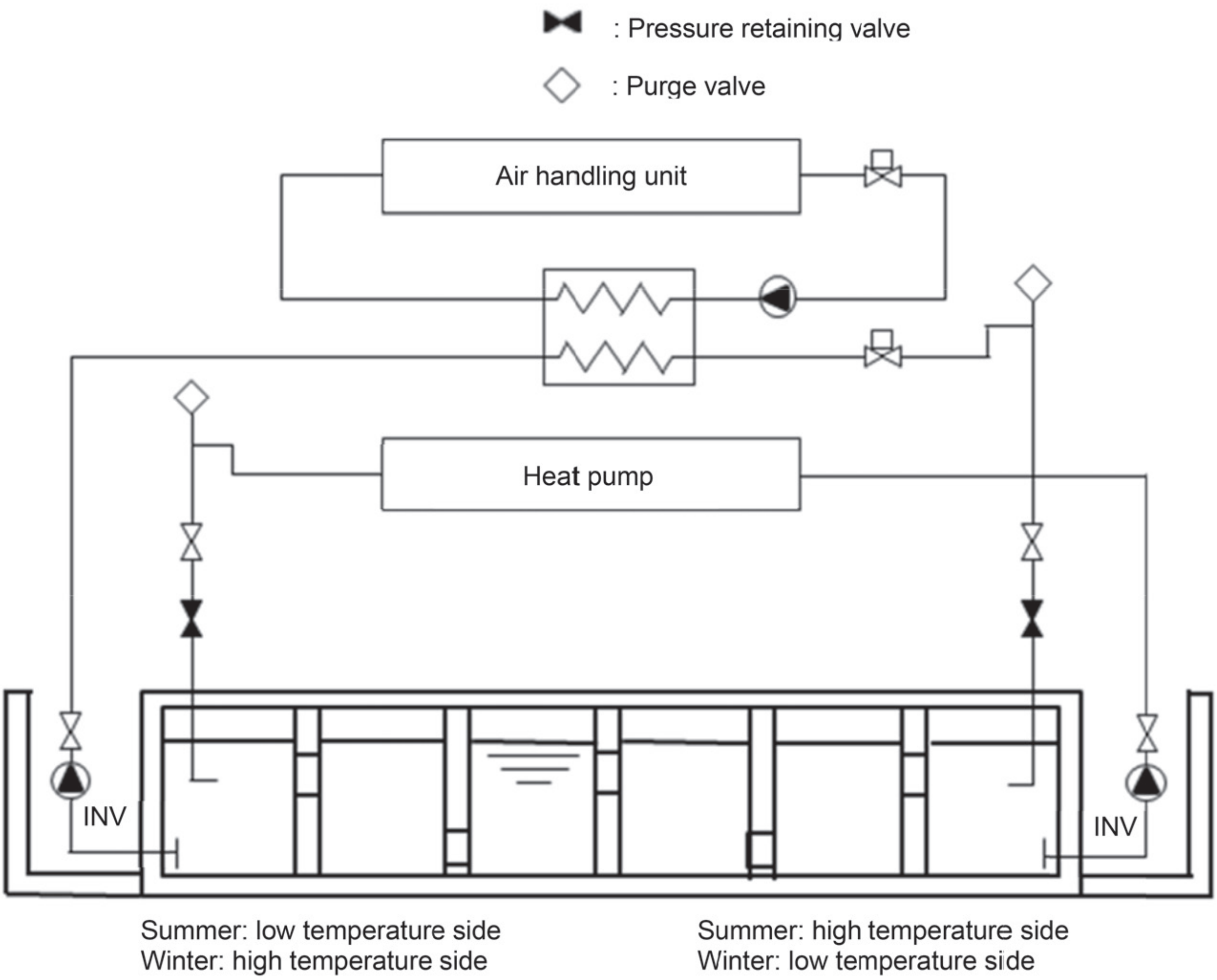


Figure A.13 — Example system diagram of the thermal storage system with connecting pipe type (in the case when the pumps can be installed below the water surface)

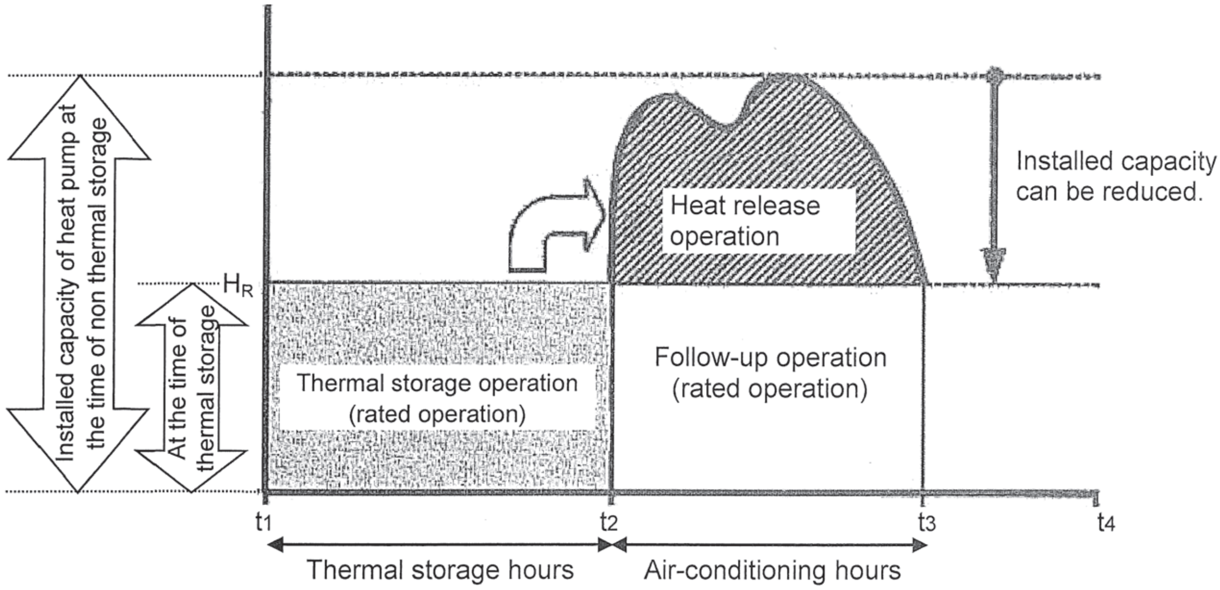


Figure A.14 — Examples of the hourly heat balance and operation of the heat pump

A.2.8.4 Calculation formula

a) Daily heat load (peak), Q_d (kW · h/day):

$$Q_d = \sum q_i \tag{A.16}$$

where

q_i is the air-conditioning heat load at time i, in kW.

b) Capacity of the heat pump H_R, in kW:

$$H_R = \frac{K_6 \cdot K_7 \cdot K_8 \cdot Q_d}{n_1 + n_2} \cdot W_{HW,gen,aux} \tag{A.17}$$

where

K_6 is the heat loss coefficient of the pipe, thermal storage tank, etc. (= 1,1);

K_7 is the aging coefficient (= 1,05);

K_8 is the performance compensation coefficient (= 1,05);

n_1 is the operating time of the heat pump, in h;

n_2 is the follow-up operation time of the heat pump, in h (= air-conditioning time);

c) Capacity of the thermal storage tank V, in m^3:

$$V = \frac{1\ 000 \cdot (n_1 \cdot H_R - \sum q_n)}{c_w \cdot \rho_w \cdot \Delta t \cdot \eta_s} \tag{A.18}$$

where

q_n is the air-conditioning heat load at time *n* during the thermal storage operating time, in kW;

Δt is the difference in the temperature to use the thermal storage tank, in °C (= 8);

η_s is the efficiency of the thermal storage tank:

— temperature stratification type = 0,8 to 0,9;

— connecting pipe type (less than 10 tanks) = 0,7;

— connecting pipe type (10 to less than 15 tanks) = 0,75;

— connecting pipe type (15 tanks or more) = 0,8;

c_w is the specific heat of the water [W · h/(kg · K)] (= 1,163);

ρ_w is the density of water, in kg/m^3 (= 1 000).

d) Rate of the heat load shift to the nighttime, η_d, in %:

$$\eta_d = \frac{V \cdot c_w \cdot \rho_w \cdot \Delta t \cdot \eta_s}{1\ 000 \cdot Q_d} \tag{A.19}$$

where

η_d is the rate of the heat load shift to the nighttime on the peak day, in %.

A.2.9 Ice storage system

A.2.9.1 Design standards

a) The capacities of the heat pump (chiller) and ice storage tank are decided based on the daily heat loads, heat balance, and operating time.

b) The operating time and stop time of the heat pump are decided in consideration of the characteristics of the daily heat loads.

A.2.9.2 Design data

A.2.9.2.1 General information

a) The capacity of the heat pump and ice storage tank should cover the daily air-conditioning loads on the peak day.

b) The heat pump should conduct the ice storage operation during the nighttime and the follow-up operation (running) during the daytime.

c) The thermal storage rate on the peak day and the annual rate of the heat load shift to the nighttime should be taken into account when deciding the capacity of the ice storage tank, and the capacity should be decided in consideration of the economics of the ice storage. The rate of the heat load shift to the nighttime means a ratio of the heat loads stored by the operating heat pump during the nighttime to the daily heat loads.

d) The water meters and manual valves should be installed in the makeup water system, and ball taps should not be used.

e) The types of the ice storage systems are shown in Figure A.16.

A.2.9.3 On-site construction type ice storage system

An on-site construction type ice storage system as presented in Figures A.16 and A.17 is selected in reference to Figure A.15.

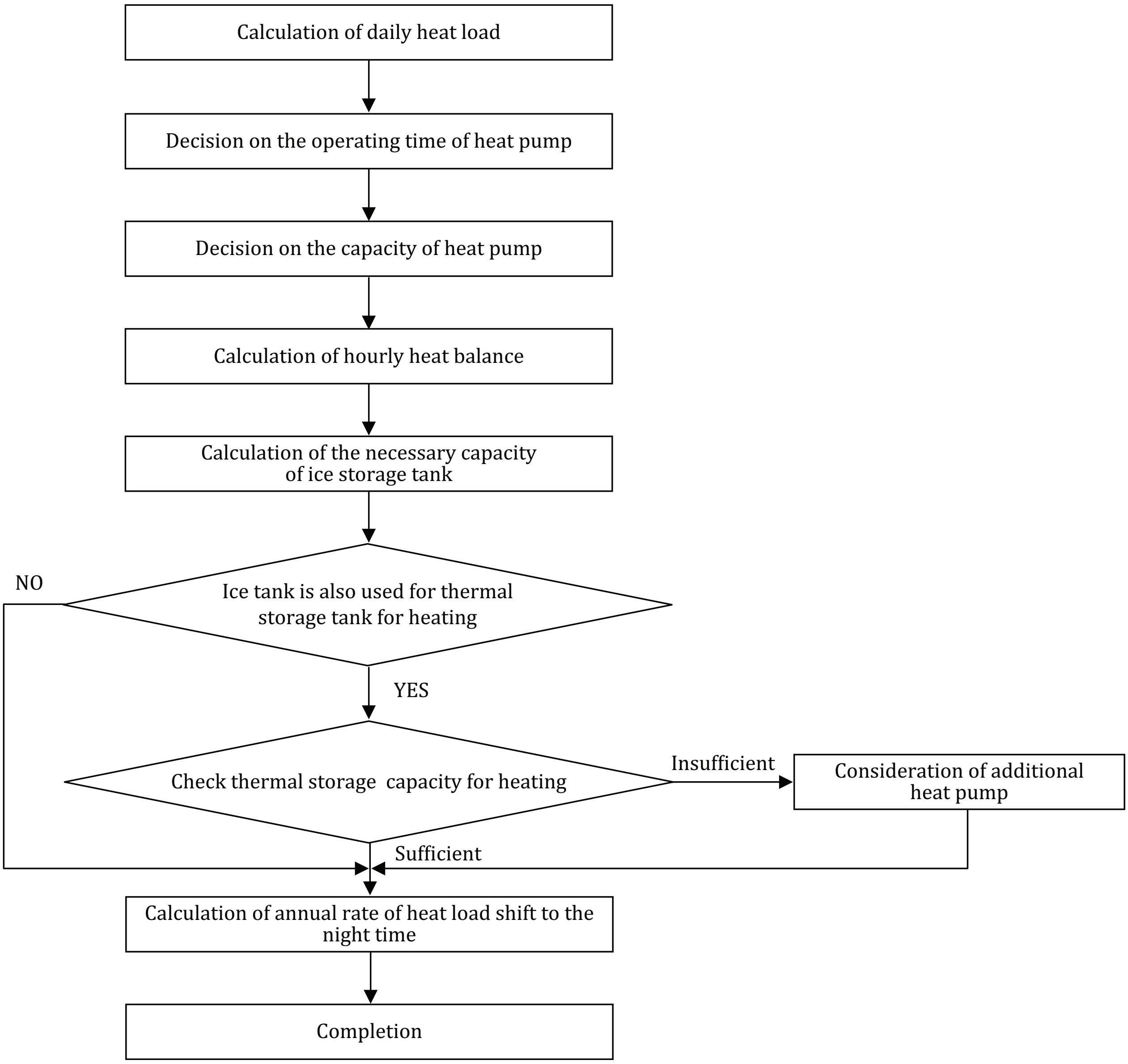


Figure A.15 — Procedures for selecting an on-site construction type ice storage system

The calculation of the on-site construction type ice storage system should be as follows:

a) daily heat load, Q_d (kW · h/day);

b) capacity of the heat pump, H_R, in kW:

$$H_R = \frac{K_6 \cdot K_7 \cdot K_8 \cdot Q_d}{n_1 \cdot K_9 + n_2} \qquad (A.20)$$

where

K_6 is the heat loss coefficient of the pipe, thermal storage tank, etc, (= 1,1);

K_7 is the aging coefficient (= 1,05);

K_8 is the performance compensation coefficient (= 1,05);

n_1 is the thermal storage operation time of the heat pump, in h;

n_2 is the follow-up operation time of heat pump, in h;

K_9 is the heat pump performance coefficient at the time of the ice making:
— static external melting type (= 0,67);
— static internal melting type (= 0,72);
— dynamic type (= 0,77).

c) capacity of the ice storage tank V_i, in m^3:

$$V_i = \frac{1\ 000 \cdot (n_1 \cdot K_9 \cdot H_R - \sum q_n)}{c_w \cdot \rho_w \cdot \Delta t \cdot \eta + \mathrm{IPF} \cdot c_i \cdot \rho_i} \qquad (A.21)$$

where

q_n is the air-conditioning heat load at time n during the thermal storage operating time, in kW;

Δt is the difference in the temperature to use the ice storage tank, in °C (= 0 °C to 6 °C);

IPF is the ice packing factor:
— static external melting type (= 0,1 to 0,45);
— static internal melting type (= 0,5 to 0,9);
— dynamic type (= 0,2 to 0,4);

c_w is the specific heat of the water [W · h/(kg · K)] (= 1,163);

c_i is the latent heat of the ice melting (W · h/kg) (= 93);

ρ_w is the density of the water, in kg/m^3 (= 1 000);

ρ_i is the density of the ice, in kg/m^3 (= 920);

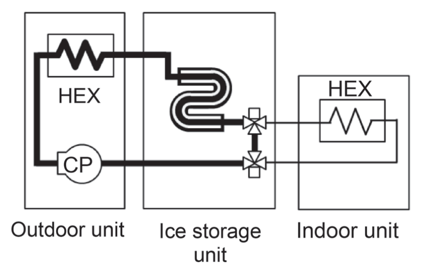
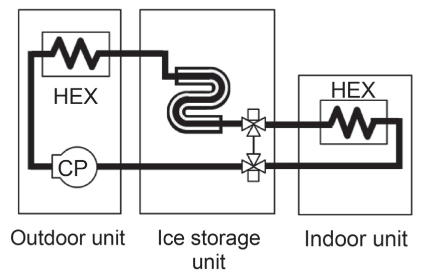
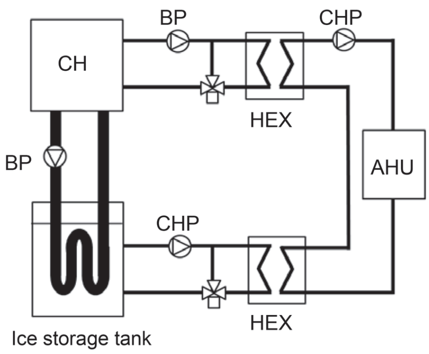
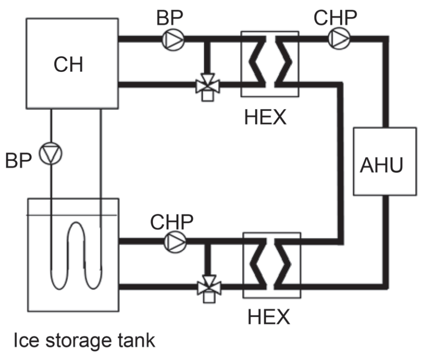
H is the efficiency of the ice storage tank (= 0,7 to 0,9);

d) rate of the heat load shift to the nighttime, η_d, in %:

$$\eta_d = \frac{V_i \cdot (c_w \cdot \rho_w \cdot \Delta t \cdot \eta + \text{IPF} \cdot c_i \cdot \rho_i)}{1\ 000 \cdot Q_d} \tag{A.22}$$

where

η_d is the rate of the heat load shift to the nighttime on the peak day, in %.

<table>
<tr><td colspan="3"></td><td>At the time of ice making</td><td>At the time of ice melting</td></tr>
<tr><td colspan="3" rowspan="3">Decentralized system</td><td>
</td><td>
</td></tr>
<tr><td colspan="2">Packaged air-source heat pump</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Central system</td><td>Static type</td><td>External melting type</td><td colspan="2">Ice is made on the external surface of ice-making coil at the time of ice making.
Ice is melted from the outside of ice in the reverse direction of ice making at the time of ice melting.
Low-temperature chilled water can be taken out.
The system is simple and can be integrated into a unit.</td></tr>
</table>

Key

AHU air-handling unit

BP brine pump

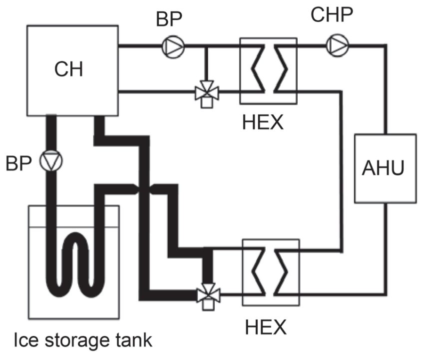
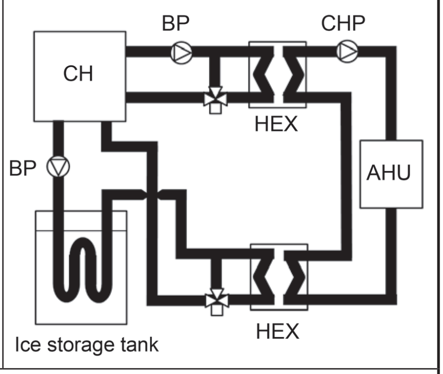
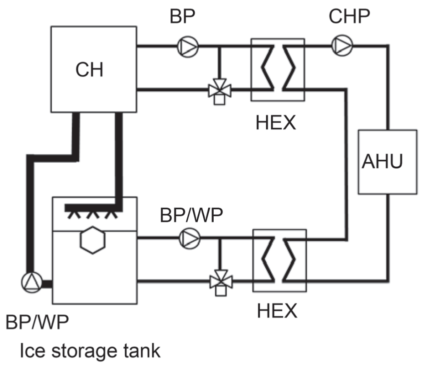
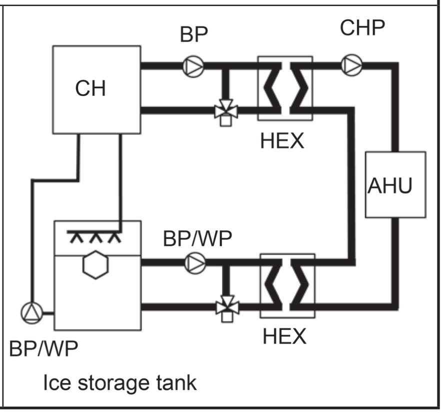
CH chiller

CP compressor

CHP chilled and hot water pump

HEX heat exchanger

Figure A.16 — Types of ice storage system

<table>
<tr><td colspan="3"></td><td>At the time of ice making</td><td>At the time of ice melting</td></tr>
<tr><td rowspan="4">Central system</td><td rowspan="2">Static type</td><td rowspan="2">Internal melting type</td><td>
</td><td>
</td></tr>
<tr><td colspan="2">Ice is made on the external surface of ice-making coil at the time of ice making.
Ice is melted from the inside of ice in the same direction of ice making at the time of ice melting.
This system is compact as its ice packing factor (IPF) is high.</td></tr>
<tr><td>Dynamic type</td><td>Slurry ice type</td><td>
</td><td>
</td></tr>
</table>

Key

AHU air-handling unit

BP brine pump

CH chiller

CP compressor

CHP chilled and hot water pump

HEX heat exchanger

WP water pump

Figure A.17 — Ice production and storage systems

Annex B
(informative)

Guidelines for the design parameters of the heat pump systems using water as a heat source

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

B.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 B.1. If in doubt, an analysis of the water source is recommended.

Table B.1 — Requirements for the quality of the extraction water

Component/unit of measurement	Value
Organic material (possibility of sedimentation)	None
pH value	7,5 to 9
Electrical conductivity (µS/cm)	50 to 500
Chloride (mg/litre)	< 300
Iron and manganese (mg/litre)	< 1
Sulfate (mg/litre)	0 to 70
O_2 content (mg/litre)	< 2
Chlorine (mg/litre	0 to 5
Nitrate (mg/litre)	0 to 100

B.1.2 Water temperature

For systems with a thermal heating capacity of 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 the ground surface. This value ($\theta_{m, e}$) can be increased by up to 3 °C in urban areas or regions with large snow covering.

B.1.3 Water quantity

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

Annex C
(informative)

Noise levels in the vicinity

In many countries, noise emissions are regulated and the determination and evaluation of the maximum allowable values for the noise levels are defined. There are differences within the zones of the industrial and residential areas. National values will be set as limits if no common regulation is available on that topic.

Annex D
(informative)

Example calculations of the domestic hot water (DHW) storage size

D.1 General

The heat pump and DHW storage is to be sized for a single family dwelling with three persons at a set DHW temperature of 50 °C. In the absence of national values, the average daily DHW consumption amounts to 25 l at 60 °C per person.

D.2 Solutions

D.2.1 Accumulation solution

The average daily DHW consumption is doubled to take into account the maximum amplitude of the daily hot water use (50 l per person per day) and the initial sizing value of the DHW storage is 150 l.

Design values are as follows:

— t_{DP} = 24 h;

— $Q_{l,\,s}$ = 2,2 kWh/d (daily thermal losses of the selected DHW storage at T = 50 °C);

— θ_{DPset} = 50 °C.

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

— $V_{l,s} = \dfrac{Q_{l,s}}{0{,}001\ 16 \cdot (\theta_{DP,60} - \theta_{cw})} = 38\ l$;

— $V_{DP,\,60}$ = 188 l at 60 °C (including the consideration of the thermal losses);

— V_{Uset} = 235 l at 50 °C (including the consideration of the thermal losses).

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

— Q_S = 0,001 16 · 250 · (50 – 10) + 2,2 = 13,8 kWh.

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

D.2.2 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 ⎝ = 50 °C)

— $V_{l,\,s}$ = 6,4 l

— V_{DP60} = 82 l at 60 °C (including the consideration of the thermal losses)

— $V_{\theta set}$ = 103 l at 50 °C (including the consideration of the thermal losses)

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

— $Q_s = 0{,}001\,16 \cdot 120 \cdot (50 - 10) + 0{,}3 = 5{,}9$ kWh.

The effective amount of energy available in the storage is as follows:

— $Q_{s,\ eff}$ = 1,5 kWh.

The 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 / 1 h = 3,25 kW.

Annex E
(informative)

Average daily tapping patterns for the domestic hot water production

Examples of the average daily tapping patterns are given in Tables E.1, E.2, and E.3, each for a different category of household. These tables are a support for the example presented in Annex F.

Table E.1 — 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	Δ*θ* desired (to be reached during draw off) K	Minimal *θ* for start of counting useful energy °C
1	07:00	0,105			Small	25	25
2	07:30	0,105			Small	40	25
3	08:30	0,105			Small	25	25
4	09:30	0,105			Small	25	25
5	11:30	0,105	X		Small	25	25
6	11:45	0,105	X		Small	25	25
7	12:45	0,315	X		Dishwashing	25	0
8	18:00	0,105	X		Small	25	25
9	18:15	0,105	X		Cleaning	25	45
10	20:30	0,420	X	X	Dishwashing	10	0
11	21:30	0,525	X	X	Large	25	45
Q_{DP} T_{DP}		**2,1 14h30**	**1,78 9h00**	**0,945 1h00**			
	36 litres at 60 °C						

Table E.2 — 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	Δ*θ* desired (to be reached during draw off) K	Minimal *θ* for start of counting useful energy °C
1	07:00	0,105		X	Small		25
2	07:15	1,400	X	X	Shower		40
3	07:30	0,105	X	X	Small		25
4	08:01	0,105	X		Small		25
5	08:15	0,105	X		Small		25
6	08:30	0,105	X		Small		25
7	08:45	0,105	X		Small		25
8	09:00	0,105	X		Small		25
9	09:30	0,105	X		Small		25
10	10:30	0,105	X		Floor	30	10

Table E.2 *(continued)*

No.	Time of the day hh:mm	Energy initial pattern kWh	Reference period for semi accumulation systems		Kind of tapping	ΔΘ desired (to be reached during draw off) K	Minimal Θ for start of counting useful energy °C
11	11:30	0,105	X		Small		25
12	11:45	0,105	X		Small		25
13	12:45	0,315	X		Dishwashing	45	10
14	14:30	0,105	X		Small		25
15	15:30	0,105	X		Small		25
16	16:30	0,105	X		Small		25
17	18:00	0,105	X		Small		25
18	18:15	0,105	X		Cleaning		40
19	18:30	0,105	X		Cleaning		40
20	19:00	0,105	X		Small		25
21	20:30	0,735	X	X	Dishwashing	45	10
22	21:15	0,105	X	X	Small		25
23	21:30	1,400	X	X	Shower		40
Q_{DP} T_{DP}		**5,845 14h30**	**5,740 14h15**	**2,24 1h00**			
	100,2 litres at 60ºC						

Table E.3 — Average daily tapping pattern for a family of three 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	ΔΘ 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	X		Shower		40
3	07:30	0,105	X		Small		25
4	07:45	0,105	X	X	Small		25
5	08:05	3,605	X	X	Bath	30	10
6	08:25	0,105	X	X	Small		25
7	08:30	0,105	X	X	Small		25
8	08:45	0,105	X	X	Small		25
9	09:00	0,105	X		Small		25
10	09:30	0,105	X		Small		25
11	10:30	0,105	X		Floor	30	10
12	11:30	0,105	X		Small		25
13	11.45	0,105	X		Small		25
14	12:45	0,315	X		Dishwashing	45	10
15	14:30	0,105	X		Small		25
16	15:30	0,105	X		Small		25
17	16:30	0,105	X		Small		25

Table E.3 *(continued)*

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
18	18:00	0,105	X		Small		25
19	18:15	0,105	X		Cleaning		40
20	18:30	0,105	X		Cleaning		40
21	19:00	0,105	X		Small		25
22	20:30	0,735	X	X	Dishwashing	45	10
23	21:00	3,605	X	X	Bath	30	10
24	21:30	0,105		X	Small		25
Q_{DP} T_{DP}		**11,655 14h30**	**11,445 13h55**	**4,445 1h00**			
	199,8 litres at 60 °C						

Annex F
(informative)

Commissioning of the system

F.1 General

F.1.1 Preliminary check considerations

The basic recommendations for the commissioning of the heat distribution system are given in prEN 14336.

The objectives of the commissioning in this part of ISO 13612 are the following:

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

— 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 designed operating conditions;

— to balance the heat distribution system.

F.1.2 Heat distribution circuit

The heat distribution circuit including the heat exchangers, tanks, and other hydronic components should be cleaned and flushed.

The water tightness of the circuit should be tested.

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

F.1.3 Earth loop

The earth loop piping (horizontal or vertical) should be cleaned and flushed.

The tightness of the circuit should be checked.

The earth loop piping should be pressure-tested in accordance with the manufacturer of the pipe and the heat pump instructions.

F.1.4 Filling and venting

The heat distribution system should be filled with water and vented.

When the whole system is filled, it should be carefully checked to ensure that the filling source connection is disconnected from the water supply. The quality of the filling water should be checked. When necessary, anti-frost products shall be added to the water.

Similarly, the earth loop should be filled with water and anti-frost additives in accordance with the design requirements.

F.1.5 Switch box and electric wiring

The tightness of the electrical connections of the heat pump and the other components of the installation (fans, pumps, electrical valves, etc.) to the energy supply should be carefully checked.

The connections of the ground potential wiring should be checked.

The voltage ratings of the various components of the installation should meet the voltage of the energy supply, and the current value of the cut-out switches should be checked.

F.1.6 Functional performance tests

The following functional performance tests should be carried out.

F.1.6.1 For water-based systems

— the operation of the electrical valves

— the operation of the manual valves

— the operation of the circulating pumps

— the operation of the control valves

F.1.6.2 For air-based systems

— the operation of the fans (direction of rotation)

F.1.6.3 For all systems — start up of the heat pump unit

The start-up procedure should be performed and the heat pump should be held in operation for a few minutes.

The shut-down procedure should be performed and checked to stop the unit.

F.1.7 Operation performance tests

F.1.7.1 General

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

F.1.7.2 Heat pump unit

The following parameters should be checked.

— the compressor discharge pressure

— the evaporator pressure

— the overheat temperature

— the compressor discharge temperature

— the energy consumption of the heat pump motor, voltage, and current

F.1.7.3 Heat distribution system

The outflow and return temperatures of the water loop should be checked. For air-based systems, the outgoing and return temperatures of the air duct system should be measured and compared to the design values.

F.1.7.4 Ground collector and ground water source

The outflow and return temperatures of the earth loop coming from a ground collector or a water source should be measured and compared to the design values.

F.1.8 Control system tuning

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

The effect of the control system on the operation of the heat pump compressor and fans or control valves should be checked before the final tuning of the parameters.

F.2 Balancing

F.2.1 General

The heat distribution circuit and, when existing, earth loop circuit should be balanced.

F.2.2 Flow rate balancing

F.2.2.1 Water-based systems

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

F.2.2.2 Air-based systems

The air mass flow rates of the heat distribution system should be balanced to meet the design requirements.

F.2.2.3 Earth loop

The water (or brine) mass flow rates of the ground collector circuit should be balanced. The mass flow rates in the different loops of the ground collector system should be adjusted in accordance with the design considerations.

F.3 Capacity and efficiency of the heat pump system

F.3.1 General

When required by the building owner or by local regulations, the efficiency of the heat pump system should be measured.

The provisions for monitoring given in 7.4.2 should be used to achieve these measurements.

F.3.2 Heat supplied to heating distribution

F.3.2.1 Water-based systems

The heat supplied to the building can be measured by installing a heat-meter in place of the pipe sleeve required in 7.4.2.2.

The heat supplied to the heating circuit can also be calculated by measuring the mass flow rate and the outflow and return air temperatures.

F.3.2.2 Air-based systems

The heat supplied to the air ducting system can be calculated by measuring the air flow rate and the outflow and return temperatures.

F.3.3 Energy consumption of the heat pump system

The energy consumption of the heat pump is measured on the basis of the regulations and standards which state the testing conditions (e.g. prEN 14511).

F.4 Handing over

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

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

— the electrical wiring circuits schemes;

— the manufacturer data sheets for all the components;

— the user manual;

— the maintenance instructions.

Bibliography

[1] ISO 5149-2, *Refrigerating systems and heat pumps — Safety and environmental requirements — Part 2: Design, construction, testing, marking and documentation*

[2] CEN/TS 14825, *Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling — Testing and rating at part load conditions*

[3] EN 255-1, *Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors — Heating mode — Part 1: Terms, definitions and designations*

[4] SHASE-S112-2009, *Simplified Calculation Methods of Cooling and Heating Loads*

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