hybrid GEOTABS

Controlling the power of the ground by integration

Generic specifications of key hybridGEOTABS system components

Table of Contents

A.1 Introduction

Specifications constitute, besides plans and bills of quantities, the most important document of the final design phase in the most commonly applied building process (Design Bid Build). Specifications are usually annexed to the contract between the contracting authority (investor) and the contractor. As such, they become legally binding for both contracting parties. Therefore, it is understood that the quality of specifications can have a significant impact on the development of the construction phase of the build process.

Like any contract, specifications shall express the designer's intent in a clear, precise and concise manner. Moreover, such specifications are easy to maintain and can quickly be adapted to reflect the technological advances in the concerned field or to fit a particular project's needs. Verbose specifications, on the other hand, are usually difficult to maintain, especially if they contain multiple interlaced dependencies at various parts of the specification. Designers often tend to write verbose specifications thinking that specifications that are more extensive are more likely to hide the eventual shortcomings. At some point, such practice can backfire, especially if the verbosity has led to contradictions or requirements that are incompatible with the specific requirements of a given project. Therefore, the specification writer shall try to find just the right balance between being too verbose and too concise. At the same time, the specifications shall be clear and precise.

In Europe, the specification styles vary from one country to another, and very often from one company to another. One can find specifications ranging from a rather verbose novel-like style on one hand to a bullet list-like style on the other one. Moreover, the specification sometimes acts as a separate document from the bill of quantities or both can be merged into one integrated document.

The format proposed in this annex follows the bullet list style and tends to be as concise as possible. If needed, the person using these texts can still expand it into a novel-like structure or, alternatively, make it even more concise. At the same time, the applied format has been selected such that it can also be used in styles where articles represent one bill of quantity unit. Such style can easily be transformed into a pure specification not linked to a bill of quantities, as it will be explained below.

In any case, the person using these generic specification texts shall adapt them in order to suit the exact project needs. In order to be applicable in the entire EU, national standards are not referenced in the following specifications. If such standards or any other locally recognized guidelines are considered as the state of the art in the country of interest, the specification writer shall adapt the content accordingly.

A.2 Structure

This section explains how the specifications presented in this document are structured.

Sections

Each specification article is divided into several sections used to group the related technical content. Sections are only added to the specification if necessary. The following sections are used:
Products
Labor
Submittals
Certification
Specifications
Operation
Execution

Products

The purpose of this section is to provide a succinct way of defining the entire scope of products covered by the article.

The products considered included in the scope of the article if a quantity is used are listed. This way, anyone reading the specification (e.g. the contractor submitting the price offer) immediately gets an idea what products are included in the article's scope. This is especially useful for auxiliary items that are usually not specified in details, e.g. fastening material.

It is definitely not the meaning of this section to describe the construction of some equipment (i.e. the way some product is assembled). Only the list of individual equipment items that clearly form a complete functional entity can be given. The following list gives some examples of complete functional entities: heat pump, boiler, buffer tank, valve, etc.

The list shall not contain individual components of one functional entity. These shall be described, if needed, under the specification section. For example, a heat pump compressor is just a component of a heat pump functional entity that is a heat pump. It shall therefore not be listed under this section, because it is automatically included in the heat pump. The same goes for components such as an impeller that is just a component of a pump functional entity.

Labor

In analogy to the section 'Products' which gives on overview of products included in the specification article, this section gives an overview of labor comprised in the described article. It is used in specification writing styles where a specification article is bound to an item in the bill of quantities.

The labor considered included in the scope of the article if a quantity is used are listed. Most commonly, this will be the supply and installation of the material, but in the case of certain products, other labor shall also be included. For example, in case of complex machines such as heat pumps, commissioning shall also be included if not specified in its own article.

Submittals

This section is used to specify the list of documents and samples that the contractor shall submit during construction. In analogy to the sections 'Products' and 'Work', this section only lists the submittal types and not their full content. In most cases, it this is sufficient. However, if it is necessary to provide more information regarding one type of submittal, this is done under the section 'Specifications'.

A special type of submittals that is required in most cases are technical data sheets. The list only mentions that technical data sheets shall be submitted, but at the same time it refers to the 'Specifications' for the precision of which sheets precisely are needed.

By default, it is not specified when during the construction phase the required submittals shall be submitted. If some submittals needs to be submitted earlier or later than required, this can be explicitly prescribed in this section.

Certification

This section can be used to specify the necessary approvals and certificates of the equipment. The approvals and certificates can be requested either for a specific functional unit or for all the equipment described in the article, depending on the context.

Specifications

This section defines all the necessary requirements for the specified product or system. If detailed product or system descriptions are necessary then they shall be provided here.

Any description given in this section tries to be succinct. Only important information is given without the unnecessary prescriptive overhead. For example, when describing a circulator pump, it is not specified that it contains an electric motor and an impeller because this is implicitly required in order to comply with the performance requirements.

The requirements provided in this section are performance based as much as possible. Prescriptive requirements are avoided if possible.

If a technical data sheet shall be submitted for some equipment (because it typically is of great interest to the designer) this is specified using the '@' symbol followed by the word 'data sheet'. The '@' symbol is used to make this requirement stand out from the rest of the text and to make is searchable in a pdf document. The data sheet requirement shall always be the first line following the subsection delimiter.

The 'Specifications' section is divided into separate subsections for every functional unit. If needed, there can also be one general section ('General') at the beginning that lists the general requirements applicable to all functional units.

The structure of this section is rather flexible and is not fixed. The description is split into logical groups, avoiding several layers if possible. Large and complex functional units (e.g. heat pumps) require separate subsections to describe individual components of functional units.

Operation

This section is used to explain the working principle of a product or system. It is most commonly used to describe the operation of an equipment that is based on some sort of automation control, although the control can also be mechanical. This section is only used if the description of the operation sequence or principle is necessary. For example, one does not describe the principles of operation of a scroll compressor because such principles are generally well known and understood.

Execution

This section provides specific instructions for execution work, i.e. how the work shall be performed and what result shall be achieved. It shall not be confused with the 'Work' which is a listing of work to be performed.

Customization

Specifications have to be adapted in order to suit the exact needs of each project. Parts of specification texts that need to be adapted or filled in by the specifier taking into account specific project requirements have been indicated with **blue** color.

A.3 Liability and trademarks

Disclaimer of liability: the authors of the specification texts provided in this document shall be not hold responsible for any damage that may arise from the use of these texts. Anyone using these specification texts solely bears the full responsibility for the legal consequences that may arise from their use.

Claims to third-party names: this report does not make any claims to third-party names:
BACnet® is a trademark of the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE).
The BTL logo (BACnet Testing Laboratory) is a trademark of BACnet International (BI), earlier BACnet Manufacturers Association (BMA).

Text may contain specific trademarks to clearly describe the design intention. This cannot be interpreted as a recommendation by the report authors. At the same time, mentioning a trademark does not mean that that particular product is best suited for the related application.

A.4 Specifications

01 Heat pumps and chillers

Heat pumps and chillers

Work:
always included
Selection
Supply and installation
Commissioning

Submittals:
always included
Product data sheet
Declaration of performance
Unit selection sheet
Vibration dampers selection sheet
Shop drawing
Operating, maintenance and safety instructions, in particular:

- Instruction for safe use under operating and maintenance conditions
- Instruction for switching on and off the equipment
- Instructions for equipment and control instruments, periodic inspections, frequency recommends for these inspections
- Description of the normal operation of the device, the instructions concerning the protection and control equipment, the instructions for troubleshooting
- Instructions for maintenance and cleaning, with diagrams

Specifications:

> Submittals

The calculation of performance in the actual operating state shall be determined using calculation software certified by Eurovent or an equivalent certification body

The declaration of performance transmitted shall comply with the requirements of the relevant EU regulations, in particular:

- Regulation (EU) 206/2012
- Regulation (EU) 813/2013
- Regulation (EU) 2016/2281

The coefficient of performance (COP, EER, COP_{rated}, EER_{rated}, SCOP, SEER) mentioned on the documentation submitted by the contractor shall be established in accordance with EN 14511 (all parts)

> Definitions

Nominal heat output (Q_n): cooling or heating output supplied by the appliance at nominal operating conditions

Monobloc version: all elements are mounted in a single frame

Split version: condenser and evaporator are mounted in separate frames and connected by means of pipes

> Performances

All performance factors shall always be determined in accordance with EN 14511 (all parts)

The following conditions apply to the coefficients of performance mentioned in these specifications:

- COP and/or EER: nominal operating conditions (defined separately for each device specified in the article of the device itself)
- COP_{rated} or EER_{rated}: test conditions (defined separately for each device specified in the article of the device itself)
- SCOP and / or SEER: average standard climate

> General

Devices shall be fully assembled and tested at the factory

All the components of a device shall be designed and produced so that they resist the corrosion classes according to EN ISO 9223 specified below in these specifications

If a coating shall be provided on the heat exchangers to meet the requirements for protection against corrosion, the selection of components shall take into account the additional heat transfer resistance

> Compressors

>> Authorized types

Unless expressly stated otherwise in the specification, the following types of compressors are allowed:

- Rotary compressors: up to 50 kW Q_n
- Piston compressors: up to 300 kW Q_n
- Scroll compressors: up to 300 kW Q_n
- Screw compressors: without restrictions
- Centrifugal compressors: without restrictions

>> Modes of execution

The following modes of execution are authorized:

- Hermetic: up to 50 kW of Q_n (exception: scroll compressors: without restrictions)
- Semi-hermetic: without restrictions
- Open execution: not authorized

>> Lubrication

Lubrication of compressor, bearings and any speed multipliers is carried out under pressure
The necessary oil pressure is supplied either by an oil pump or by the compressor itself (if the oil pan is on the high-pressure side)
For semi-hermetic compressors there is also a removable oil filter, an oil pressure switch and an oil level sight glass
Oil shall be compatible with the refrigerant
The oil pan contains an electrical resistance, which keeps the oil at the necessary temperature when the compressor is not running

>> Compressor cooling

The compressor and the drive motor of the hermetic and semi-hermetic compressors are cooled by the refrigerant and possibly by oil
The oil is also cooled by the refrigerant

>> Number of compressors

A device can contain a maximum of four compressors

>> Special requirements: piston compressors and scroll compressors

A piston compressor has at least two cylinders
The heat output of the device is adjustable at least as follows:

- Q_n less than 30 kW: on / off

- Q_n between 30 and 100 kW: min. 2 stages (lower stage: max. 50% of Q_n)
- Q_n between 100 and 200 kW: min. 3 stages (lower stage: max. 33% of Q_n)
- Q_n between 200 and 300 kW: min. 4 stages (lower stage: max. 25% of Q_n)

The heat output shall be adjusted either by the use of several compressors, or by an adjustable power compressor; in the latter case, three methods are allowed:

- A bypass between the suction side and the discharge side of one or more cylinders / spirals
- Lifting the suction valve of one or more cylinders / spirals
- Variation of the rotation speed of the drive motor

>> Special requirements: screw compressors

The sealing between screws as well as between screws and body is ensured by the oil of the lubrication system

The heat output shall be able to be continuously adjustable between 10 and 100% of Q_n; the following methods of adjustment are permitted:

- A bypass between the suction side and the discharge side
- Variation of the rotation speed of the drive motor

>> Special requirements: centrifugal compressors

Centrifugal compressors are of the single or multi-stage type

The heat output shall be able to be continuously adjustable between 10 and 100% of Q_n; the following methods of adjustment are permitted:

- Adjustable blades mounted on the suction
- Variation of the rotation speed of the drive motor

> Electric drive motor

>> Features

The following types of electric motors are authorized:

- Three-phase asynchronous motor according to EN 60034-1
- Three-phase synchronous motors with permanent magnets

Min. protection index: IP 54

Insulation class min.:

- Standard: class B (130 to 155 °C)
- Motors powered by frequency regulators: class F (155 to 180 °C)

Efficiency class min.: IE3 according to EN 60034-30-1
A temperature sensor is placed in the motor windings

>> Motor starting

Direct starting of motors is allowed insofar as there are no harmful consequences for the drive system and for the functioning of the electrical installation
In any case, it is prohibited to directly start motors with a power greater than 20 kVA
In general, the maximum inrush current is limited to the following values according to the nominal power of the motor:

- $P_n \leq 3$ kVA: 4x I_n
- 3 kVA < $P_n \leq 5$ kVA: 3x I_n
- 5 kVA < $P_n \leq 10$ kVA: 2x I_n
- 10 kVA < P_n: 1.5x I_n

In order to satisfy the requirements concerning the inrush current, the following solutions can be used:

- Variable speed drives
- Star-delta starters with contactors according to EN 60947-4-1
- Starters with semiconductors (soft-starter) according to EN 60947-4-2 (in this case, the starter can also fulfill the function of contactor); start time and torque or current shall be adjustable

It is necessary to take all the necessary precautions so that during the switching of the poles, or of the star-delta passage, the axis of the motor does not undergo too violent shocks likely to damage the transmission or the load driven or shorten its lifespan
The starting current limiting devices shall be installed in the control panel of the device itself or in the electrical panel, which supplies the device
During start-up, the device always works at the lowest power level

>> Speed control

The speed control of the drive motors is optional with compressors (unless expressly indicated) and compulsory with fans and circulator pumps
Variable speed drives shall be of the electronic frequency converter type (possibly as part of a synchronous motor with permanent magnets)
Drives that are not part of the motor shall be installed in the electric panel of the device

> Expansion valve

Only the electronic type expansion valve is authorized

> Water cooled/heated condenser/evaporator

if applicable

Compliance: EN 14276
The following construction types are authorized:
- Coaxial (Q_n: max. 50 kW): the pipes are made of copper
- With plates (Q_n: max. 300 kW): the plates are made of stainless steel (material 1.4401 or 1.4404) and welded or brazed
- With tube bundle (without restrictions): the tubes are made of copper, the envelope of steel

Equipped with a drain valve and a water side air purge
Pressure drop (water side): max. 50 kPa (for delta T indicated below in the specification)
Operating pressure: at least 6 bar
Fouling factor: the device selection shall take into account the following fouling factor:
- Evaporator: 0.018 (m^2K) / kW
- Condenser: 0.035 (m^2K) / kW

If a heat exchanger is used as an evaporator and condenser, the selection shall be made taking into account the most unfavorable value

> Air cooled/heated condenser/evaporator or free cooling heat exchanger
if applicable
Compliance: EN 14276
The following constructions are authorized:
- Fin-and-tube: copper tubes, aluminum fins
- Micro-channels: entirely in aluminum

The air flow through the exchanger is ensured by one or more fans which are part of the device itself
Coating (only applicable if specified in the article of the specified device itself): the surface of the heat exchangers shall also be protected by a coating system in accordance with EN ISO 12944-5 (durability class H: more than 15 years) although the uncoated material may already meet the required corrosion environment class
The corrosion environment class is defined below in the item of the specified device itself

> Fans
if applicable
The following constructions are authorized:
- Centrifugal type with backward curved blades
- Axial type

The impeller is mounted directly on the motor shaft

Any contact between different metals shall be avoided
Impellers are mounted on self-aligning bearings and greased for life
Bearings shall be dimensioned for a minimum service life (L10 according to ISO 281-1) of 40,000 hours of operation at maximum speed
The fan motor unit shall be statically and dynamically balanced in accordance with ISO 14694 and ISO 1940-1, class G: 2.5
The impeller and the blades are made of:

- Aluminum
- Fiber reinforced material

Reaction to fire class of plastics: min. B-s1,do

> Thermal insulation

All elements of the hydraulic and refrigeration circuit in the appliance shall be thermally insulated in the factory
Insulation material:

- Flexible elastomer closed cell foam
- Compliance: EN 14304
- Does not contain CFC or HCFC
- Reaction to fire class: min. B(L)-s3,do
- Declared thermal conductivity (at +10 ° C): ≤ 0.040 W/(mK)
- Coefficient of resistance to water vapor diffusion: ≥ 10,000

The minimum thickness of thermal insulation allowed is 20 mm

> Frame

>> General

All components are mounted on a solid frame made of steel profiles or on a self-supporting construction in which the different elements are fixed to each other
In the case of outside installation, the motor-compressor assembly and accessories are placed in a compartment composed of removable metal panels

>> Anti-vibration measures

Devices with rotating elements shall always be installed on a raised base:

- Either on a concrete base with a minimum thickness of 8 cm, the edge of which is protected by an angle profile 50 x 50 x 5 mm
- Either on a metallic structure in stainless steel (min. EN 1.4301)

- Either on a wall support made of powder-coated sheet steel profiles (exceptionally for direct expansion devices whose nominal electrical power does not exceed 5 kW)

Anti-vibration elements shall be placed between the base and the device; their characteristics shall meet the acoustic requirements

>> Noise reduction

When the acoustic conditions require it, the device shall be fitted with a soundproof box
The box is either made of removable metal panels, coated inside with sound absorption material or is double-walled
All control and signaling devices shall remain visible and freely accessible
The non-combustible sound absorption material in the box, in the noise attenuators and in the screens (class A2 according to EN 13501-1) shall be durable, rot-proof and vermin-resistant; it is also provided with the necessary means of protection to prevent it from eroding and becoming wet in the event of rain
The panels shall be removable while the hydraulic and electrical connections are operational

> Control panel

Compliance: EN 61439 (series)
The panel is completely wired, connected to the compressor and its accessories and tested in the manufacturer's factory
The 24 V DC control transformer in the panel shall have a power reserve of at least 1 A

> Controls

The device is equipped with microprocessor control unit
The control unit is installed in the control panel of the device
Each device shall be fitted with a potential-free contact, which, by means of an external signal, can prevent the device from operating
In the case of several devices connected in parallel, the control system shall be able to operate in cascade; the regulation of at least one device shall be configured as master, or the contractor shall provide an additional master regulator
A dip in the mains voltage causes an ordered shutdown of the device and, when the mains voltage returns, an automatic start-up

> Human-machine interface

A control unit with a screen and a keyboard shall be provided

> BMS interface

The control unit is provided by default with a BACnet (IP or SC) or Modbus interface

> Nameplate

The device is equipped with a nameplate in durable material and whose inscriptions are indelible
The plate is securely spun in an easily accessible and visible place
It bears at least the following indications:

- Name of manufacturer
- Model and serial number
- Year of manufacture
- Type and quantity of refrigerant
- Thermal/cooling capacity for nominal conditions
- Temperatures at nominal conditions
- Nominal voltage
- Maximum current

> Temperature range

When stopped, the device shall be able to withstand without adverse consequences, all the temperatures that could result from the nature of the installation and the indoor and outdoor climatic conditions

- Outside: -15 to +40 °C
- Indoors (underground or in an isolated room): +10 to +40 °C
- Indoors (in a non-isolated room): -5 to +40 °C

The contractor shall take all the necessary measures for this purpose
Without prejudice to the more specific prescriptions below, any device shall be able to operate when the temperatures are as follows:

>> Chilled water units

Air condenser:

- Air temperature: between -10 and +40 °C

Water condenser:

- Inlet water temperature: between +20 and +30 °C
- Difference in water temperature between the inlet and outlet of the condenser: between 4 and 8 K

Air evaporator: not applicable
Water evaporator:

- Outlet water temperature: between +5 and +15 ° C

- Difference in water temperature between the inlet and outlet of the evaporator: between 4 and 8 K

>> Heat pumps

Air condenser: not applicable

Water condenser:

- Outlet water temperature (flow temperature):
  - Standard application: between +25 and +55 °C
  - High temperature (HT) application: between +25 and +70 °C
- Difference in water temperature between the inlet and the outlet of the condenser: between 4 and 8 K

Air evaporator:

- Inlet air temperature: between -15 and +30 °C

Water or brine evaporator:

- Inlet water temperature
  - Water/water type heat pump: between +7 and +25 °C
  - Soil/water type heat pump: between -5 and +25 °C
- Difference in temperature of water or brine between the inlet and outlet of the evaporator: between 4 and 8 K

>> Reversible heat pumps and multipurpose machines

The requirements for chillers, as well as for heat pumps apply

> Restart interval

In the event of a total power supply interruption (compressor and control unit power supply), the device shall be fully operational within an interval defined below after the return of the mains voltage (according to the specifications in the article of the device itself):

- Standard variant: 10 minutes
- Data center variant: 2 minutes

The device shall be factory fitted with all the necessary devices in order to guarantee this interval

If the variant applied in the specifications is omitted, the standard variant applies

> Frost protection

if applicable

All the elements of the hydraulic circuit in the device shall be equipped with a protection against freezing of the system fluid in the event of negative temperatures down to -20 °C
The protection shall be carried out by means of electrical tracing fitted in the factory under thermal insulation

Execution:

> Access area
An access area for maintenance shall be provided
The width of the access area shall be at least equal to that prescribed by the device manufacturer
Overlap: it is accepted that the access area of a device overlaps the access area of an adjacent device without, however, overlapping the horizontal projection of this other device

> Water content
Before choosing a compressor technology, the contractor shall verify that the water content in the proposed installation is sufficient; if it turns out that the content is not sufficient for the proposed technology, the contractor shall include in his offer all the measures necessary to increase the water content (e.g. installation of a buffer tank)

Notes:
The meaning of the word water in this article and the following articles in this chapter may vary depending on the context and may mean either water or brine

Hydraulic modules

Work:
always included
selection
supply and installation
commissioning

Submittals:
always included
product data sheet

device selection note
workshop drawing

Specifications:

> Hydraulic module
Construction :

- Connections to the hydraulic circuit
- Filter
- Buffer tank (if applicable - see device article)
- Expansion tank
- Safety valve
- Purge valve
- Air vent
- Circulator pump
- Pressure gauge
- Thermometer (flow and return)
- Flow switch
- Frost protection (if specified in the device article)

All the elements of the hydraulic module shall be integrated into the chassis of the device which they supplement
The dimensions are not specifically indicated in the specifications; the dimensions of the device in which the module is integrated apply

01.01 Chillers

01.01.01 Chiller - air/water

Material:
Chiller
Hydraulic module

Specifications:

> General
Layout: indoor / outdoor
Corrosion environment according to EN ISO 9223: C_3

> Chiller

>> General
Type: water / water
Construction: monobloc
Operating mode: cooling
Configuration: 2 pipes (monovalent)
Restart interval variant: standard / data center
System fluid:
- Primary: water
- Secondary: water

Approximate dimensions:
- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Refrigerant: [optional]
Min. refrigerant circuits: [optional]
Min. compressors per circuit: [optional]

>> Performance at nominal service conditions
Nominal service conditions (cooling):
- Condenser (inlet / outlet): 25/30 ° C
- Evaporator (inlet / outlet): 15/10 ° C

Nominal useful cooling capacity: ___ kW
Max current (according to nameplate): ___ A
Max sound power : ___ dB(A)

>> Performance under test conditions
Test conditions (for EER_{test}):
- Condenser (inlet/outlet): 30/35 ° C
- Rvaporator (inlet/outlet): 12/7 ° C

EER_{test}: min. ___
SEER: min. ___

> Hydraulic module
Number of pumps: 1
Buffer tank: yes
Volume of the buffer tank: ___ L

01.01.02 Chiller - air/water

Material:
Chiller
Hydraulic module

Specifications:

> General
Layout: indoor / outdoor
Corrosion environment according to EN ISO 9223: C_3

> Chiller

>> General
Type: air/water
Construction: monobloc
Operating mode: cooling

Configuration: 2 pipes (monovalent)
Restart interval variant: standard / data center
System fluid: water
Approximate dimensions:
- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Frost protection: yes
Refrigerant: [optional]
Min. refrigerant circuits: [optional]
Min. compressors per circuit: [optional]
Coating on the air/refrigerant heat exchanger: yes

>> Performance at nominal service conditions
Nominal operating conditions (cooling):
- Condenser (inlet: dry bulb): 32 °C
- Evaporator (inlet/outlet): 15/10 °C

Nominal useful cooling capacity: ___ kW
Max current (according to nameplate): ___ A
Max sound power : ___ dB(A)

>> Performance under test conditions
Test conditions (for EER_{test}):
- Condenser (inlet: dry bulb): 35 ° C
- Evaporator (inlet/outlet): 12/7 ° C

EER_{test}: min. ___
SEER: min. ___

> Hydraulic module
Number of pumps: 1
Frost protection: yes

Buffer tank: yes
Volume of the buffer tank: ___ L

01.01.03 Chiller - air/water (with heat recuperation)

Material:
Chiller
Hydraulic module

Specifications:

> Heat recovery
The term heat recovery implies an additional double wall heat exchanger in the vapour compression cycle, upstream of the condenser and downstream of the compressor
The heat exchanger for heat recovery has connections for an additional hydraulic circuit; this circuit is hydraulically separated from the chilled water circuit coming from the evaporator
There are two possible versions of heat pumps with heat recovery which are distinguished by the type of outlet temperature control on the secondary side of the heat exchanger and the extent of heat recovery (total/partial recovery)

>> Partial heat recovery
The additional heat exchanger is dimensioned to be able to recover part of the rejected heat
The power of this exchanger and the outlet temperature are not controlled and vary according to The requested cooling capacity

>> Total heat recovery
The additional heat exchanger is sized to be able to recover the same power as the condenser
The regulation of the device keeps the outlet temperature on the secondary side of the exchanger constant by adapting the compressor power and the condensing pressure
The chilled water flow temperature is not the primary set point of the control loop if the heat recovery mode is active
The chilled water flow temperature is the primary set point of the control loop if the heat recovery mode is not active

> General

Layout: indoor/outdoor
Corrosion environment according to EN ISO 9223: C3

> Chiller

>> General
Type: air/water
Construction: monobloc
Operating mode: cooling and heat recuperation
Configuration: 4 pipes
Type of heat recuperation: partial
Restart interval variant: standard / data centre
System fluid:
- Cooling: propylene glycol 25%
- Heat recuperation: water

Approximate dimensions:
- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Frost protection: yes
Refrigerant: [optional]
Min. refrigerant circuits: [optional]
Min. compressors per circuit: [optional]
Coating on the air/refrigerant heat exchanger: yes

>> Performance at nominal service conditions
Nominal operating conditions (cooling):
- Condenser (inlet: dry bulb): 32 °C
- Evaporator (inlet/outlet): 15/10 °C

Nominal operating conditions (heat recuperation):
- Condenser (inlet/outlet): 50/45 °C

Nominal useful cooling capacity: ___ kW
Nominal recuperated heating capacity: ___ kW
Max current (according to nameplate): ___ A
Max sound power : ___ dB(A)

>> Performance under test conditions
Test conditions (for EER_{test}):
- condenser (inlet: dry bulb): 35 ° C
- evaporator (inlet / outlet): 12/7 ° C

EER_{test}: min. ___
SEER: min. ___

> Hydraulic module
Number of pumps: 1
Frost protection: yes
Buffer tank: yes
Volume of the buffer tank: ___ L

01.01.04 Chiller - air/water (with free cooling)

Material:
Chiller
Hydraulic module

Specifications:

> General
Layout: indoor/outdoor
Corrosion environment according to EN ISO 9223: C_3

> Chiller

> Free cooling

the air/water chiller is equipped with an additional heat exchanger cooled by outside air
the additional exchanger cools the system liquid when the dry bulb temperature of the outside air is lower than the return temperature of the cooled system liquid
free cooling is of the indirect type, that is to say that the system fluid never comes into contact with air
free cooling shall be activated automatically by chiller's control system if the gain in electrical power due to free cooling is greater than the additional energy consumption of fans and pumps
under conditions when free cooling alone is not able to provide 100% of the required cooling capacity, the free cooling and mechanical cooling modes with compressors shall be able to operate in parallel; free cooling always takes priority
at a sufficient temperature difference between the outside air and the system liquid (defined in the article of the appliance itself), the appliance shall be able to supply 100% of the required cooling capacity without compressor operation

>> General

Type: air/water
Construction: monobloc
Operating mode: cooling and/or free cooling
Configuration: 2 pipes (monovalent)
Type of heat recuperation: partial
Restart interval variant: standard / data centre
System fluid: propylene glycol 25%
Approximate dimensions:

- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Frost protection: yes
Refrigerant: [optional]
Min. refrigerant circuits: [optional]
Min. compressors per circuit: [optional]
Coating on the air/refrigerant heat exchanger: yes

>> Performance at nominal service conditions

Nominal operating conditions (cooling):

- Condenser (inlet: dry bulb): 32 °C
- Evaporator (inlet/outlet): 15/10 °C

Nominal useful cooling capacity: ___ kW

free cooling shall be capable of delivering 100% of the nominal cooling capacity under the following operating conditions:

- System return temperature (Tr): +15 ° C
- Dry bulb outside air temperature: Tr - 13 K

Max current (according to nameplate): ___ A

Max sound power : ___ dB(A)

>> Performance under test conditions

Test conditions (for EER_{test}):

- condenser (inlet: dry bulb): 35 ° C
- evaporator (inlet / outlet): 12/7 ° C

EER_{test}: min. ___

SEER: min. ___

> Hydraulic module

Number of pumps: 1

Frost protection: yes

Buffer tank: yes

Volume of the buffer tank: ___ L

01.02 Heat pumps (heating only)

01.02.01 Heat pump (heating only) - water/water or ground/water

Material:

Heat pump

Hydraulic module

Specifications:

> General
Layout: indoor
Corrosion environment according to EN ISO 9223: C3

> Heat pump

>> General
Type: water/water or ground/water
Construction: monobloc
Operating mode: heating
Configuration: 2 pipes (monovalent)
Application (heating flow temperature): standard/high temperature
System fluid:
- primary side: water/propylene glycol 25%
- secondary side: water

Approximate dimensions:
- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Refrigerant: [optional]
Min. refrigerant circuits: [optional]
Min. compressors per circuit: [optional]

>> Performance at nominal service conditions
Nominal operating conditions (heating):
- Condenser (inlet/outlet): 30/35 °C
- Evaporator (inlet/outlet): 10/5 °C [water/water] or 5/0 °C [ground/water]

Nominal useful heating capacity: ___ kW

Max current (according to nameplate): ___ A
Max sound power : ___ dB(A)

>> Performance under test conditions
Test conditions (for COP_{test}):
- condenser (inlet/outlet): 30/35 ° C
- evaporator (inlet/outlet): 10/7 ° C [water/water] or 0/-3 °C [ground/water]

COP_{test}: min. ___
SCOP (at 35/55 °C): min. ___

> Hydraulic module
Number of pumps: 1
Buffer tank: yes
Volume of the buffer tank: ___ L

01.02.02 Heat pump (heating only) - air/water

Material:
Heat pump
Hydraulic module

Specifications:

> General
Layout: indoor/outdoor
Corrosion environment according to EN ISO 9223: C_3

> Heat pump

>> General
Type: air/water

Construction: monobloc
Operating mode: heating
Configuration: 2 pipes (monovalent)
Application (heating flow temperature): standard/high temperature
System fluid: propylene glycol 25%
Approximate dimensions:

- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Frost protection: yes [if outdoor]
Refrigerant: [optional]
Min. refrigerant circuits: [optional]
Min. compressors per circuit: [optional]
Coating on the air/refrigerant heat exchanger: yes

>> Performance at nominal service conditions
Nominal operating conditions (heating):

- Condenser (inlet/outlet): 30/35 °C
- Evaporator (inlet: dry bulb): -10 °C

Nominal useful heating capacity: ___ kW
Max current (according to nameplate): ___ A
Max sound power : ___ dB(A)

>> Performance under test conditions
Test conditions (for COP_{test}):

- Condenser (outlet): 35 ° C
- Evaporator (inlet: dry bulb/wet bulb): 2/1 ° C

COP_{test}: min. ___
SCOP (at 35/55 °C): min. ___

> Hydraulic module

Number of pumps: 1
Frost protection: yes [if outdoor]
Buffer tank: yes
Volume of the buffer tank: ___ L

01.03 Heat pumps (reversible)

01.03.01 Heat pump (reversible) - water/water or ground/water

Material:
Heat pump
Hydraulic module

Specifications:

> Reversible water/water or ground/water heat pump
There are two possible versions of reversible heat pumps which are distinguished by the way in which the operating mode is reversed (cooling/heating)
The device operating mode is inverted either manually from the man-machine interface or remotely via the BMS interface

>> Water-side inversion
The evaporator and condenser function is not reversible
In heating mode, the control system maintains the desired flow temperature at the condenser outlet
In cooling mode, the control system maintains the desired flow temperature at the evaporator outlet
The control system is capable of controlling 4 external reversing valves which ensure the reversal on the water side; the control unit has the contacts and intelligence necessary to control at least 4 motorized reversing valves depending on the operating mode of the device

>> Refrigerant-side inversion
The evaporator and condenser function is reversible by means of a reversing valve in the vapour compression cycle circuit
In heating mode, the heat exchanger on the secondary side operates as a condenser and the heat exchanger on the primary side as an evaporator
In cooling mode the functions of the heat exchangers on the primary and secondary side are reversed
The control system always maintains the desired temperature setpoint on the secondary side

> General
Layout: indoor
Corrosion environment according to EN ISO 9223: C3

> Heat pump

>> General
Type: water/water or ground/water
Construction: monobloc
Operating mode: heating or cooling
Configuration: 2 pipes (reversible on the water/refrigerant side)
Application (heating flow temperature): standard/high temperature
System fluid:
- primary side: water/propylene glycol 25%
- secondary side: water

Approximate dimensions:
- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Refrigerant: [optional]
Min. refrigerant circuits: [optional]
Min. compressors per circuit: [optional]

>> Performance at nominal service conditions
Nominal operating conditions (heating):
- Condenser (inlet/outlet): 30/35 °C
- Evaporator (inlet/outlet): 10/5 °C [water/water] or 5/0 °C [ground/water]

Nominal operating conditions (cooling):
- Condenser (inlet/outlet): 20/25 °C
- Evaporator (inlet/outlet): 15/10 °C

Nominal useful heating capacity: ___ kW
Nominal useful cooling capacity: ___ kW
Max current (according to nameplate): ___ A
Max sound power : ___ dB(A)

>> Performance under test conditions
Test conditions (for COP_{test}):
- condenser (inlet/outlet): 30/35 ° C
- evaporator (inlet/outlet): 10/7 ° C [water/water] or 0/-3 °C [ground/water]

Test conditions (for EER_{test}):
- condenser (inlet/outlet): 30/35 ° C
- evaporator (inlet/outlet): 12/7 ° C

COP_{test}: min. ___
EER_{test}: min. ___
SCOP (at 35/55 °C): min. ___
SEER: min. ___

> Hydraulic module
Number of pumps: 1
Buffer tank: yes
Volume of the buffer tank: ___ L

01.03.02 Heat pump (reversible) - air/water

Material:
Heat pump
Hydraulic module

Specifications:

> Reversible air/water heat pump

The device operating mode is inverted either manually from the man-machine interface or remotely via the BMS interface
The evaporator and condenser function is reversible by means of a reversing valve in the vapor compression cycle circuit
In heating mode, the heat exchanger on the secondary side operates as a condenser and the heat exchanger on the primary side as an evaporator
In cooling mode the functions of the heat exchangers on the primary and secondary side are reversed
The control system always maintains the desired temperature setpoint on the secondary side (building side)

> General
Layout: indoor/outdoor
Corrosion environment according to EN ISO 9223: C_3

> Heat pump

>> General
Type: air/water
Construction: monobloc
Operating mode: heating
Configuration: 2 pipes (reversible on the refrigerant side)
Application (heating flow temperature): standard/high temperature
System fluid: propylene glycol 25%
Approximate dimensions:
- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Frost protection: yes [if outdoor]
Refrigerant: [optional]
Min. refrigerant circuits: [optional]
Min. compressors per circuit: [optional]
Coating on the air/refrigerant heat exchanger: yes

>> Performance at nominal service conditions
Nominal operating conditions (heating):

- Condenser (inlet/outlet): 30/35 °C
- Evaporator (inlet: dry bulb): -10 °C

Nominal operating conditions (cooling):

- Condenser (inlet: dry bulb): 32 °C
- Evaporator (inlet/outlet): 15/10 °C

Nominal useful heating capacity: ___ kW
Nominal useful cooling capacity: ___ kW
Max current (according to nameplate): ___ A
Max sound power : ___ dB(A)

>> Performance under test conditions

Test conditions (for COP_{test}):

- Condenser (outlet): 35 ° C
- Evaporator (inlet: dry bulb/wet bulb): 2/1 ° C

Test conditions (for EER_{test}):

- Condenser (inlet: dry bulb/wet bulb): 35 ° C
- Evaporator (inlet/outlet): 12/7 ° C

COP_{test}: min. ___
EER_{test}: min. ___
SCOP (at 35/55 °C): min. ___
SEER: min. ___

> Hydraulic module

Number of pumps: 1
Frost protection: yes [if outdoor]
Buffer tank: yes
Volume of the buffer tank: ___ L

01.04 Multifunctional units

Specifications:

> Multifunctional water/water or air/water unit
The primary side has 2 hydraulic connections for the primary hydraulic circuit ***[only applicable to water/water units]***
The secondary side has 4 hydraulic connections for two independent hydraulic circuits: 1x heating + 1x cooling
The reversal of the vapor compression cycle is performed automatically by the integrated control system according to the power requested from the secondary hydraulic circuits
The integrated control system maintains the desired flow temperature for each secondary hydraulic circuit simultaneously and independently
During simultaneous heating and cooling the heat rejected from one process is recovered internally by the other and vice versa; the deficit or surplus comes from the compressor and/or the primary side

01.04.01 Multifunctional unit - water/water

Material:
Heat pump
Hydraulic module

Specifications:

> General
Layout: indoor
Corrosion environment according to EN ISO 9223: C3

> Heat pump

>> General
Type: water/water
Construction: monobloc
Operating mode: heating and cooling
Configuration: 4 pipes (2x heating + 2x cooling)
Application (heating flow temperature): standard/high temperature
System fluid:

- primary side: water/propylene glycol 25%
- secondary side: water

Approximate dimensions:

- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Refrigerant: [optional]
Min. refrigerant circuits: [optional]
Min. compressors per circuit: [optional]

>> Performance at nominal service conditions

Nominal operating conditions (heating):

- Condenser (inlet/outlet): 30/35 °C
- Evaporator (inlet/outlet): 10/5 °C

Nominal operating conditions (cooling):

- Condenser (inlet/outlet): 25/30 °C
- Evaporator (inlet/outlet): 15/10 °C

Nominal useful heating capacity: ___ kW
Nominal useful cooling capacity: ___ kW
Max current (according to nameplate): ___ A
Max sound power : ___ dB(A)

>> Performance under test conditions

Test conditions (for COP_{test}):

- Condenser (inlet/outlet): 30/35 ° C
- Evaporator (inlet/outlet): 10/7 ° C

Test conditions (for EER_{test}):

- Condenser (inlet/outlet): 30/35 ° C
- Evaporator (inlet/outlet): 12/7 ° C

COP_{test}: min. ___
EER_{test}: min. ___

SCOP (at 35/55 °C): min. ___
SEER: min. ___

> Hydraulic module
Number of pumps: 1
Buffer tank: yes
Volume of the buffer tank: ___ L

01.04.02 Multifunctional unit - air/water

Material:
Heat pump
Hydraulic module

Specifications:

> General
Layout: outdoor
Corrosion environment according to EN ISO 9223: C3

> Heat pump

>> General
Type: air/water
Construction: monobloc
Operating mode: heating and cooling
Configuration: 4 pipes (2x heating + 2x cooling)
Application (heating flow temperature): standard/high temperature
System fluid:

- secondary side - heating: water/propylene glycol 25%
- secondary side - cooling: water/propylene glycol 25%

Approximate dimensions:
- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Frost protection: yes [if outdoor]
Refrigerant: [optional]
Min. refrigerant circuits: [optional]
Min. compressors per circuit: [optional]
Coating on the air/refrigerant heat exchanger: yes

>> Performance at nominal service conditions

Nominal operating conditions (heating):
- Condenser (inlet/outlet): 30/35 °C
- Evaporator (inlet: dry bulb): -10 °C

Nominal operating conditions (cooling):
- Condenser (inlet: dry bulb): 32 °C
- Evaporator (inlet/outlet): 15/10 °C

Nominal useful heating capacity: ___ kW
Nominal useful cooling capacity: ___ kW
Max current (according to nameplate): ___ A
Max sound power : ___ dB(A)

>> Performance under test conditions

Test conditions (for COP_{test}):
- Condenser (outlet): 35 ° C
- Evaporator (inlet: dry bulb/wet bulb): 2/1 ° C

Test conditions (for EER_{test}):
- Condenser (inlet: dry bulb): 35 ° C
- Evaporator (inlet/outlet): 12/7 ° C

COP_{test}: min. ___
EER_{test}: min. ___

SCOP (at 35/55 °C): min. ___
SEER: min. ___

> Hydraulic module
Number of pumps: 1
Frost protection: yes
Buffer tank: yes
Volume of the buffer tank: ___ L

02 Dry coolers

02.01 Dry cooler - table model

Work:
Selection
Supply and installation
Commissioning

Submittals:
Product data sheet
Unit selection sheet
Vibration dampers selection sheet
Shop drawing

Specifications:

> Submittals
The calculation of performance in the actual operating state shall be determined using calculation software certified by Eurovent or an equivalent certification body

> General
Devices shall be fully assembled and tested at the factory
All the components of a device shall be designed and produced so that they resist the corrosion classes according to EN ISO 9223 specified below in these specifications
If a coating shall be provided on the heat exchangers to meet the requirements for protection against corrosion, the selection of components shall take into account the additional heat transfer resistance

> Electric drive motor
The motor is of the permanent magnet type
Min. protection index : IP 54

Efficiency class min. : IE4 according to EN 60034-30-1
A temperature sensor is placed in the motor windings
The motor is equipped with a device for limiting the starting current; during startup, the device always operates at the lowest power level
Continuous speed regulation of motors is compulsory
Variable speed drives shall be of the electronic frequency converter type (possibly as part of a permanent magnet motor)
Drives that are not part of the motor shall be installed in the control panel of the device

> Fans

The following constructions are authorized:

- Centrifugal type with backward curved blades
- Axial type

The impeller is mounted directly on the motor shaft
Any contact between different metals shall be avoided
Impellers are mounted on self-aligning bearings and greased for life
Bearings shall be dimensioned for a minimum service life (L10 according to ISO 281-1) of 40,000 hours of operation at maximum speed
The fan motor unit shall be statically and dynamically balanced in accordance with ISO 14694 and ISO 1940-1, class G: 2.5
The impeller and the blades are made of:

- Aluminum
- Fiber reinforced material

Reaction to fire class of plastics: min. B-s1,do

> Air cooled heat exchanger

Compliance: EN 14276
The following constructions are authorized:

- Fin-and-tube: copper tubes, aluminum fins
- Micro-channels: entirely in aluminum

The air flow through the exchanger is ensured by one or more fans which are part of the device itself
Coating (only applicable if specified in the article of the specified device itself): the surface of the heat exchangers shall also be protected by a coating system in accordance with EN ISO 12944-5 (durability class H: more than 15 years) although the uncoated material may already meet the required corrosion environment class
The corrosion environment class is defined below in the item of the specified device itself

The heat exchanger shall be able to be drained

> Frame

>> General

All components are mounted on a solid frame made of steel profiles or on a self-supporting construction in which the different elements are fixed to each other

>> Anti-vibration measures

Devices with rotating elements shall always be installed on a raised base:

- Either on a concrete base with a minimum thickness of 8 cm, the edge of which is protected by an angle profile 50 x 50 x 5 mm
- Either on a metallic structure in stainless steel (min. EN 1.4301)

Anti-vibration elements shall be placed between the base and the device; their characteristics shall meet the acoustic requirements

>> Noise reduction

When the acoustic conditions require it, the device shall be fitted with a soundproof box
The box is either made of removable metal panels, coated inside with sound absorption material or is double-walled
All control and signaling devices shall remain visible and freely accessible
The non-combustible sound absorption material in the box, in the noise attenuators and in the screens (class A2 according to EN 13501-1) shall be durable, rot-proof and vermin-resistant; it is also provided with the necessary means of protection to prevent it from eroding and becoming wet in the event of rain
The panels shall be removable while the hydraulic and electrical connections are operational

> Control panel

Compliance: EN 61439 (series)
The panel is completely wired, connected to the compressor and its accessories and tested in the manufacturer's factory
Components:

- A switch-disconnector with padlock acting as an emergency stop
- Short circuit protection
- Overload protection

> Controls

The device is equipped with microprocessor control unit

The control unit is installed in the control panel of the device
Each device shall be fitted with a potential-free contact, which, by means of an external signal, can prevent the device from operating
In the case of several devices connected in parallel, the control system shall be able to operate in cascade; the regulation of at least one device shall be configured as master, or the contractor shall provide an additional master regulator
A dip in the mains voltage causes an ordered shutdown of the device and, when the mains voltage returns, an automatic start-up

Components:

- Electronic control unit
- Fluid temperature sensor (outlet/return)

Functions:

- Fan speed regulation as a function of the measured outlet temperature
- Control of operating parameters
- Alarm signaling

> BMS interface

The control unit is provided by default with a BACnet (IP or SC) or Modbus interface

> Nameplate

The device is equipped with a nameplate in durable material and whose inscriptions are indelible
The plate is securely spun in an easily accessible and visible place
It bears at least the following indications:

- Name of manufacturer
- Model and serial number
- Year of manufacture
- Type and quantity of refrigerant
- Thermal capacity for nominal conditions
- Temperatures at nominal conditions
- Nominal voltage
- Maximum current

> Performance criteria

Corrosion environment according to EN ISO 9223: C3
System fluid: propylene glycol 25%
Min. number of heat exchangers (coils): [optional]
Min. number of circuits: [optional]
Approximate dimensions:

- Length: ___ mm
- Width: ___ mm
- Height: ___ mm

Nominal operating conditions:

- Outdoor air (inlet/outlet): 35 °C
- System fluid (inlet/outlet): 45/40 °C

Nominal useful heat exchange capacity: ___ kW
Max current (according to nameplate): ___ A
Max sound power : ___ dB(A)

Execution:

> Access area
An access area for maintenance shall be provided
The width of the access area shall be at least equal to that prescribed by the device manufacturer
Overlap: it is accepted that the access area of a device overlaps the access area of an adjacent device without, however, overlapping the horizontal projection of this other device

> Hydraulic connections
The hydraulic connections are made:

- Either by means of Victaulic couplings
- Either by means of flange connections
- Either by means of 3-piece threaded fittings (up to DN 40 max.)

03 Ground (geothermal) heat exchangers

Specifications:
The pressure drop between the vertical geothermal heat exchanger and the collector shall not exceed 0.2 bar

Execution:
The connections between the vertical geothermal heat exchangers and the collector shall be made by means of PE pipes having the same characteristics as the pipes in the exchangers
All flow and return piping from vertical geothermal heat exchangers will be collected in 2 collector chambers where they will be connected to the collector
The pipes are installed with the slope towards the collector

03.01 U-tube heat exchangers

03.01.01 U-tube heat exchanger

Note:
The depth of a vertical geothermal heat exchanger is defined as the distance between the foot and the head of the probe; this only takes into account the part of the probe which is in contact with the grout

Material:
Geothermal probes
Grout
Spacers

Work:
Realization of vertical boreholes
Installation of piping
Pressure test with report
Rinsing
Grout injection
Disposal of drill cuttings

Removal of the surface finishing layer

Submittals:
Before execution:
- Technical data sheet: see specifications
- Certificate of the filling material used (grout)

After execution:
- Tightness and resistance test report
- Flow test report
- Drilling report

Specifications:

> General
Compliance: EN ISO 17628 chapter 5
Type: single/double vertical U-loop (2/4 vertical pipes per probe)
Space between boreholes: see plans
Configuration (layout): see plans
Hydraulic connection of vertical geothermal heat exchangers on collectors:
- EITHER all vertical geothermal heat exchangers are connected in parallel on the collector
- EITHER (up to) X vertical exchangers in a group are connected in series with each other; the groups are connected in parallel on the collector
- EITHER according to plans/schematics

> Boreholes
Borehole diameter: 130 mm
Borehole depth: depending on quantity
Number of boreholes: according to quantity
Drilling technique to be used:
- EITHER hydraulic drilling
- EITHER downhole hammer drilling
- EITHER to be defined by the contractor according to the geological profile

Sampling:
- EITHER required
- EITHER if required by the local regulations

> Geothermal probes
@ Data sheet

[Option: PN16 standard pipes]
>> Pipes
Concerns: the vertical piping of the exchanger (probes)
Conformity :
- Pipes in general: EN 12201-2
- PE100-RC pipes: NBN T 42-116 or equivalent

Material: PE100-RC
Dimensions: d32 x 2.9 mm (SDR11)
Service pressure: 16 bar (safety factor 1.25)
Service temperature: -20 to +40 ° C
Lifespan: 50 years

[Option: PN35 high pressure pipes]
>> Pipes
Concerns: the vertical piping of the exchanger (probes)
Conformity :
- pipes in general: NBN EN 12201-2
- PE100-RC pipes: NBN T 42-116 or equivalent

Material and construction (interior to exterior):
- PE100-RC layer
- Metal layer
- PE100-RC layer

Dimensions: d42 x 3.5 mm
Service pressure: 16 bar (safety factor 1.25)

Service temperature: -20 to +40 ° C
Lifespan: 50 years

>> Foot
The pipes are factory-welded to the foot
Designed to be able to support ballasting
Provided with a dirt retention volume

>> Ballast
Material: structural steel S235JR / S355J or equivalent
Weight: to be defined by the contractor

> Grout
@ Data sheet
Type: frost resistant cement grout
Thermal conductivity: min. 2.0 W/(mK)
Permeability: max. 10E-09 m/s

Execution:

> General
Compliance: EN ISO 17628 chapter 5
The contractor is himself responsible for the supply of water and energy necessary to be able to carry out the work
A water connection is available at the construction site

> Realization of vertical wells
The underground conditions are considered to be known by the contractor and cannot give rise to any additional cost
Drilling work may not start before the delivery of vertical heat exchanger piping to the site, because the piping shall be installed no later than 24 hours after drilling
Throughout the execution of the work, the contractor shall provide protection to avoid damaging the boreholes and preventing the intrusion of foreign matter

The driller shall take all the necessary precautions to prevent contamination of the groundwater by runoff, unwanted water from another groundwater layer, gasoline or other contaminant
The driller shall take all the necessary precautions to channel the water extracted from the boreholes in order to prevent the blocking of sumps and sewers, or the contamination of water bodies; it shall create a temporary settling tank from which surface water is pumped
A continuous protection of the location of boreholes shall be ensured so as to prevent future activities from affecting the performance of the well, both quantitatively and qualitatively
The contractor shall ensure the verticality of the drilling over its entire depth: the borehole shall be sufficiently straight and vertical (89.5° to 90.5°) so as not to interfere with the installation of the probe and future filling
The contractor shall seal the head of boreholes with a tight flanged cover fitted with a gasket

> Installation of piping
During storage, pipes and accessories may not be exposed to direct solar radiation
The ends of the pipes shall be sealed with a plug until the moment of installation
Apart from the pipe joints at the bottom and top of the vertical probes, no joints are allowed

> Pressure test
The pressure test of the vertical heat exchanger probes shall be carried out before the installation into the boreholes
Each vertical probe shall be tested separately
The piping shall be filled with water, tested under pressure to check its integrity and tightness, then sealed

> Grout injection
Sufficient storage capacity shall be provided to minimize or avoid injection in sequences

03.02 Manifold chambers

03.02.01 Prefabricated PE manifold chamber

Material:
Prefabricated manifold chambers

Work:

Supply and installation

Submittals:
Technical data sheet: see specifications

Specifications:

> Prefabricated manifold chamber

>> General
@ Data sheet
The manifold chamber is made up of a PE housing, manifolds and connection fittings on the outside of the chamber, ready to be connected to the distribution circuits to the vertical geothermal heat exchangers and the building
The casing of the manifold chamber as well as the connections passing through its wall are made in a completely waterproof manner
Outside the manifold chamber, a sufficient length of pipe is provided per connection to make the connection to the distribution pipes by means of electrofusion sleeves
The chamber is fully equipped at the factory with all necessary regulating and shut-off valves
Manifolds are installed and pressure tested, including external connections for piping
The chamber is equipped with a manhole with waterproof cover
An access ladder shall be provided if the depth exceeds 0.80 m
The exact position of the fitting outlet for the piping shall be defined by the contractor
The manifold chamber is large enough to be accessible for maintenance of the manifold elements (min. 0.6 x 0.8 m)
Max. working pressure : 6 bar
Operating temperature: -20 to +50 °C
Number of connections per manifold: specify

>> Housing
Material and construction:
- Housing: PE-HD
- Cover: round, d600 mm, in PE-HD

Cover class according to EN 124: A15 (1500 kg)

>> Manifolds
Material and construction:
- 1 stop valve per supply connection
- 1 stop and balancing valve per return connection
- 1 pressure gauge per manifold
- 1 drain valve per manifold
- 1 stop valve per manifold
- 1 purge and rinse valve per manifold

Spacing between connections: min. 130 mm

Execution:
The manifold chamber shall represent the highest point of the geothermal installation (at least with regard to the part outside the building)
The manifold chamber is installed so that it does not rise in the event of a rise in the water table
The level of the cover shall be at the same level as the ground level
The installation shall be carried out according to the manufacturer's instructions
The chamber shall be installed on solid and flat ground

03.03 Thermal response tests (TRT)

03.03.01 Conventional thermal response test (TRT)

Work:
Thermal response test (TRT)

Submittals:
After execution:
- Test report

Specifications:

> Test report
Compliance: EN ISO 17628
Measurement data shall also be transferred electronically in CSV or Excel format

Execution:

> Thermal response test (TRT)
Compliance: EN ISO 17628
The test will be carried out on a vertical geothermal heat exchanger already carried out on the site (depth ___ m)
Result: the test shall lead to the determination of the following properties:

- Average thermal conductivity of the soil (W/(mK))
- Thermal resistance of the average borehole ((mK)/W)
- Average undisturbed soil temperature (°C)

The average volumetric thermal capacity of the soil necessary for the determination of the drilling resistance shall be estimated by the driller according to the soil samples that will be taken during the drilling

03.03.02 Distributed thermal response test (DTRT)

Work:
Thermal response test (TRT)

Submittals:
After execution:

- Test report

Specifications:

> Test report
Compliance: EN ISO 17628
Measurement data shall also be transferred electronically in CSV or Excel format

Execution:

> Distributed thermal response test (DTRT)

Compliance: the test installation is based in principle on that described in EN ISO 17628; however, the temperature shall be measured across the entire depth of the vertical heat exchanger by means of a distributed temperature sensor comprising an optical cable and a central measurement and data processing unit

Result: the test shall lead to the determination of the following properties:

- The vertical profile of the thermal conductivity of the ground (W/(mK)) for each vertical meter of the geothermal heat exchanger (resolution min. 1 m)
- The average thermal resistance of the borehole ((mK)/W)
- Vertical profile of undisturbed soil temperature (°C)

The average volumetric thermal capacity of the soil necessary for the determination of the drilling resistance shall be estimated by the driller according to the soil samples that were taken during the drilling

The test will be carried out on a vertical geothermal heat exchanger already carried out on the site (depth ___ m)

The theoretical context of the test is described in the following scientific article (see section 2.1 - Distributed thermal response test (DTRT)): Wilke S., et al. Advanced thermal response tests: A review. Renewable and Sustainable Energy Reviews 119, 2020. https://doi.org/10.1016/j.rser.2019.109575

Any approach described in the abovementioned article can be used provided the test yields the required properties

04 Plate heat exchangers

04.01 Brazed plate heat exchangers

Material:

Brazed plate heat exchanger
Removable insulating shell
Base support

Work:

Supply and installation

Submittals:

Technical data sheets: see specifications
Selection note

Specifications:

> *Brazed plate heat exchanger*
@ Data sheet
Type: counter-current, single pass, single/double-wall
Material :
- Plates: stainless steel EN 1.4401
- Brazing: copper

Service pressure: min. 16 bar
Service temperature : min. -10 °C to + 95 °C
Transfer capacity reserve: min. 10%
Heat transfer capacity: ___ kW
Warm side:
- Fluid: water/glycol __%
- Temperature (inlet / outlet): __/__ °C
- Maximum pressure drop: 0.2 bar

Cold side:
- Fluid: water/glycol __%
- Temperature (inlet/outlet): __/__ °C
- Maximum pressure drop: 0.2 bar

> *Base support*
Material: powder-coated galvanized steel sheet

04.02 Gasketed plate heat exchanger

Material:
Gasketed plate heat exchanger
Removable insulating shell
Floor mounting feet

Work:
Supply and installation

Submittals:
Technical data sheets: see specifications
Selection note

Specifications:

> Gasketed plate heat exchanger
@ Data sheet
Type: counter-current, single pass, single/double-wall
Material :
- Plates: stainless steel EN 1.4401
- Frame: powder-coated galvanized steel sheet

Service pressure: min. 16 bar
Service temperature : min. -10 °C to + 95 °C
Transfer capacity reserve: min. 10%
Heat transfer capacity: ___ kW
Warm side:
- Fluid: water/glycol __%
- Temperature (inlet / outlet): __/__ °C
- Maximum pressure drop: 0.2 bar

Cold side:
- Fluid: water/glycol __%
- Temperature (inlet/outlet): __/__ °C
- Maximum pressure drop: 0.2 bar

> Floor mounting feet
Material: powder-coated galvanized steel sheet

05 Thermally activated building structures (TABS)

05.01 TABS pipes and modules

Specifications:

> General

A heating and/or cooling system by means of pipes installed in the core of concrete slabs in accordance with EN ISO 11855
All system elements shall come from a single manufacturer

> Sizing

The sizing of the system is carried out by the contractor according to the material offered
The sizing shall comply with EN ISO 11855-4
The following criteria apply:

- Max pressure drop of a circuit: 20 kPa
- Max speed in pipes: 0.5 m/s
- Flow temperatures:
  - Heating: ___ °C
  - Cooling: ___ °C

> Guarantee certificate

Concerns: execution and material
Duration: 10 years from provisional acceptance
The warranty certificate shall include a written declaration from the manufacturer or his representative in which he declares that the installation has been carried out entirely in accordance with the installation instructions and the rules of good practice

Execution:

Before execution, submit calculations and construction drawings with:

- Indication of pipe diameter and spacing
- Pipe layout in view
- Total length per area

- Flow rate, temperature differential and pressure drop per circuit

The execution shall comply with the manufacturer's installation instructions and EN ISO 11855-5
Pipes are installed in the concrete slab at regular distances
Pouring of the slab can only take place after the successful completion of the pressure test
During the pouring and drying of the slab pipes shall be permanently under a pressure of 2 bar
At the crossings of the expansion joints and the connections to the manifolds, pipes shall be protected by protection hoses
The contractor is advised to carry out the pressure test and keep the pipes under pressure during and after the pouring of the tiles with compressed air instead of water in order to avoid possible damage caused by frozen water at negative outside temperatures

05.01.01 In situ installed pipes

Material:
Multilayer PE pipes
Fastening material
Protection hoses (expansion joints traversal)
Ceiling lead-through elements

Work:
Supply and installation
Pressure test with report
Rinsing
Photographing of pipe layout traces

Submittals:
Before execution:

- Technical data sheets: see specifications

After execution:

- Warranty certificate
- Leak test report
- Pictures

Specifications:

> *Multilayer PE pipes*
@ Data sheet
Compliance: EN ISO 21003-2
Material and construction (interior to exterior):
- PE-X layer
- Aluminum layer, min. 0.2mm or EVOH membrane
- PE-X layer

Application class (temperature): class 4 according to EN ISO 21003-2
Oxygen diffusion class: min. class 4 according to EN ISO 15875
Service pressure: 10 bar
Pipe diameter: ___ mm

[To be included if applicable]
> *Wire mesh*
@ Data sheet
Construction :
- Steel wire mesh
- Plastic pipe fixing clips

Steel wire: zinc galvanized
Possible installation spacing: 5 to 35 cm
Steel wire thickness: min. 3 mm

05.01.02 Prefabricated TABS pipe modules

Material:
Prefabricated TABS pipe modules
Fastening material
Protection hoses (expansion joints traversal)
Ceiling lead-through elements

Work:
Supply and installation
Pressure test with report
Rinsing
Photographing of pipe layout traces

Submittals:
Before execution:
- Technical data sheets: see specifications

After execution:
- Warranty certificate
- Leak test report
- Pictures

Specifications:

> Prefabricated TABS pipe modules
@ Data sheet

>> Multilayer PE pipes
Compliance: EN ISO 21003-2
Material and construction (interior to exterior):
- PE-X layer
- Aluminum layer, min. 0.2mm or EVOH membrane
- PE-X layer

Application class (temperature): class 4 according to EN ISO 21003-2
Oxygen diffusion class: min. class 4 according to EN ISO 15875
Service pressure: 10 bar
Pipe diameter: ___ mm

>> *Wire mesh*

@ Data sheet

Construction :

- Steel wire mesh
- Plastic pipe fixing clips

Steel wire: zinc galvanized

Possible installation spacing: 5 to 35 cm

Steel wire thickness: min. 3 mm

>> *Fittings*

Compliance: EN ISO 21003-3

Material: synthetic material or metal

Equipped with a bad press control system

05.02 TABS manifolds

05.02.01 TABS manifold

Material:

Always included in a set of manifolds:

- Supply and return manifold
- Couple of wall supports with fixing material
- Two ball valves at the head of the manifolds
- Manifold cabinet

Work:

Supply and installation

Circuit balancing

Submittals:

Before execution:

- Technical data sheet: see specifications

After execution:

- Balancing report

Specifications:

> General

@ Data sheet
Max. service pressure : 10 bar
Service temperature: +5 to +95 °C

> Supply and return manifold

Authorized materials: brass, bronze, stainless steel
Number of connections per manifold: 2 to 12
Diameter:

- manifold: 1"
- connections: 3/4"

Connection spacing: 50 mm
Every connection of the supply manifold is equipped with a flow meter and a balancing valve
Every connection of the return manifold is equipped with shut-off valve that can be fitted with an electro-thermic actuator
A connector for connecting plastic pipes (PE-X or multilayer) per connection
A supply and drain valve per manifold
A manual lockable air vent per manifold
Marking to distinguish the supply and return manifold
Number of connections per collector: to be defined

> Wall supports with fixing material

Material: galvanized sheet steel
For mounting on the wall or in a cabinet
Noise isolation: according to DIN 4109 or equivalent

> Ball valves

Compliance: EN 13828

Material and construction:

- Brass or bronze body
- Brass or chrome-plated bronze ball
- O-ring in EPDM or FKM
- PTFE ball seals

Noise (EN ISO 3822): group I

> Manifold cabinet

Material: sheet steel, powder coated, min. 1.5mm

White color

With door and cylinder lock

Execution: recessed / surface-mounted [choose]

Dimensions: to be defined

Execution:

> Connections

The connections to manifolds of the distribution piping shall always be installed in the direction of the piping layout

Each circuit is connected to its own manifold connection

> Balancing report

The contractor shall carry out a detailed calculation of pressure losses in the network; this calculation shall lead to a value of the differential pressure available at nominal service conditions at the point of the system where the manifold is installed

The calculation shall be made for each manifold individually

The contractor shall determine for each branch the setting of the balancing valve; he shall take into account the available differential pressure, the desired flow and the diameter and length of the pipes

Important: if the contractor chooses manifolds with pressure independent balancing valves, the detailed calculation does not have to be performed; in this case it is sufficient to determine the adjustment position of the valve of each connection according to the required flow using the diagram available in the installation instructions of the balancing valve

06 Fan coils

Specification:

> General

Compliance: EN 16430 part 1 to 3
All fan coil units of one type shall come from the same manufacturer; all components are factory compatible
Operating pressure of all system components: min. 10 bar
All fan coil units are designed for a two-pipe system

> Heating and cooling capacity

Compliance: EN 1397
The calorific values indicated in the tender documents correspond to the power supplied at the project design conditions
The equipment proposed by the contractor shall be capable of supplying the required heat capacity (cooling and/or heating) at the middle fan speed (max. 6 V in the case of EC motors)

> Dimensions

The contractor shall check in advance the possibility of installation on site and take into account any changes to the tender documents
Unless explicitly stated otherwise, the lengths indicated in the project are indicative; however, the accepted deviations are limited to the following values provided that all the relevant rules of good practice are observed:

- Length or width:
  - Up to and including 1000 mm: 5%
  - From 1000 mm: 10%
- Depth or height: 5%

As regards larger deviations, the contracting authority reserves the right to refuse them without justification
In any case, the installation of the devices is not authorized without prior approval of the dimensions by the contracting authority
The contractor shall submit to the contracting authority a complete list of fan coil units; this list shall include at least the following information (per device):

- Room number
- Room name
- Heat loss and/or gain
- Fan coil dimensions according to the tender documents

- Fan coil power according to the tender documents
- Fan coil dimensions according to the construction documents
- Fan coil power according to the construction documents
- Difference in dimensions between tender and construction (yes, no)

> Fan coil units

>> Fin and tube heat exchangers
Material: copper tubes and aluminum fins
Test pressure: min. 25 bar
Screw connections

>> Motors
Type: only EC type motors (single-phase synchronous motor with permanent magnets) with ball bearings are authorized
Speed regulation: continuous via an external 0 to 10 V signal
Insulation class min.: class B (130 to 155 °C)
Efficiency: min. IE4 according to EN 60034-30-1
In case of motor failure (e.g. overheating), the fan will stop automatically

Execution:

> Supply
Fan coil units for surface installation are supplied in a wear-resistant package (one per device); they are kept in this packaging until provisional acceptance; they shall be intact at this time
The replacement of damaged units is carried out at the expense of the contractor after contradictory expertise

> Installation
The installation of units shall always be coordinated with the equipment other trades; the coordination shall be performed on plans; these plans shall be submitted to the contracting authority for approval
After installation, the fastening of the unit shall no longer be visible
Units suspended from ceiling are fitted with at least 4 suspension points

All costs relating to the supply and installation of units, fasteners, supports, etc. shall be included in the unit price of the device
A modification of the location of devices in relation to the location indicated on the plans within a radius of 2 meters, due to the proximity of obstacles (e.g. lights), cannot give rise to an additional cost
Each possible gap shall be completely masked by the grill of the unit or the finish of the wall, floor or ceiling

> Connection pipes
The connection of devices by means of flexible EPDM (or equivalent) hoses reinforced with stainless steel braid is prohibited
The price for the connecting pipes shall be included in the price of the piping

> Fittings (wall units without feet)
The connection shall always be made from the wall; there shall be no visible pipe parts

> Visible fixing parts
The exposed fasteners shall be painted in the same color and quality (as regards heat resistance, color quality and degree of finish) as the painting of the fan coil unit

> Installation openings
Before installation, all the necessary information shall be collected by the contractor in order to cut openings in the wall, floor and ceiling structures, or to modify them, in order to obtain a system in working order
The contractor takes into account in his price offer the making of openings for the installation of units

06.01 Fan coil unit for concealed installation

Material:
Fan coil
Installation material

Work:
Supply and installation

Documents:

Technical data sheet: see specifications

Specifications:

> Fan coil

@ Data sheet

Description: fan coil without casing for concealed installation in construction voids

Material and construction:

- Mounting frame made of galvanized sheet steel, insulated against surface condensation
- Fin and tube tubular heat exchanger
- Air purge and drain valve per heat exchanger
- Centrifugal or tangential fans
- Condensate tray in rust resistant material
- Removable and washable filter

Electrical connection: 1 x 230 V, 50 Hz

Max. working pressure: 10 bar

Max. installation depth: ___ mm

No. of heat exchangers: ___

BMS interface:

- 1x AI: fan speed

Performance - heating:

- Water temperature regime (flow/return): ___ °C
- Room temperature: ___ °C
- Sensible heating capacity: ___ W

Performance - cooling:

- water temperature regime (flow/return): ___ °C
- room temperature: ___ °C
- relative humidity: ___%
- Total cooling capacity: ___ W
- Sensible cooling capacity: ___ W

06.02 Fan coil unit with metal casing for exposed installation

Material:
Fan coil
Installation material

Work:
Supply and installation

Documents:
Technical data sheet: see specifications

Specifications:

> Fan coil
@ Data sheet
Description: fan coil with metal casing for exposed installation
Material and construction:

- Rectangular shaped casing composed of:
  - Flat finishing panel on the front side
  - Closed flat finish panels on the lateral sides
  - A fitting aluminum grille on top
  - Panels and grille forming a whole with the fan coil
  - Entirely powder coated in the same color
  - Folded galvanized sheet steel panels, min. 1.25mm
- Mounting frame made of galvanized sheet steel
- Fin and tube heat exchanger
- Air purge and drain valve per heat exchanger
- Centrifugal or tangential fans
- Condensate tray in rust resistant material
- Removable and washable filter

- Concealed wall connections
- Integrated electronic control thermostat

Paint (casing): primer paint + powder coating finish
Color: RAL 9010 of RAL 9016 (white)
Finish: satin look, finely structured
Electrical connection: 1 x 230 V, 50 Hz
Max. working pressure: 10 bar
Max. installation depth: ___ mm
No. of heat exchangers: ___
BMS interface:

- 1x AI: fan speed

Performance - heating:

- Water temperature regime (flow/return): ___ °C
- Room temperature: ___ °C
- Sensible heating capacity: ___ W

Performance - cooling:

- water temperature regime (flow/return): ___ °C
- room temperature: ___ °C
- relative humidity: ___%
- Total cooling capacity: ___ W
- Sensible cooling capacity: ___ W

06.03 Fan-assisted radiator for exposed installation

Material:
Fan-assisted radiator
Installation material

Work:
Supply and installation

Documents:
Technical data sheet: see specifications

Specifications:

> Fan-assisted radiator
@ Data sheet
Description: hybrid radiator with forced convection by means of axial fans for horizontal wall installation (vertical air supply)
Compliance: EN 442-1
Material and construction:

- Water conducting panels with concealed convection fins
- Battery of axial fans in horizontal plane above the convection fins
- Fans are installed on a bogie and can be pulled-out laterally for maintenance after removing a side panel
- Flat cover plate on the front side
- Fully welded construction, with no visible welds
- Without convection fins on the outside
- Flat closed finish panels on the lateral sides
- A fitting grille on top
- panels and grid forming a whole with the radiator
- Fully powder coated in the same color
- Integrated electronic control thermostat
- Motorized control valve with preset kv value

Hydraulic connections: 2x at the base of the radiator, centered
Paint: primer paint + powder coat finish
Color: RAL 9010 of RAL 9016 (white)
Electrical connection: 1 x 230 V, 50 Hz
Max. working pressure : 10 bar
Value of exponent n (at maximum speed): min 1.1
Performance - heating:

- Water temperature regime (flow/return): ___ °C
- Room temperature: ___ °C

- Sensible heating capacity: ___ W

Performance - cooling:

- water temperature regime (flow/return): ___ °C
- room temperature: ___ °C
- Sensible cooling capacity: ___ W

07 Electronic variable air volume (VAV) controllers

07.01 Round/rectangular electronic VAV controller

Material:
Round/rectangular electronic VAV controller
Round/rectangular noise attenuator

Work:
Supply and installation
Flow adjustment at the control unit
Setting of the actual site altitude

Submittals:
Technical data sheet: according to specifications
Selection note

Specifications:

> Electronic VAV controller
@ Data sheet

>> Casing with flow rate sensor and control damper
Material :

- Casing: galvanized sheet steel
- Damper: galvanized sheet steel or aluminum
- Differential pressure sensor: aluminum
- Insulation: min. 50 mm mineral wool, reaction to fire: min. A2(L) -s1; do

Measuring range: 1.0 to 6.0 m/s
Max pressure drop at design flow (with open damper): 10 Pa
Dynamic control range (minimum/design flow rate): min. 1/3

Casing air leakage according to EN 1751:
- Rectangular casing: class B
- Round casing: class C

Blade air leakage according to EN 1751:
- Rectangular casing: class 3
- Round casing:
  - Class 2: d80 to 100 mm
  - Class 3: d125 to 160 mm
  - Class 4: d200 and above

Maximum straight duct length required:
- Upstream: 3 x equivalent diameter
- Downstream: 1.5 x equivalent diameter

Measurement accuracy:
- Min. 20% at minimum adjustable flow
- Min. 10% at maximum adjustable flow

Operating temperature: +10 to +50 ° C
Adjustment of the flow rate setpoint on the outside of the casing
Adjustment remains accessible from the outer side of the casing after mounting and insulation (up to 50 mm of insulation thickness)
Connection to ducts:
- Rectangular ducts according to EN 1505: with flanges
- Round ducts according to EN 1506: with EPDM gasket

Meets hygienic requirements according to VDI 6022 or equivalent
Factory tested
Independent of mounting position
Maintenance free
Max. differential operating pressure : 500 Pa

>> Control unit with servomotor
@ Data sheet
Control and diagnostic functions:
- Choice between constant or variable flow regulation

- Min. and max. flow rate setting
- Display of actual flow rate
- Command: damper closed/open position
- Command: damper at max./min. position

Operating principle:

- Flow measurement: via differential pressure or ultrasonic sensor
- Constant flow rate control regardless of pressure variations in the duct

Aluminum casing
Connection cable 1 m
Mechanical position display
Manual control possible
Conditions of service:

- Temperature: 5 to +40 ° C
- Relative humidity: 10 to 90% (non-condensing)

Maintenance free
Supply voltage: 24 V AC/DC
Protection index: min. IP54
Protection class: III
Running time: max. 300 s
BMS interface:

- Control signal: 0/2-10 V (adjustable: flow rate, damper position, pressure differential)
- Return signal: 0/2-10 V (adjustable: flow rate, damper position, pressure difference)

> Sound attenuator

>> General
@ Data sheet
Absorption material:

- Material: mineral wool
- Reaction to fire: min. A2 (L) -s1; d0

Attenuation at 6.0 m/s (Lw): min. 10 dB (A) at 250 Hz

Insulation thickness: 50 mm
Casing air leakage according to EN 1751: min. class B
Max. working pressure: 600 Pa

>> For connection to round units
Casing and perforated inner sheath: galvanized sheet steel
Connection to ducts: according to EN 1506 with gasket

> For connection to rectangular units
Type: with splitters
Casing and splitter frame: galvanized sheet steel
Connection to ducts: according to EN 1505 with flanges

Execution:
An inspection hatch shall be installed in the immediate vicinity of the air flow controller

08 Buried horizontal geothermal pipes

Specifications:

> General

The system as a whole shall offer, after completion, total protection against humidity, water infiltration, mechanical, chemical and electrical actions

> Connections

Pipe connections between pipes and fittings have to be :

- Waterproof
- Able to withstand the axial forces generated by the axial movements of the pipes in the ground
- Able to resist radial forces and bending movements
- Able to withstand the effects of temperature and temperature fluctuations

Execution:

> General

Pipes shall be in one piece; buried connections are prohibited when the length does not exceed 80 m

> Penetrations

Penetration of piping through the walls of buildings and inspection chambers is carried out according to the manufacturer's instructions using parts and special seals in order to obtain a watertight assembly

> Laying of pipes

>> Laying in trenches

Pipes are laid on a bed of sand at least 10 cm thick
The trench is backfilled with sand up to a height of 15 cm above the upper edge of the pipe
A warning tape is placed above the pipes

08.01 Pressure test

Work:
pressure test

Submittals:
report

Execution:

> General
Carry out a pressure test on the entire network of buried pipes (refer to section "plastic piping test procedure")
The test shall be carried out before carrying out the backfilling of the trenches
During the test, the buried piping system shall be isolated from the rest of the hydraulic installations
The test can be carried out in phases

> Preparatory work
Before carrying out the tests, the pressurization pump and the pipes are rinsed with potable water and the pipes are completely filled with potable water and purged
Connections and ends of the circuit are closed with plugs
Accessories of the piping system and the other elements of the installation which do not resist the pressure to be applied during the tests shall be disconnected or isolated beforehand

> Test conditions
The installation is subjected to hydraulic pressure p_{test} for a minimum duration of two hours
During the test, no leakage or resistance fault may appear
The pressure is equal to 3 times the maximum operating pressure with a maximum of 10 bar
The test is carried out at room temperature, that is to say without heating or cooling the heat transfer fluid

> Pressurization

The pressure is applied statically; in the case of use of a hand pump, all precautions are taken to avoid the production of water hammer, in particular, by the placement of a device intended to dampen vibrations on the discharge pipe of the pump
The test pressure is read by a pressure gauge connected to the lowest point of the installation's piping
The pressure gauge shall allow a reading with an accuracy of 0.1 bar and have a sufficient measurement range

> Plastic piping test procedure
The test procedure is based on method B of § 10.2.3 of standard CEN/TR 12108
If the loss between p_{t30} and p_{t60} or between p_{t60} and p_{t180} is greater than the authorized value, it is necessary to identify the cause of the leakage of the installation and remedy it, then repeat the procedure from the beginning

08.02 Flexible PE pipes

Material:
Pipes
Fittings for electro-welding
Warning tape

Work:
Supply and installation
Layout of pipes (or pipe placement)according to drawings from manufacturer

Submittals:
Technical data sheets: see specifications

Certification:
10 year warranty

Specifications:

> General

Operating pressure: 8 bar
Operating temperature: -20 to +30 ° C

> Pipes
@ Data sheet
Compliance: EN 12201-2
Material: min. PE80 SDR17

> Electro-welding fittings
@ Data sheet
Compliance: EN 12201-3

09 Solar thermal collectors

09.01 Flat plate solar thermal collectors

Material:
Flat plate solar thermal collectors
Roof mounting structure
Fastening material

Work:
Supply and installation
Hydraulic connection to hot water storage tank

Documents:
Technical data sheet: see specifications
Keymark certificate + annex (test report)

Certification:
Keymark certification
10 year warranty certificate

Specifications:

> Flat plate solar thermal collectors
@ Data sheet
Compliance: EN 12975-1
Testing method: EN ISO 9806 or EN 12975-2
Material and construction:

- Housing made of corrosion resistant material
- Low iron tempered glass cover plate

- Aluminum or copper absorber with high selectivity coating
- Meandered copper tubes
- Thermal insulation on the rear and side of the absorber

Black color
Connection of collectors in series possible through using internal connectors
Min. number of collector panels that can be connected in one module:

- Connection on one side: ___
- Connection on two sides: ___

Max operating pressure: 6 bar
Max stagnation temperature: ___ °C
Collector efficiency (η_{col}) in accordance with ErP: min. 60 %
Approximate gross dimensions (length x height): ___ x ___ mm
Thermal output (G = 1000 W/m², Tm - Ta = 30 K): ___ W

Execution:
Installation on a sloping roof by means of rails and anchor rafters or chevron hooks
Recessed into a sloping roof by means of a recessed frame
Installed on a flat roof by means of a supporting structure and necessary ballast

09.02 Evacuated tube solar thermal collectors

Material:
Evacuated tube solar thermal collectors
Mounting material
Fastening material

Work:
Supply and installation
Hydraulic connection to hot water storage tank

Documents:

Technical data sheet: see specifications
Keymark certificate + annex (test report)

Certification:
Keymark certification
10 year warranty certificate

Specifications:

> Evacuated tube solar thermal collectors
@ Data sheet
Compliance: EN 12975-1
Testing method: EN ISO 9806 or EN 12975-2
Material and construction:

- Vacuum tube
- Heat pipe
- Absorber
- Condenser
- Heat exchanger

Connection of collectors in series possible through using internal connectors
Min. number of collector panels that can be connected in one module: ___
Max operating pressure: 6 bar
Max stagnation temperature: ___ °C
Collector efficiency (η_{col}) in accordance with ErP: min. 60 %
Approximate gross dimensions (length x height): ___ x ___ mm
Number of tubes per collector: ___
Thermal output (G = 1000 W/m², Tm - Ta = 30 K): ___ W

Execution:
Installation on a sloping roof by means of rails and anchor rafters or chevron hooks
Recessed into a sloping roof by means of a recessed frame

Installed on a flat roof by means of a supporting structure and necessary ballast

10 Control and automation systems

10.1 General

Note:
A hybridGEOTABS building is a building with advanced technical systems. Such systems add an additional layer of complexity to control and automation systems. Without proper quality control management, a performance gap between the design intent and measured energy use is very likely to appear. Usually, the largest share of responsibility for the performance gap stems from the problems with the control and automation system.

In order to avoid the quality gap, the contractor shall be contractually obliged to participate in the quality control process as this usually involves additional labor to be provided by the latter. In the absence of the contractual obligation, it cannot be realistically expected that the contractor will participate in the process on a voluntary basis. Since specifications represent a contractual obligation, it is important that they include all the necessary provisions that bound the contractor to the full participation in the process.

The following template of the specification text outlines some clauses that can be added to the specification in order to assure full participation of the contractor in the quality management process. They can also be used even if no strictly defined quality management process is followed. It is important to adapt the template to suit the local legislation and building practice. Some deliverables that are supposed to be submitted by the contractor according to the proposed specification may in fact be part of the services that shall be provided by the designer. In is important to understand that in some EU member states, execution design is performed by the contractor and not by the design office. This specification was written supposing such local practice. If needed, requirements that are part of the services provided by the design office can simply be removed.

10.1.1 Direct Digital Control (DDC) system

The contractor shall supply and install a complete Direct Digital Control (DDC) Building Automation System (BAS) as required to accomplish the sequences of control for heating, ventilating, air-conditioning and other building-level equipment and systems as described herein.
The BAC contractor is responsible for quality assurance for all materials and workmanship provided under this specification.

10.1.2 Project sequence

The control system work shall proceed in the following order:

- Submit and receive approval on submittals
- Install the control system hardware, including all checkouts and tuning
- Submit and receive approval of the commissioning plan
- Perform the commissioning testing
- Submit and receive approval on the commissioning report
- Perform the trial operation
- Receive approval of the trial operation
- Submit and receive approval on the follow-up surveillance plan
- Engage in the follow-up surveillance
- Receive approval of the follow-up surveillance

10.1.3 Submittals

Pre-submittal meeting:

- The contractor shall convene a pre-submittal meeting with the engineer within one month of the notice to proceed.
- The purpose of this meeting is to review sequences of operation, outline where the proposed system deviates from the specified sequence of operation, and identify potential problems with the specified sequence.
- Once the sequences of operation are agreed to by all parties, the contractor shall proceed with the formal controls submittal process.

The contractor shall submit the following documents:

- A complete bill of materials of all equipment to be provided and/or used. For every piece of equipment, a unique identifier, manufacturer name and model number shall be provided.
- A riser diagram for each segment of the building technical communication network. The diagram shall outline execution and details of all communication and structural data cabling. The following information shall be included:
  - All DDC hardware with controller number, unique identifier or tag, location, equipment and service
  - All network hardware (routers, switches, etc.) with equipment number, unique identifier, location and service
  - Network cabling configuration and execution specification
  - Location of all cabling termination points and end-of-line terminations
  - Location of all network interface jacks
- A separate equipment data sheet for every piece of equipment being installed. Data sheets shall provide all the information necessary for the engineer to verify their compliance with specifications. At least the following information shall be included:
  - Name and address of the manufacturer

- Shop drawing of the equipment
- List of reference standards
- Mechanical and electrical characteristics
- Dimensions and operational mass
- Details concerning assembly or adjustment
- Wiring diagram and connection schematics

- A control schematics and wiring diagram for every piece of equipment being controlled by and/or associated with the building automation system. At least the following information shall be included:
  - Control schematic flow diagram of each system being controlled showing actual physical configuration and relative location of all control devices and sensors of controlled equipment (e.g. fans, coils, dampers, valves, pumps, heat exchangers, etc.).
  - Controller termination details showing every controller point termination, type and mnemonic.
  - Wiring Diagrams of all packaged equipment, motor starters, relay wiring, equipment interlock, safety circuits, etc. clearly indicating all interconnecting wiring and termination of all conductors and cables including labels of all cables and point mnemonics.
  - Control Enclosure details for every enclosure including panel identifier, location, physical layout, dimensions, instrumentation, labels, etc. Detail wiring (I/O, network and power) and power source for each panel, transformer and controller shall also be included.
- A sequence of operation and state graph and/or table for every piece of equipment being controlled by and/or associated with the building automation system. At least the following information shall be included:
  - Functional control operation. Sequences of operation shall be described in a functional control operation description. The submitted description shall refer to equipment identifiers and tags. The use of generic tags is not permitted. Do not merely provide a copy of the sequence of operation specified in the contract documents, as the engineer will refuse it. The description shall include control sequence operation under normal and failure conditions. All default failback values used by the control sequence under failure conditions shall also be defined.
  - State graph or table is a graphical representation of states, their transitions, transition conditions and actions. System parts using complex logic interlocks involving more than three states shall be treated as finite state machines represented by means of state transfer graphs. An accompanying assignment table listing the state (value) of all associated data points also be provided for clarity if required.

10.1.4 Commissioning

The commissioning shall demonstrate compliance of the control system work with the contract requirements; it shall be performed by the contractor and witnessed and approved by the engineer

The contractor shall submit a detailed commissioning plan that shall be approved by the engineer. The plan shall be developed specifically for the control system in this project. Do not merely provide a generic plan not adapted to this project because the engineer will refuse it.

The plan shall be arranged in a logical sequence. It shall include at least the following:

- Listing of all the intended test procedures (grouped by component type), the expected response, and the pass/fail criteria for every component tested
- Description of the testing procedure; the plan shall also indicate where assisting personnel are required
- Description of procedures used to simulate test conditions
- Time table for all testing procedures

The following verification shall be performed:

- Verify the completion of all installation work according to the specifications, submittals and manufacturer's installation and application instructions
- Verify the installation of all DDC controllers, sensors, switches, and actuators
- Verify the installation of all electric wiring
- Verify all wiring, components, and panels are properly labeled
- Verify all control circuits operate at the proper voltage and are free from grounds or faults
- Verify all required surge and overvoltage protection is installed
- Verify all DDC controllers are on-line and that each controller's programming is backed up
- Verify all required points are wired and programmed into devices
- Verify all network devices' tags/identifications match approved drawings
- Verify all network devices' address matches approved drawings
- Verify all network communications function properly using a communication protocol analyzer tool
- Verify all sensor readings are calibrated
- Verify all actuator zero and span adjustments are set properly
- Verify all actuators' rotation direction is correct
- Verify each actuator goes to designed position upon loss of power
- Verify each controller works properly in stand-alone mode
- Verify all electrical interlocks work properly
- Verify all safety controls work properly
- Verify as-built documents are completed

The contractor shall furnish all personnel, equipment, instrumentation and supplies necessary to perform all aspects of the commissioning tests

Any items that do not meet the contract requirements shall be identified

Immediate repairs and re-testing shall be performed if time permits; otherwise, deficiencies shall be investigated, corrected and re-tested later using initial testing procedures

The engineer may require re-testing of any control system components affected by the original failed test

10.1.4 Trial operation

The trial operation shall demonstrate that the control system operation is fit for continuous independent operation. The duration of the trial operation shall be at least two full weeks.
The contractor shall demonstrate that the HVAC system operates properly through the complete sequence of operation
The contractor shall provide the engineer prior to the start of the trial operation with remote access to the building management system (BMS). The access to the BMS shall allow the engineer to supervise the system operation. He shall be able to change set points to observe control loop stability and accuracy and display trend data of all logged points.
Any sudden change of the control variable set point (20% change) shall result in a stable system response without cycling and excessive undershoot and overshoot. Once the new set point is reached, it shall be stable and maintained.
At the end of each 7-day period of the trial operation (within 24h after the end of each 7-day period), the contractor shall transmit all logged data to the engineer for further analysis. Control loop trend data shall have time interval of maximum 30 seconds.
Upon successful completion of the commissioning, the contractor shall submit a report to the engineer. A report shall not be submitted until all observed problems are corrected and successfully re-tested. Where problems were identified, the contractor shall explain each problem and the corrective action taken.

10.1.5 Provisional acceptance

The provisional acceptance takes place after commissioning testing and trial operation have been completed and approved by the engineer.

10.1.6 Follow-up

A follow-up period of at least two years is foreseen following a successful provisional acceptance. During this phase the contractor is responsible for:

- Resolution of faults resulting from system operation
- Maintenance of all parts of the building automation system
- Transfer of measurement data (trends)
- Leading periodic energy use optimization activities

The contractor shall provide the engineer prior to the start of the follow-up phase with remote access to the building management system (BMS). The access to the BMS shall allow the engineer to supervise the system operation.

<u>Faults:</u>

Any discrepancy between the submitted sequence of operation and the witnessed behavior of the control system is considered a fault:

- All faults identified by the owner or the engineer will be reported to the contractor either by telephone or e-mail. The contractor shall put in place a "hotline" (i.e. 24-hour telephonic support). The contractor shall be responsible that such hotline service be always operational and available. The hotline shall ensure that faults relating to system controls are promptly rectified.
- The contractor shall maintain an updated list of all faults. The list shall be made available to the owner and the engineer. The faults in the list shall be organized in a logic manner. For every item in the list, a status shall be indicated (open, closed, resolved, etc.).
- All faults concerning major comfort and air quality problems (not fulfilling min. requirement of EN 16798-1) are considered urgent and shall be resolved immediately. In the absence of immediate response, the owner may contact another specialized contractor to carry out the necessary work at the expense, risk and peril of the contractor. This intervention by third party does not influence in any way the current warranty.
- All other faults shall be resolved at latest 7 days after they had been reported.

If the submitted sequence of operation appears to be incomplete, the contractor shall supplement and re-submit the document:

- If an operation sequence has been programmed but not described in the submitted document
- If a control sequence has been described in the submitted document but not programmed

<u>Maintenance:</u>

The contractor shall provide maintenance of the control system during the entire duration of the follow-up

The objective is to maintain the serviceability of the of the control system infrastructure in a sustainable manner at the lowest operating and maintenance cost while ensuring compliance to contract specification

For each piece of equipment, all work will be carried out to standards as required by the Original Equipment Manufacturer (OEM) as well as any applicable government law and/or regulations

Where OEM standards differ from those required by this document the more stringent requirements shall apply

All work shall be carried out in accordance with prevailing industry norms and best practice and will always comply with OEM requirements

The contractor shall continuously ensure that all staff is suitable, able and competent for the duties required of them. He shall continuously ensure that all staff is knowledgeable and trustworthy to provide maintenance of controls system services

The contractor will be expected to attend meetings relating to maintenance and operations that may arise from time to time. As far as this is practicable, the contractor will make all required persons available for these meetings. The contractor shall not submit claims for payment for staff attending any of these meetings.

All work shall be performed within the required response times. Any breakdown affecting operations shall be attended-to until restored to good reliable condition. No breakdown may be left unattended or incomplete for the next day or shift.

Response times and service levels:

- System availability of heat pumps, chillers, boilers: ___ %
- Response time during working hours: ___ min
- Response time after working hours: ___ min
- Closure of corrective work orders: all corrective maintenance work orders should be closed within ___ days of issue unless it is because of circumstances beyond the control of the contractor
- Closure of preventive maintenance work orders should be closed within 14 days of issue

All maintenance work shall be scheduled and a roster presented to the owner at the end of the preceding month. Work shall be scheduled in a manner as not to interfere with any normal building operations.

All maintenance of control systems shall be scheduled, at least at minimum, to the following requirements:

- Daily:
  - Check that the control system and BMS are working
  - Check that sequence of operation is functioning according to design
- Monthly:
  - Check that all sensors linked to the control system are working and replace where necessary
  - Check that the heat generator rotation/sequencing is working and adjust where necessary
  - Check and adjust sequence of operation settings where necessary
  - Download and provide historical data and trends
  - Check and test the fire detection signal relay
  - Check and test that all control valves are functioning within specification
  - Check and test all temperature sensors status
  - Test all emergency stop interlocks
  - Check all energy meter readings
  - Check for controller security updates and install them
- Yearly:
  - Re-calibrate all sensors
  - Check the backup of all controllers

<u>Trends:</u>

The contractor shall periodically transfer the recorded data of all measured points to the engineer for analysis.

The transfer shall take place at the end of each month and shall contain data for the entire calendar month. The data shall be sent by e-mail in an attached *.csv file format.
The file name shall contain the start date of logging (YYYY-MM-DD) and the name of the building.

Energy use optimization activities:

The contractor shall take the leading role in managing the energy use optimization activities:

- Analysis of trends
- Periodic meetings with the engineer and owner
- Optimization of operation sequences
- Controller reprogramming

Meetings shall take place:

- Monthly during the first 6 months of the follow-up phase
- Bi-monthly during months 6-12 of the follow-up phase
- Quarterly during months 12-24 of the follow-up phase

The goal of energy optimization meetings is to:

- Verify that the sequences of operation work properly in all seasons of the year
- Compare the measured energy use trends with the anticipated and benchmark values
- Discuss energy use optimization strategies

The trends to be analyzed during meetings and related issues are raised by the engineer and building owner at latest 7 days before the meeting takes place. The contractor may include additional trends if required
During the meeting, the contractor takes notes and sends a meeting report at the latest 7 days after the meeting. The report shall contain the list of discussed points with conclusions and action timeline
In his offer, the contractor shall consider that at least 25% of the control sequences will have to be modified as a result of the optimization meetings

10.1.7 Final acceptance

The final acceptance takes place at the earliest two years after the provision acceptance under the condition that all issues identified during the follow-up have been resolved.
Upon a successful final acceptance, the contractual obligations of the contractor are deemed fulfilled.

10.2 Rule-based control (RBC)

Note:
Specification templates in this chapter only describe the sequence of control. The specification text for material components (e.g. control valves, sensors, controllers, etc.) is not part of this specification and shall be specified separately or added to the provided specification templates.

There is no standard solution for rule-based control of Ground Source Heat Pump (GSHP) and Thermally Activated Building Systems (TABS). The sequences presented hereafter represent just some of the commonly applied control sequences.

10.2.01 Control of primary ground source heat exchanger pump

Work:
Controller programming
Commissioning
Optimization

Operation:
This sequence of operation concerns the control of the pump in the primary circuit of the ground source heat exchanger (GSHX)
The pump shall enable external control by means of a 0-10 V control signal
The pump in this configuration shall be hydraulically decoupled from the heat pump circuit by means of a pressure equalization bypass
The pump shall be enabled when there is a heating need (heat pump primary pump operational) or cooling need (passive cooling enabled)
The pump speed shall be controlled so that the a constant temperature differential between the supply and return pipe of the GSHX is maintained constant and equal to the design value; this shall be accomplished by means of a PI controller that controls the pump speed
The pump speed shall be limited by a low limit value that corresponds to the minimum flow rate at which a sufficient heat exchange can still be achieved in the GSHX (avoidance of laminar flow)

10.2.02 Control of thermally activated concrete core distribution manifold

Note:

This section contains a proposal for temperature and valve control sequences. It can be applied to individual TABS zones (if the building is divided in TABS zones) or the entire building if no zoning has been foreseen (in this case one can expect poorer comfort conditions if loads vary considerably among zones).

The proposed principle can be further adapted or detailed by the designer on a per project basis in order to suit the exact project needs. For example, one can specify other pump control strategies (e.g. day/night operation, continuous intermittent operation, discontinuous intermittent operation), or other temperature control strategies (e.g. controlling mean TABS water temperature instead of supply or return water temperature).

Work:
Controller programming
Commissioning
Optimization

Operation:

> General
T_{rm}: running mean outdoor temperature (see section 3.14 in EN 16798-1)
Each manifold set (supply and return) is equipped with one [pressure independent] control valve with a servomotor for 0-10 V control signal and a PT1000 [active] temperature sensor in the supply and return pipe

> Control of TABS zone supply temperature
The supply temperature is calculated based on the averaged outside temperature and the operation mode:
- Heating: T_{supply} = 18 °C + A (18 °C - T_{rm}) where coefficient A equals 0.35
- Cooling: T_{supply} = 18 °C + B (18 °C - T_{rm}) where coefficient B equals 0.45

Coefficients A and B in the equations above represent default values that need to be corrected during the commissioning phase, taking into account selected thermal comfort performance indicators
The operation mode is defined based on the averaged outside temperature:
- $T_{rm} \leq$ 10 °C: heating
- T_{rm} > 10 °C and < 12 °C: standby
- $T_{rm} \geq$ 12 °C: cooling

The evaluation of the averaged outside temperature for the switching of the operation mode is performed once per day at midnight

In standby mode, the circuit supplying the manifold zone is isolated from the heat generation side but the pump stays enabled and runs at 50 % of its nominal speed
A direct mode change from heating into cooling shall not be possible; one shall always transfer through the standby mode for a duration of at least 24 hours
A warning shall be generated if the supply temperature exceeds the supply temperature set point by more than 2 K in heating mode; if the temperature is exceeded by more than 4 K the circuit shall be isolated from the primary heat supply
A warning shall be generated if the supply temperature falls below the supply temperature set point by more than 2 K in heating mode; if the temperature drops by more than 4 K below the set point the circuit shall be isolated from the primary heat supply

>> Control of the distribution manifold control valve (option A)

Note:
This option introduces a correction factor as a function of running mean outdoor temperature, which is used to control the flow rate in order to take into account the influence of internal heat gains.

In zones with low internal heat gains, the correction factor shall be higher in heating mode (more TABS output due to low internal gains) and lower in cooling mode (less TABS output to low internal gains). In zones with high internal heat gains, the correction factor shall be low in heating mode (less TABS output needed due to high internal loads) and high in cooling mode (more TABS output needed due to high internal loads).

In each operation mode (heating, cooling, standby) the valve control signal is a function of running mean outdoor temperature
There function shall be individually configurable per manifold control valve
The shape of the function shall be determined during the commissioning phase for each thermal zone controlled by a given control valve, taking into account selected thermal comfort performance indicators

>> Control of the distribution manifold control valve (option B)

Note:
This option introduces a correction factor as a function of running mean outdoor temperature, which is used to control the temperature differential between TABS zone supply and return water temperature. This factor is introduced in order to take into account the influence of internal heat gains. The control valve is controlled to maintain a calculated return water temperature. In order to avoid situations where the calculated return water temperature cannot be practically achieved (e.g. the calculated return temperature is lower than zone air temperature in heating), the max temperature differential is bound by the supply temperature one hand and the zone temperature on the other hand.

In zones with low internal heat gains, the correction factor shall be lower in heating mode (smaller temperature differential and thus more TABS output) and high in cooling mode (larger temperature differential and thus less TABS output). In zones with high internal heat gains, the correction factor shall be high in heating mode (larger temperature differential and thus less TABS output) and low in cooling mode (smaller temperature differential and thus more TABS output).

In heating and cooling mode a PI-controller maintains a set return temperature by controlling the flow rate through a TABS element; the feedback signal comes from a temperature sensor installed in the return pipe from the collecting manifold

The set return temperature is calculated by the controlled according to the following equation:

$T_r = T_s - C (T_v - T_i)$, where:

- T_r: return temperature
- T_s: supply temperature
- T_i: zone air temperature set point
- C: correction factor (a value between greater than zero and smaller than one)[1]

The correction factor C is a function of running mean outdoor temperature

There function shall be individually configurable per manifold control valve

The shape of the function shall be determined during the commissioning phase for each thermal zone controlled by a given control valve, taking into account selected thermal comfort performance indicators

In standby mode, the control valve is fully opened

[1] Note that a correction factor of 1 will result in the calculated return temperature equal to the zone air temperature set point. Such temperature can be achieved only in limit condition for flow rate equal to zero. The same goes for a factor of 0, which corresponds to the return temperature equal to supply temperature, what can only be achieved in theory if the flow rate is unlimited. Therefore, caution should be used when determining the factor applicable to each zone.

10.3 Model predictive control (MPC)

Note:
This particular description of an MPC system assumes that MPC is implemented on top of Direct Digital Control (DDC) system. In this architecture (most common nowadays), the acquisition of and generation of physical control signals (analog and digital) takes place in DDC controllers installed in proximity of field sensors and actuators. The advantage of using a system of decentralized DDC controllers is that they are capable of rapidly polling sensors and switches for their value because of direct and individual physical connection to each of these elements. Therefore, a DDC controller is capable of producing a real-time[2] response to changes detected field devices. This is something that is especially convenient when an immediate response of the control system is required. This is typically the case in safety functions (e.g. interlocks related to a frost alarm in an air-handling unit). Moreover, DDC controllers can maintain system in operation even if the communication link with other internetwork devices fails (e.g. by using pre-programmed failback or most recent values).

In this architecture, the MPC is an additional module that communicates with DDC controllers over a communication network. The communication is performed using a communication protocol. This specification is based on BACnet (EN ISO 16484-5 and ASHRAE 135). Thanks to the use of a communication protocol, the MPC is capable of reading locally measured values and changing set points and operating modes of control programs in DDC controllers. If the communication link between controllers and MPC is interrupted, the system can continue to operate using fallback control algorithms or default values.

Another advantage of MPC as an independent system attached to the underlying control is that the client has the possibility of changing the provider of the MPC in the future, shall he not be satisfied with its performance or the quality of service provided by its supplier. By carefully planning for the integration of the MPC in the building automation and control system from the very beginning, extra cost involved with the integration of MPC into the control system can be minimized to bare minimum. By failing to account for the MPC in advance, various problems can appear during the installation and commissioning of the system, such as:
Missing or unsupported BACnet objects at controllers' interface
Controllers with missing BACnet Interoperability Building Blocs (BIBBs)
Inability to correctly override write variables used by controllers' control program
Etc.

In some cases (e.g. missing BIBBs or unsupported BACnet objects), problems can only be resolved by replacing the hardware. Other problems, e.g. missing BACnet objects or control programs not designed to be overridden by an overlying control system, can be resolved later, but usually for a cost much higher than if they had been accounted for in the design phase.

[2] Here, real-time means that the longest response time can be determined in advance and does not depend on some unpredictable behaviour of the system.

To avoid problems during the execution and commissioning phase, the designer shall take care of the following tasks and make sure that they are correctly represented in the project:
Describe sequence of operation for all system parts where DDC will be applied
For each sequence of operation, list all the necessary BACnet objects that shall be exposed at the interface of the system
For each DDC controller, list all BACnet BIBBs and object types that it shall support

Work:
Programming
Configuration
Commissioning
Optimization

Specification:

> General
All devices without native BACnet support shall be integrated in the building communication network via BACnet gateways
The MPC controls all system components (air handling units, heat pumps, chillers, boilers, dry coolers, cooling towers, pumps, fans, air volume dampers, valves) by writing in the relevant property fields of concerned BACnet objects in local DDC controllers
The MPC acts on top of the conventional DDC, which is used to control local processes
The MPC shall exert full control over at least the following devices through their direct or indirect BACnet interface:
- Heat pumps, chillers and boilers
- Pumps
- Air dampers
- Control valves
- Fans and variable speed drives

MPC shall have full access to at least the following meters, sensors and switches through their direct or indirect BACnet interface:
- Heat meters
- Electricity meters
- Temperature sensors
- Humidity sensors

- Air quality sensors

All air flow controllers and control vales shall be controllable over their maximal control range
The MPC software shall be installed on a local workstation delivered by the contractor
The MPC may use an additional cloud-based backend to perform resource-intensive calculations. In this case, it shall be the local MPC controller that always establishes the connection to the cloud-based backend so that no inbound IP connection is necessary and thus no ports in the firewall have to be opened
Every zone for which temperature and/or CO_2 control is required shall be equipped with at least one temperature or CO_2 sensor
Every fan, pump or a group of (parallel) pumps shall be equipped with equipment for flow measuring
Electricity used by all HVAC equipment shall be metered; all major equipment (air handling units, pumps, heat pumps, chillers) shall be equipped with individual electricity meters
IP-infrastructure shall be designed and executed for link speeds of at least 100 Mbit/s; all structural cabling shall be tested after the installation according to EN 50346; links that do not achieve the demonstrated performance shall be replaced and re-tested

> Key Performance Indicators (KPIs)

The following system KPIs shall be calculated for every day, week, month and year:

- Heating: kWh_{th}/m^2 and kWh_{el}/m^2
- Cooling: kWh_{th}/m^2 and kWh_{el}/m^2
- Ventilation: kWh_{el}/m^2
- Pumps: kWh_{el}/m^2
- Discomfort hours: Kh/year and Kh^2/year
- Electricity cost (taking into account variable rate): €

The surface used for the calculation of KPIs shall be total net surface area
KPI values shall be logged and archived in a persistent data storage
Visualization of KPI tends shall be performed in the Building Management System (BMS)

> Model

The MPC shall use a mathematical model of building and technical systems to calculate controlled variables; this model shall calculate flows and temperatures of all HVAC system parts that significantly influence building energy use; the calculated values shall be logged and exported for analysis
The model shall adhere to the law of conservation of energy and the law of conservation of mass
Zones with independent temperature, air flow rate or air quality control shall be modelled separately so that the temperature of each individual room is calculated as a separate variable in the model; it is not allowed to simulate separate rooms, each individually cooled and heated, as one zone and to use post-processing to calculate the value for individual rooms

Room temperature shall be calculated taking into account heat transfer with HVAC, internal heat loads, solar heat loads through transparent construction elements and heat loads through opaque construction elements; the calculation shall be performed for external construction elements that border on outside air and internal construction elements that border on other zones of the same building

Solar gains shall be calculated using a physical model that takes into account the dimensions of the glazed surfaces and their technical characteristics such as absorption and reflection coefficients, orientation and shading

Heat transfer between adjacent rooms and outside environment shall be calculated using physical models for heat conduction, convection and radiation, taking into account the material properties of all building fabrics, the order and thickness of material layers and the transient behavior of the heat transfer due to building fabric mass

The model shall be used to calculate the electricity use of all controlled technical systems; it calculates efficiency of pumps and fans, efficacies of heat exchangers, coefficients of performance (COP) of heat pumps and chillers based on relevant flow rates, pressure and temperature measurements

The model shall be used to simulate the behavior of the building and its technical systems for the period of at least 48 hours in advance; the simulation shall be performed using weather forecast data

The MPC shall minimize the total electricity use for the simulated period; it shall take variable electricity rate into account

The MPC shall respect operational limits for temperature and CO_2:

- Temperature: class 2 as per EN 16798-1 (annex B)
- CO_2: max. 1200 ppm

A BACnet Schedule object stored in the BMS server controls the above operational limits; MPC shall subscribe via COV mechanism to receive notifications if the schedule is updated

> Control

MPC shall use priority ___ when writing to BACnet objects in other BACnet devices (local forcing uses priority ___ and DDC controls priority ___). If some other system writes on the same variable at a higher priority, MPC shall interpret this as imposed value for the entire simulation period and try to maintain the imposed comfort level at minimal operational cost using the imposed value

MPC shall recognize if the input value of physical outputs has been overridden by the BMS; in this case the Out_Of_Service property of the corresponding BACnet object shall be activated by the BMS; MPC shall either subscribe for the COV Out_Of_Service property of each observed object (push) or it shall periodically poll for the change of value (pull)

Activating the Out_Of_Service property will cause the Present_Value property to be removed from the associated physical output; in this case, the output value used by the MPC remains equal to the last value set until overwritten by the command from the BMS

When the Out_Of_Service property is reset to the default state, the current value shall be taken over immediately and automatically

MPC does not have to be BTL-certified if it only acts as BACnet client on the network: this means that MPC is only using BIBBs of type A; if MPC is BTL-certified, it may be used as a BACnet server if necessary (e.g. to store object of type such as Schedule, Trend Log, etc.)

10.4 Building automation controllers

Documents:
Data sheet: see specifications
BACnet BTL certificate
BACnet Protocol Implementation Conformance Statement (PICS)

General specifications:

> General requirements
@ Data sheet
Material and construction:
- Polycarbonate, polyamide, ABS or equivalent housing
- All functions and indications are on the front of the device
- Mounting on a 35 mm DIN rail

Protection index: IP20
Conditions of service:
- Temperature: 0 to +50 ° C
- Humidity: 10 to 90% (non-condensing)

Power supply:
- 24 V DC voltage, tolerance -15 / + 10%
- Note: If the controller is equipped with an internal rectifier, the power supply can be 24 V AC (50 Hz, tolerance +/2%)

> Hardware
Microprocessor:
- Capacity and speed are determined by the contractor based on the amount of information to be processed; in any case, the architecture of the microprocessor shall be at least 16 bit
- The duration of a cycle does not exceed 5 seconds (including the request of the values of the measurement points, the execution of the operations and calculations necessary starting from these values, the transmission of the resulting values to the control points and if necessary, data exchange with the control unit or with another system
- At least one cycle is executed every 5 seconds

Memory and internal storage:
- Memory: min. DDR2 SDRAM
- Internal storage: EEPROM (NOR or SLC NAND flash)
- External storage: space for an SD card (min. SDSC / SCHC) min. 8 GB
- Reserve capacity: min. 30% of the memory capacity occupied
- Note: the reserve can be reduced to 10% if the memory / storage is expandable

Real time clock and 365-day calendar
Battery of capacitor to support the real time clock and RAM for at least 72 h
Integrated Ethernet network switch:
- Application: 10BASE-T, 1000BASE-TX
- Ports: 2x RJ45 which allow to connect several programmable controllers in series like a bus
- Functions: auto-negotiation, auto-MDIX, DHCP, DNS, RTSP

Diagnostic LEDs: power supply, communication, processor status

> BACnet stack

>> General

Native BACnet device according to ANSI/ASHRAE Standard 135
Tested and certified by BACnet Testing Laboratories (BTL)
Data Link Layer:
- BACnet IP, Foreign Device
- MS / TP master, baud rate 9600 to 115200

Supported character set: UTF-8 (length 32 characters)
Support for segmented messages
BBMD (BACnet Broadcast Management Device) function
In the event of a power supply interruption and when the mains voltage returns:
- The properties of dynamic variables shall be kept in the buffer for at least 72 hours; this applies to objects such as Trend Log, Schedule and Calendar
- The Recipient_List properties in the Notification Class object are preserved; clients continue to automatically receive event and alarm information without having to re-subscribe
- Personal COV messages are maintained
- COV subscriptions to other BACnet servers are automatically reestablished

- Connections between controllers are updated (resubscription)

>> BACnet Interoperability Building Blocs (BIBB)

Device profile: B-BC

Additional BIBBs required (not included in the standard B-BC profile):

- Data Sharing: DS-COV-A, DS-COV-B
- Alarm and Event Management: AE-N-E-B, AE-ASUM-B
- Scheduling: SCHED-I-B
- Trending: T-VMT-I-B, T-VMT-E-B, T-ATR-B

>> Objects

The device shall be able to generate and expose at least the following objects:

- Do not have to be created and deleted dynamically:
  - Device (DEV)
  - Analog Input (AI), Binary Input (BI), Multi-state Input (MI)
  - Analog Output (AO), Binary Output (BO), Multi-state Output (MO)
  - Analog Value (AV), Binary Value (BV), Multi-state Value (MV)
  - File (FIL)
  - Loop (LP)
- Shall created and deleted dynamically:
  - Calendar (CAL)
  - Schedule (SCHED)
  - Trend Log (TLOG)
  - Notification Class (NC)
  - Event Enrollment (EE)

Objects shall support all the properties necessary for COV Reporting and Intrinsic Reporting

> Embedded software

>> General

The on-board software and the control program are stored in the non-volatile internal storage

Operating system: multitasking and deterministic
SNTP client: automatic clock synchronization via internet
HTTPS server: device configuration via internal website
The on-board software update and control program shall be able to be carried out remotely from a computer via the local network and without interrupting the operation of the controller
The device shall be able to prevent unauthorized persons from accessing the on-board software (e.g. by means of a password)
A cut of the mains voltage causes an ordered deactivation of the device and, when the mains voltage returns, an automatic and ordered start-up

>> Gateway

The device shall be able to function as master and BACnet/IP gateway for at least the following communication protocols:

- BACnet MS/TP
- KNX (S-mode)
- Modbus RTU
- M-Bus

The integration of the communication protocols mentioned above is carried out either by means of a driver in the software of the device itself (native support); the use of an external gateway, which translates the unknown communication protocol into an intermediate protocol supported by the software of the controller, is not allowed in this case
Update of the embedded software shall be possible via the internet without the need of hardware replacement

>> Events (alarms and notifications)

It shall be possible, regardless of the communication technology or the type of underlying physical point, to define notification conditions for each data point read by the controller
Generated alarms and notifications are recorded in a buffer database in the internal storage of the device
Event records log at least the following information about the event:

- Reference of the source (data point)
- Timestamp
- Value
- Message
- Type (abnormal value, normal value, error)
- Priority level
- State (active, acknowledged, inactive)

There shall exist a possibility of sending alarms and alerts via email and SMS (via SMTP) without the use of additional software, web server or BMS server; messages sent shall be able to be personalized and contain variables configured in the controller

>> Schedules

It shall be possible to generate hourly schedules on a monthly, weekly and daily basis, and to program exceptions (public holidays, vacation periods, etc.)
Schedules are saved in a local database and synchronized with the real time clock
Each schedule shall be able to change the state or value of a data point independently of the communication technology or the type of underlying physical point
Each device shall support schedules in accordance with the following minimum conditions:

- At least 12 switching times per weekday
- At least 6 exceptions (direct entry or reference to a calendar object), each with at least 6 switching times

Each device shall be able to record at least 3 schedules with each a list for at least 10 date entries

>> Data logging and trends

It shall be possible to collect, to process and save current values of any data point as logs in a buffer database in the internal storage of the device
The possibility of registration shall be independent of the communication technology or the type of underlying physical point; this means that it shall be possible to collect external data points, which the device can access via its network interfaces
The recording of each data point shall be possible according to at least the following modes:

- Fixed interval
- Defined change in the value of an observed data point (COV)
- Trigger by a data trigger point

Minimum sampling interval shall be no more than one second
Recorded data shall be able to be exported to an SLC NAND SD card; at least one of the following digital formats is supported: CSV, XML, JSON

> Programming and configuration software

Programming, configuration and management of the controller shall be performed in an integrated development environment (IDE) on the Windows operating system in standardized languages according to IEC 61131-3 (or equivalent)
The IDE has modules for configuring the BACnet, Modbus (TCP/RTU), M-Bus and DALI communication protocols
Everyone shall be able to obtain and use the development environment (IDE) without additional requirements from the supplier (training, certifications, etc.); any form of vendor lock-in is strictly prohibited

The number of licenses for the use of the IDE depends on the total number of machines supplied and installed; one shall provide at least one license per 50 devices

Execution:

> General

DDC controllers shall always be installed in low-voltage switchgear assemblies
All controllers shall come from a single manufacturer and shall be able to be programmed, configured and managed by a single common software
Controllers shall not depend on a connection to a server or a master regulator to be able to execute the regulation program
Automation of a technical node (e.g. local heat production, substation, air-handling unit, etc.) shall be carried out with at most one programmable controller with sufficient hardware and software capacity; distribution of control logic among several controllers is not allowed

> Events

All announcements shall be generated in the controller and not on the side of the BMS

> Control of order execution

In binary and multi-state objects, the Feedback_Value property shall allow the desired state to be defined via Intrinsic Reporting
In case of discrepancy between the actual and desired state, an alert shall be generated after a specific adjustable time
The real state shall be acquired via the physical input

> Integration of meters with bus interface

Meters (fluids, energy) are integrated into the controller via a communication module
Data points from meters shall be made available as BACnet objects of the Analog Value type

> Totalization of operating time

The total operating time is recorded in seconds in binary objects via the Elapsed_Active_Time property
The recorded value in seconds shall be converted into hours by being displayed using an additional object of the Analog Value type; the time shall be available via the Present_Value property; the Units property contains the time as a unit
An additional conversion function is necessary for the conversion of seconds into hours
The user shall be able to reset the totalizer to zero and set the upper limit in order to trigger a maintenance notification

Reset of the operating time shall be carried out via the overwriting of value by value zeor of the Elapsed_Active_Time property and saved in the Time_Of_Active_Time_Reset property

Notifications are sent using the Intrinsic Reporting mechanism; the upper limit shall be set in the High_Limit property

> Manual control

In the event of modification of the Present_Value property of outgoing BACnet objects in forcing mode, the Priority parameter shall receive the value of 8; if there are no commands with higher priority (<8), the physical output is set to the value chosen manually

In the event of manual control of incoming BACnet objects, the Out_Of_Service property of the associated object shall be activated; consequently, the value of the Present_Value property can be adjusted as required from the BMS until the cancellation of the manual command

Activating the Out_Of_Service property causes the Present_Value property to be removed from the associated physical output; in this case, the output value remains equal to the last value set until overwritten by the command from the BMS

When the Out_Of_Service property is reset to the default state, the current value shall be taken over immediately and automatically

Manual interventions by means of micro switches on interface modules or multi-pole switches not connected via BACnet shall also be reported; objects of type Binary Input (via physical connection) or Binary Value (via communicative connection) shall be used for this purpose

11 Energy meters

11.01 Ultrasonic energy meters

Products:
Ultrasonic heat meter

Work:
Supply and installation
Commissioning

Documents:
Data sheet: see specifications
Commissioning report

Certification:
CE marking
12 year warranty on the battery

Specifications:

> Ultrasonic heat meter

>> General
Conformity: EN 1434-1/2/4/5

>> Ultrasonic flowmeter
MID class: 2
Max working pressure: 16 bar
Max pressure drop: 0.15 bar (at nominal flow)
Dynamic measurement range (min/nominal flow): 1/100

Protection index: IP68

>> Programmable data logger

Polycarbonate, ABS or equivalent housing
Meter type: hot and cold
Min temperature range (fluid): +5 to +105 ° C
Differential temperature range (fluid): 0.2 to 100 K
Protection index: IP54
Battery: type D (Li-ion), autonomy at +20 ° C: min. 12 years
Memory: EEPROM for min. 2,000 retrieved values
External power supply: 1x230 V, 50 Hz
Communication module: BACnet MS/TP

>> Temperature probes and thermowells

Material:

- Two temperature probes: Pt500 or Pt1000 according to EN 60751
- Thermowells: EN 1.4301 or EN 1.4401
- Connection cable

Execution:

Installation and commissioning in accordance with EN 1434-6
Install temperature sensors in thermowells