

1. The basic requirements on the design of a heating system comprising the heat pump

As compared with standard heating systems, heating medium temperature is limited in the heating systems comprising the heat pump due to technical as well as economic reasons. The maximum temperature level of the heating medium is within a range of 50 to 55 °C. The limitation is determined primarily by strength points of view (unit design) but energetic points of view (heating factor drop) as well.

To eliminate the disadvantage of heating medium lower temperature when designing a heating system, a smaller working difference in heating medium temperature is employed which ensures a higher medium mean temperature for the heating system. A higher medium flow rate must be used to transfer certain heating performance when the working temperature difference is smaller. As a rule, the flow rate can be more than double in comparison with the standard heating systems. This must be considered when designing circulation pumps, distribution lines and the respective heating system. Neglecting this fact results in problems!

Heating medium flow rate in the heating system is mostly selected in such a way that medium warming-up inside the heat pump is 5 K at nominal working conditions. Only in the systems where heating medium working temperature is lower (up to 40°C), higher warming is permissible, e.g. 6 to 7 K. For energetic and functional reasons, the medium flow through the heat pump must be constant as flow rate decreasing causes an increase in output temperature and the maximum temperature could be exceeded in the case of higher temperatures and the system failure could occur.

The heating system with the heat pump must provide a constant flow through the heat pump according to the specifications and, as against it, variable flow through the heating system due to performance regulation or when zones are working independently. Thus, the system hydraulic connection must be designed so that both conditions can be satisfied.

1.1 A system comprising a thermo-hydraulic distributor - header

The basic connection of the heating system hydraulic circuit satisfying these conditions is represented in the diagrammatic figure 1. The heating system is divided into two autonomous circuits; the heat pump (TC) is in one of them, the heating system (OS) is in the second circuit. In each circuit is integrated a circulation pump (C1, C2) providing flow within the circuit. Both circuits are interconnected through a so-called thermo-hydraulic distributor - header (THR) which can be attached in various manners. When the flow rates in both circuits are the same, the flow through the distributor is zero. When the flow rates differ, flowing through the distributor equalizes flow disproportions.

a) four-pipe connection

This connection is mostly used in practice and it is **recommended**. In the following examples of connection of the heating systems comprising the heat pump, always the four-pipe connection is shown.

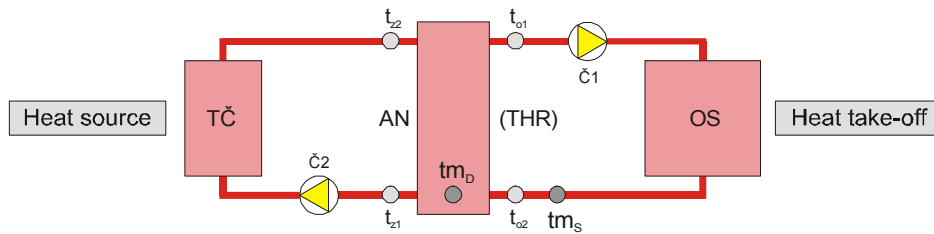


Fig. 1a Hydraulic connection – four-pipe

Explanation to the diagram:

- AN buffer tank
- Č1 circulation pump in the heating system circuit
- Č2 circulation pump in the heat pump circuit
- OS heating system
- TČ heat pump
- THR thermo-hydraulic distributor - header
- t_o temperature on the heat take-off side
- t_z temperature on the heat source side
- tm_s control temperature of the heating medium from the heating system; the heating system comprising the thermo-hydraulic distributor
- tm_D control temperature of the heating medium; the heating system comprising a buffer tank or being in „run-down“ mode

b) three-pipe connection

This connection is less frequently used in practice. In the case of this connection, the heating system (OS) is mostly unsufficiently hydraulically separated and the heating water circulating through the circulation pump in the heat pump (TC) circuit can be partially sucked from the heating system (OS) circuit and forced out back into it.

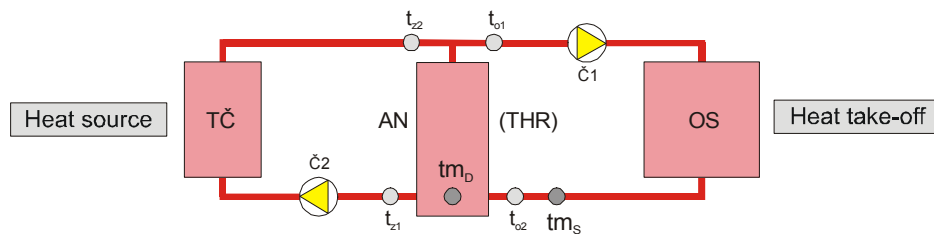


Fig. 1b Hydraulic connection – three-pipe

Explanation to the diagram:

- AN buffer tank
- Č1 circulation pump in the heating system circuit
- Č2 circulation pump in the heat pump circuit
- EK electric boiler
- OS heating system
- TČ heat pump
- THR thermo-hydraulic distributor - header
- t_o temperature on the heat take-off side
- t_z temperature on the heat source side
- tm_s control temperature of the heating medium from the heating system; the heating system comprising the header
- tm_D control temperature of the heating medium; the heating system comprising a buffer tank or being in „run-down“ mode

c) two-pipe interconnection

This simplified interconnection can be employed in case the heating system contains a sufficient water amount and the water flow is not regulated, e.g. a heating system without thermostatic valves, floor heating. In the case of floor heating however, attention must be paid to the heating water low temperature that can be lower than the allowed system temperature if a temperature reduction occurs in the heated room, or in the case of the „air/water“ heat pump when the temperature can be insufficient for icing defrosting on the evaporator. In both cases, it would result in putting the heat pump out of operation.

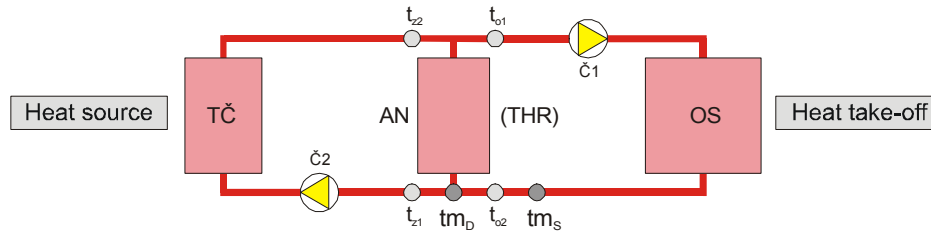


Fig. 1c Hydraulic connection – two-pipe

Explanation to the diagram:

AN	buffer tank
Č1	circulation pump in the heating system circuit
Č2	circulation pump in the heat pump circuit
EK	electric boiler
OS	heating system
TČ	heat pump
THR	thermo-hydraulic distributor - header
t_o	temperature on the heat take-off side
t_z	temperature on the heat source side
t_{mS}	control temperature of the heating medium from the heating system; the heating system comprising the header
t_{mD}	control temperature of the heating medium; the heating system comprising a buffer tank or being in „run-down“ mode

d) Location of the thermal probe measuring the control temperature

For the control thermal probe (t_{mD}), a separate well according to the Fig.1 must be integrated in the pipeline so that the probe can monitor actual reference temperature of the heating medium; operation of the heat pump and the heating system will be controlled according to this temperature in all the operating modes.

In the standard cases, this well (t_{mS}) is situated in the return pipeline from the heating system (OS), before the thermo-hydraulic distributor - header (THR).

In the case that so-called „run down“ control for the heat pump is used, e.g. if a buffer tank is used (see below), this well (t_{mD}) must be located so that the thermal probe can monitor the medium control temperature even if the C1 circulation pump has been switched off. In this case, namely, the system heat pump does not switch off immediately after the required space temperature in the reference room is achieved but only after the switching-off temperature of the heating medium in the reduced circuit (AN – C1 – TC) is achieved.

e) Adjustment of the flow rate by means of temperature measuring

Flow rates are verified and adjusted using the t_{z1} , t_{z2} temperatures (characterizing the heat source) and the t_{o1} , t_{o2} temperatures (characterizing heat take-off) (see Fig. 1abc):

- The heating medium flow through the heat pump is adjusted according to the $(t_{z2} - t_{z1})$ temperature difference.
- The heating medium flow through the heating system is adjusted according to the temperatures in the opposite necks of the header or the buffer tank in the case of any of connections:
 - a) If $t_{o1} = t_{z2}$ and $t_{z1} > t_{o2}$, the heating medium flow rate in the heating system is smaller than the flow rate in the heat pump.

This state is not suitable both from the energetic and from the functional point of view. The flow rate in the heating system must be increased.

- b) If $t_{z1} = t_{o2}$ a $t_{o1} < t_{z2}$, the heating medium flow rate in the heating system is higher than the flow rate in the heat pump. This state is more suitable than that mentioned above. From the functional point of view, it is desirable; it incorporates the heating medium volume in the buffer tank into the system active filling. The flow rate in the heating system needs adjustment to a temperature difference value of $t_{o1} - t_{z2} = 0,5$ to 1 K ($^{\circ}$ C)

1.2 A system comprising a buffer tank

Heat pump performance cannot be regulated in a technically simple way and primarily in an advantageous way as to energy. Heat pump surplus performance as against the required heating performance, particularly at the heating period beginning/end and above the bivalence condition temperature in general, is resolved by means of intermittent operation of the heat pump. The demand of heat pump switching on/off derives from the heating medium temperature in the heat pump inlet while the required value of this temperature varies or can vary depending on the outside temperature.

There are limits for frequency of starting in intermittent operation. Frequent starting reduces heat pump life. In general, the maximum recommended frequency of starting is 3 to 4 per hour.

To maintain the required frequency of starting, **heat accumulation must be ensured in the heating system, i.e. a certain minimum filling with the heating medium in the system.**

The following is applicable for the minimum filling:

$$V_{aku} = ca .15 \times Q_{zdr} [l]$$

V_{aku} – minimum filling with the heating medium [l]

Q_{zdr} – heat pump performance [kW]

ca. 15 – calculating constant [l kW⁻¹]

The relation given above is applicable under the prerequisite that only the thermal capacity of the heating medium – water participates in the accumulation. This is especially the case of a heating system with radiators. In the case of floor and wall heating where heating system thermal capacity significantly influences the accumulation, the system filling may be smaller.

The minimum heating medium filling in a system must be always provided for the „air-water“ heat pump with evaporator defrosting by means of reversation. In the course of defrosting, heat is taken-off from the system and a small heating medium filling would cause undesirably high medium cooling.

In case the minimum filling is not provided directly by the system volume, i.e. pipe distribution lines and heating system volume, another volume must be added into the system – a buffer tank (AN). **Regardless of filling amount, the buffer tank must be used in a system each time, when performance regulation in the heating system is executed by means of flow rate change**, either continuous (thermostatic valves) or step-by-step (in the case of heating system dividing into zones with autonomous heat pumps). Then, the buffer tank is connected instead of the header and takes over its function.

Fig. 2 shows the simplest connection of a system with a buffer tank. This more detailed diagram presents one of the basic designs of a heating system comprising TC. It shows also possible connections of the second source – electric boiler. Besides all the basic system elements, in the diagram are also included members monitoring parameters according to which the system is controlled, including sequence of their activation.

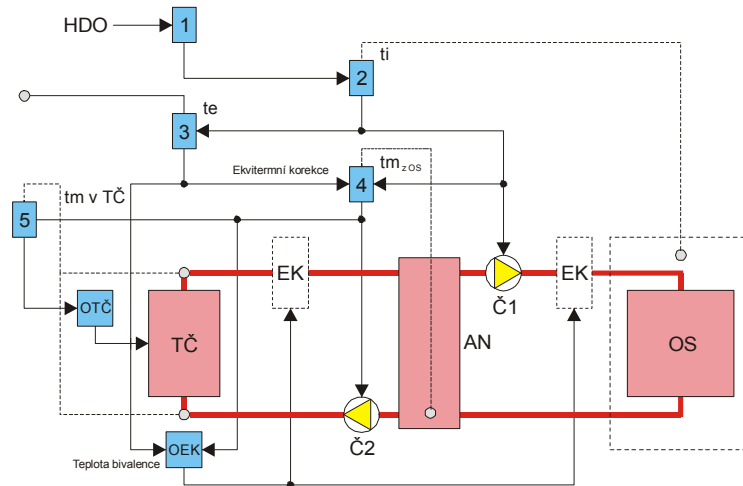


Fig. 2 Basic connection of the system comprising a buffer tank
The sequence of control signals starting up a system comprising the heat pump

Explanation to the diagram:

- AN buffer tank
- Č1 circulation pump in the heating system circuit
- Č2 circulation pump in the heat pump circuit
- EK electric boiler
- OS heating system
- TČ heat pump
- OTČ heat pump control
- OEK electric boiler control
- te external temperature – outside temperature
- ti internal temperature – heated room temperature
- tm heating medium temperature

1.3 The sequence of control signals starting up a system comprising the heat pump

- 1 - Signal from electric power distributor „operation release“ (HDO)
- 2 - Temperature in the heated room (ti). If the signal of demand to be heated is sent from the room thermostat situated in the reference room, the circulation pump (C1) of the heating system (OS) circuit is put into operation and heat pump operation is released. The heat pump is further controlled by the temperature of the (tm) heating medium returning from the heating system.
- 3 - Outside temperature monitoring (te). According to outside temperature, so-called equithermic correction of the temperature required in the heating system is made and possible operation of the complementary-bivalence source (OEK-EK) is released.
- 4 - Heat pump (TC) operation and circulation pump (C2) operation are controlled according to the temperature of the heating medium returning from the heating system (OS).
- 5 - Other operating parameters are monitored inside the heat pump from the operation safety point of view, particularly the temperatures in the heat pump inlet and outlet, according to which heat pump operation is furthermore controlled (OTC).

1.4 Requirements on the room thermostat (measuring temperature in the heated room – ti)

For optimum operation control of a heating system comprising the heat pump, in the reference rooms there are to be used room (programmable) thermostats with two basic features:

- the output (potential-free contact) is permanently switched on if the room temperature is lower than the required temperature;
- the hysteresis can be set, a recommended value of 0,5 K.

In the event that wireless thermostats are used, the batteries generally energizing the thermostats may discharge which will cause non-closing in the relay potential-free contact and puts out of operation the respective zone of the heating system or possibly the whole system. Thus, a „fictive“ failure of the system is caused. The user of the system should be warned of such eventuality. Modern wireless thermostats are equipped with indication of battery conditions and in addition indication of signal strength as well.

1.5 Connection of an assigned complementary – bivalence source

As the assigned complementary-bivalence source, an electric boiler or an electric heating element (EK) is unequivocally taken herein. This source can be integrated in the heating system in several manners:

- a) In the heat pump circulation circuit, i.e to the left of THR (Fig. 2). The solution is used for the compact heat pumps, where electric boiler is a part of it.
- b) In the heating system circulation circuit (OS), i.e to the right of THR (Fig. 2). The solution is used in the cases when electric boiler is not a part of the heat pump. Its advantage is that the heat pump circulation circuit can be shut down too in the case of a possible heat pump failure.
- c) As a part of the buffer tank.
In this case, the buffer tank must be „four-pipe“ connected, its outlet into the heating system must be in its top point.

2. General examples of heating system designs with the buffer tank

2.1 Example of heating system design with the buffer tank

The heating system is divided into three independent vertical zones

The diagram shows the possibility of heat pump use in a multi-branches heating system and equal temperatures of the heating medium. This is a case of less frequent use of connection, e.g. in multi-storey houses.

Each heating branch has its own circulation pump and its own room thermostat controlling heating in the room in question.

In this case, the buffer tank with a corresponding volume must be always used.

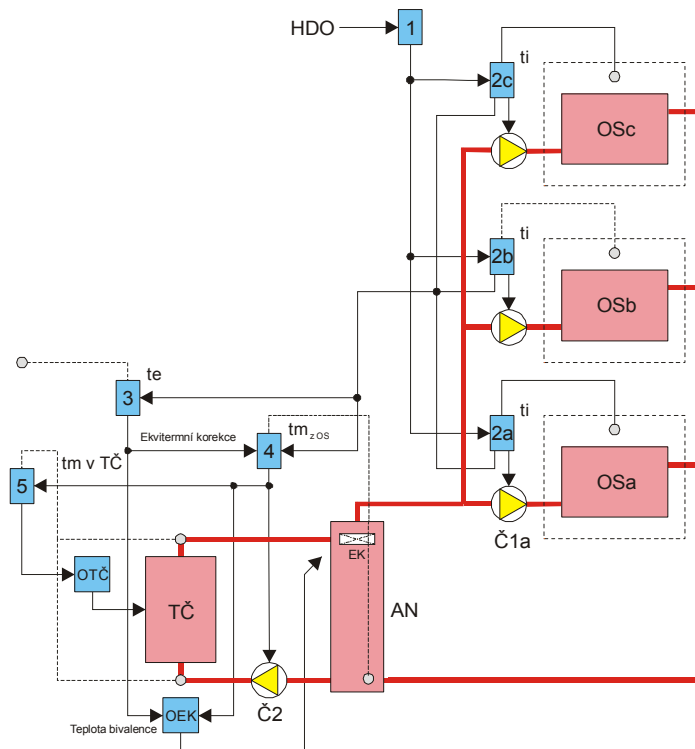


Fig. 3 Design example for the system comprising a buffer tank
The heating system divided into three independent vertical zones

Explanation to the schematics:

AN	...	buffer tank	OTČ	...	heat pump control
Č1	...	circulation pump in the heating system circuit	OEK	...	electric boiler control
Č2	...	circulation pump in the heat pump circuit	te	...	external temperature – outside temperature
EK	...	electric boiler	ti	...	internal temperature – heated room temperature
OS	...	heating system	tm	...	heating medium temperature
TČ	...	heat pump			

2.2 Example of heating system design with the buffer tank

The heating system is divided into two independent vertical zones

The diagram shows the possibility of heat pump use in a multi-branches heating system and equal temperatures of the heating medium. This is a very frequently used connection.

Each heating branch has its own circulation pump and its room thermostat controlling heating in the room in question. In the case of multiple branches, the use of a heating engineering distributor is always recommended.

In this case, the buffer tank with a corresponding volume must be always used.

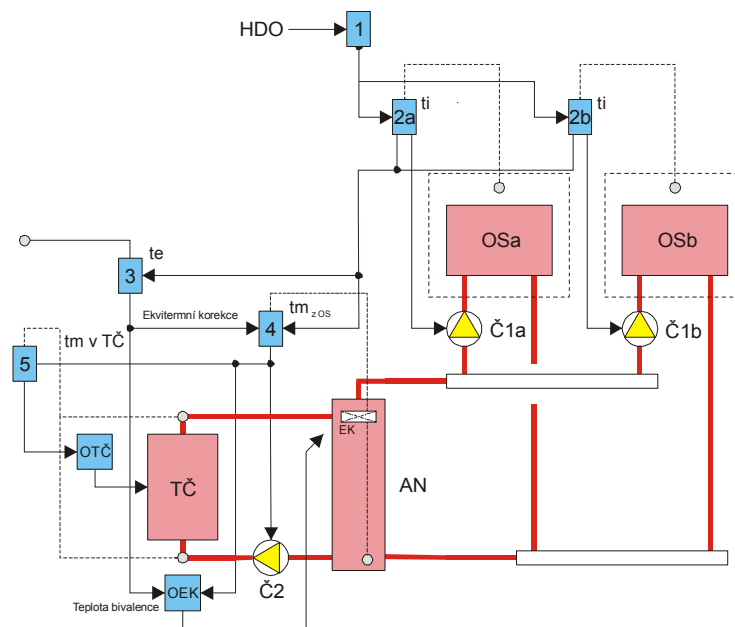


Fig. 4 Design example for the system comprising a buffer tank
The heating system divided into two independent horizontal zones

Explanation to the schematics:

AN	...	buffer tank	OTČ	...	heat pump control
Č1	...	circulation pump in the heating system circuit	OEK	...	electric boiler control
Č2	...	circulation pump in the heat pump circuit	te	...	external temperature – outside temperature
EK	...	electric boiler	ti	...	internal temperature – heated room temperature
OS	...	heating system	tm	...	heating medium temperature
TČ	...	heat pump			

2.3 Example of heating system design with two levels of heating medium temperature

The basic connection of a heating system with one heat pump only requiring two temperature levels of the produced heat is shown in the figure 5. The higher temperature level is provided directly by the heat pump, the lower level is provided through mixing. This is the case, when there is e.g. radiator heating system in one heating zone and floor or wall heating in the second one.

In this case too, it is necessary to set a buffer tank with a corresponding volume in the system. The energy demand of such system is unequivocally given only by the higher temperature level, i.e. the level reached by heat pump production.

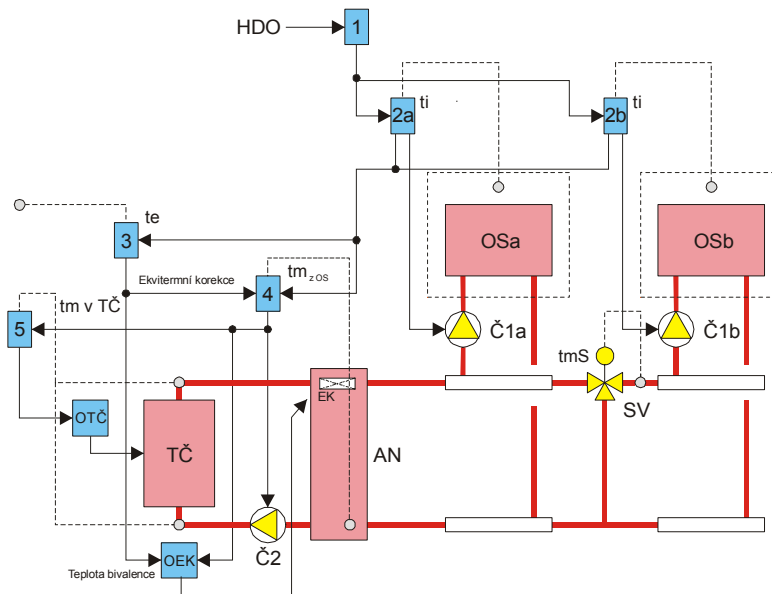


Fig. 5 Design example for the system with two levels of heating medium temperature
The lower of which is provided by mixing

Explanation to the schematics:

AN	...	buffer tank	OTČ	...	heat pump control
Č1	...	circulation pump in the heating system circuit	OEK	...	electric boiler control
Č2	...	circulation pump in the heat pump circuit	te	...	external temperature – outside temperature
EK	...	electric boiler	ti	...	internal temperature – heated room temperature
OS	...	heating system	tm	...	heating medium temperature
TČ	...	heat pump			
SV	...	mixing valve			

3. Domestic hot water warming in the heat pump heating systems

Domestic hot water warming in the heating systems comprising the heat pump can be provided by two basic methods. In each of them, optional connections are possible. The most important of them are shown.

Although a temperature ranging from 45 to 50°C can be achieved for domestic hot water if suitable way of pre-warming is used, we can talk on „pre-heating“. Such temperature namely does not provide liquidation of the Legionella bacteria. For this liquidation, it is necessary to employ additional warming (or periodic additional warming only) minimally to a temperature of 60 to 65°C.

Also high quality thermal insulation of the heater for warming (pre-warming) is a basic prerequisite to ensure an effect of TUV pre-warming by means of TC.

3.1 Domestic hot water warming (pre-warming) during heating operation

It is suitable:

- a) in the heating systems with large-area radiators or in the systems operating with a „high“ temperature of the heating medium (on the limits of heat pump capabilities);
- b) in the buildings where a high proportion of heating heat exists thus a low proportion of the heat necessary for domestic hot water warming.

Pre-warming occurs each time, when the system provides heating in a building. In this condition, a portion of the heat produced by the heat pump is utilized for domestic hot water pre-warming. Heating system operation is controlled only as to heating, it is not necessary to make any control system setting specifically for providing domestic hot water pre-warming.

Cold water can be pre-warmed in a heat exchanger located in the buffer tank or possibly in the boiler, mostly a double-jacket one (the tank-in-tank system) where water is pre-warmed to a temperature near that of the heating medium used for heating. Water additional warming is provided in another electric heater connected in series behind the pre-warming heater.

The advantage of this method is that additional warming can be provided quite independently of pre-warming.

The disadvantage is that the effect of domestic hot water pre-warming drops when heating medium temperature decreases by means of the so-called equithermic regulation as depending on the outside temperature.

Example of domestic hot water warming (pre-warming) during heating operation Pre-warming in a buffer tank (Fig. 6a and 6b)

This method is appropriate, if a buffer tank (AN) must be incorporated in the heating system.

In this case, the buffer tank can also provide domestic hot water pre-warming using a tubular heat exchanger in-built in the reservoir.

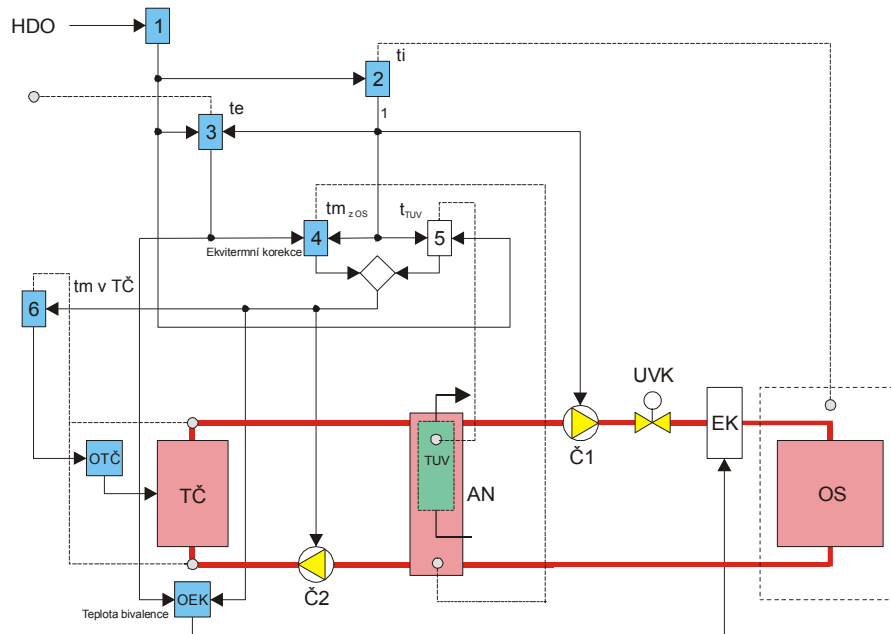


Fig. 6a Example of domestic hot water warming (pre-warming) during heating system operation
Pre-warming in a buffer tank during heating system operation (winter operation)

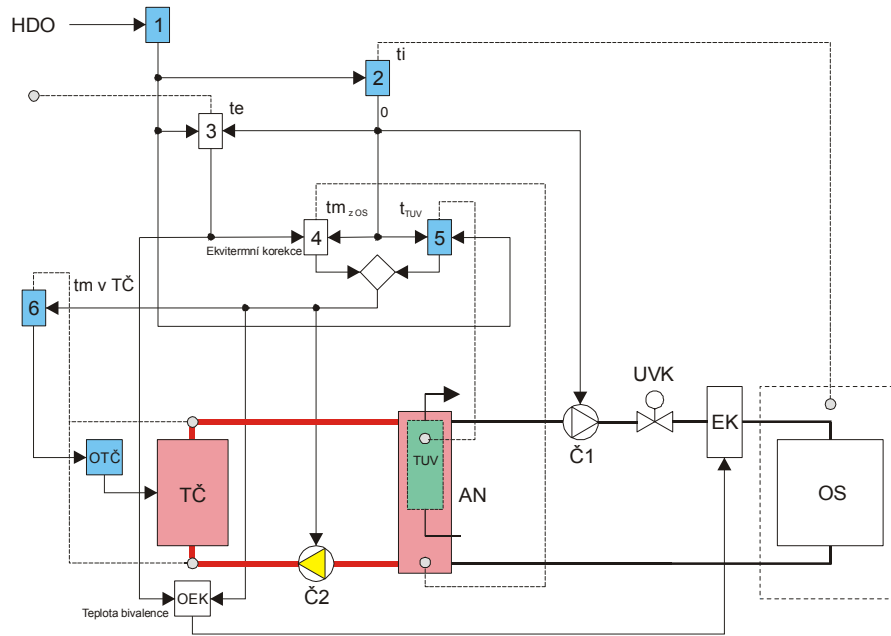


Fig. 6b Example of domestic hot water warming (pre-warming) during heating system operation
Pre-warming in a buffer tank during shutdown of heating system operation (summer operation)

Explanation to the schematics:

AN	...	buffer tank	OEK	...	electric boiler control
Č1	...	circulation pump in the heating system circuit	UVK	...	closing valve
Č2	...	circulation pump in the heat pump circuit	te	...	external temperature – outside temperature
EK	...	electric boiler	ti	...	internal temperature – heated room temperature
OS	...	heating system	tm	...	heating medium temperature
TČ	...	heat pump	t_{TUV}	...	temperature TUV
TUV	...	heat exchanger in a buffer tank			
OTČ	...	heat pump control			

Example of domestic hot water warming (pre-warming) during heating operation Pre-warming in a double-jacket heater (Fig. 7a and 7b).

This method is suitable:

- when the heating system does not need too large buffer tank;
- when the need for domestic hot water is so high, that it is useful to divide its preparation into two heaters; one of them for pre-warming, only additional warming in the second one.

The design must take into consideration the pressure loss of the heater in the heat pump circuit.

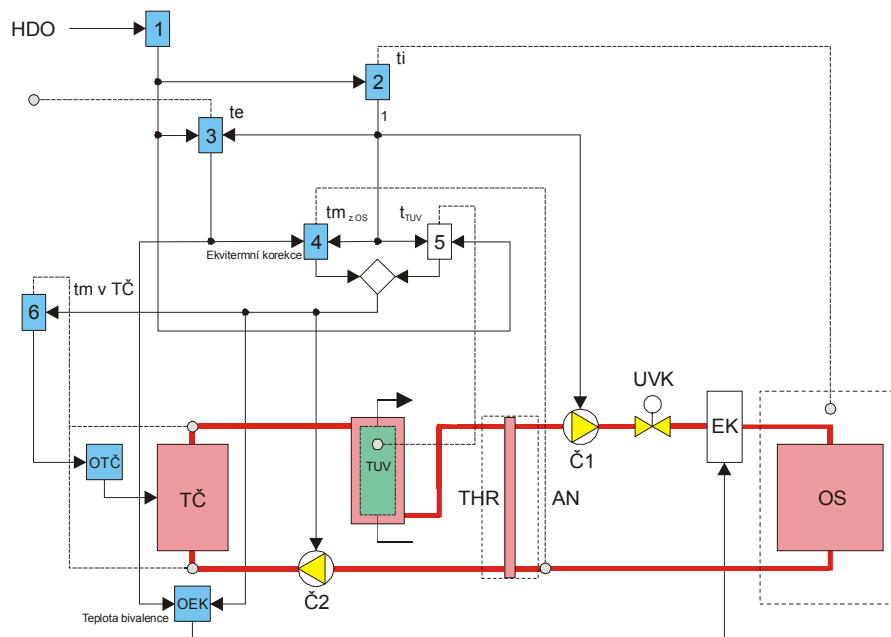


Fig. 7a Example of domestic hot water warming (pre-warming) during heating system operation
Pre-warming in a double-jacket heater during heating system operation (winter operation)

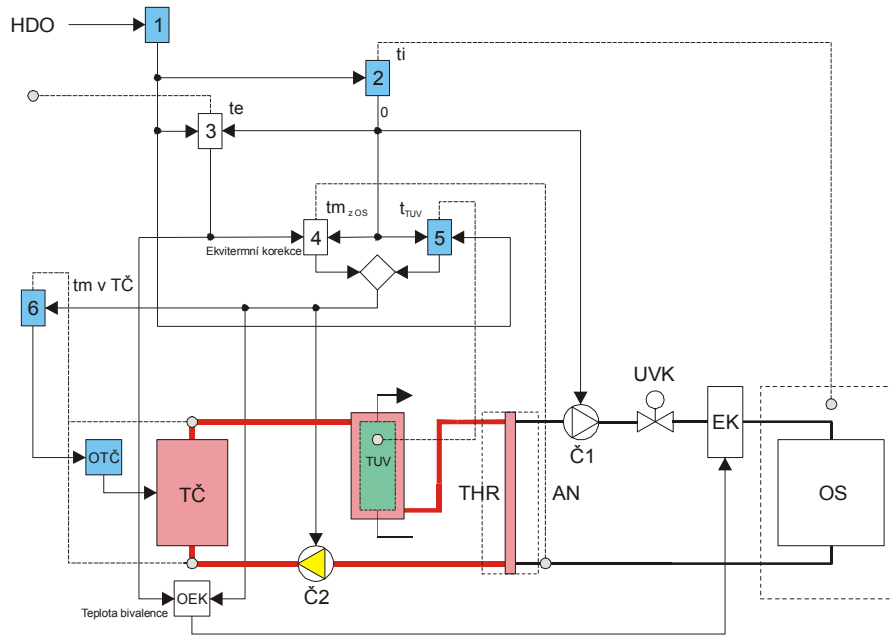


Fig. 7b Example of domestic hot water warming (pre-warming) during heating system operation
Pre-warming in a double-jacket heater during shutdown of heating system operation (summer operation)

Explanation to the schematics:

AN	...	buffer tank	OTČ	...	heat pump control
THR	...	thermo-hydraulic distributor - header	OEK	...	electric boiler control
Č1	...	circulation pump in the heating system circuit	UVK	...	closing valve
Č2	...	circulation pump in the heat pump circuit	te	...	external temperature – outside temperature
EK	...	electric boiler	ti	...	internal temperature – heated room temperature
OS	...	heating system	tm	...	heating medium temperature
TČ	...	heat pump	t_{TUV}	...	temperature TUV
TUV	...	Pre-warming in a double-jacket heater			

3.2 Hot water warming (pre-warming) when the priority is specified whether the system is to warm DHW or heating water for the heating system

It is suitable:

- for floor or wall heating, i.e. for heating systems operating with a „low“ temperature of the heating medium;
- for radiator heating with the regulation of heating medium temperature depending on the outside temperature, so-called equithermic regulation;
- for buildings where the proportion of the heat necessary for domestic hot water preparation is significant.

Water warming (pre-warming) is completely separated from the heating system. The temperature, to which DHW is pre-warmed, is independent of heating medium temperature used for heating. Both temperatures are set independently of each other. If DHW warming is to have priority over heating, this shall be determined by the user of HP by changing the parameter in HP user menu.

This way of DHW warming is specific for HPs incorporating EB as their component. Such EB represents not only a bivalence source but also an electric heating element for DHW additional warming up to a required temperature. In order to make use of warming by means of HP really, additional warming cannot be provided quite independently of pre-warming, it must be suitably linked (e.g. by time).

In the case of this method of water warming, the heating system operates in two modes. In each mode, system connection is changed and operation of the system inclusive the heat pump is controlled

according to different criteria. Mode switching-over and heat pump control according to different temperatures is provided by the control system.

In TCLM KOMPLET HPs of air-water system, DHW warming as well as additional warming within HP runs in a way different from that in HP with the electric boiler; DHW is pre-warmed in a cylinder containing a heat exchanger (e.g. a floating, “tank-in-tank” cylinder) with an electric heating element for additional warming.

Connection according to the following examples does not influence the heating system in any undesirable way. It is however important, that the heating medium return pipeline from the heater is connected between the thermo-hydraulic distributor - header (THR) or the buffer tank (AN) and the heat pump (TC).

An example of hot water warming (pre-warming)

Pre-warming in a heat exchanger cylinder (Fig. 8a, 8b)

The heater is incorporated into the heating system in its source section, i.e. between the heat pump (TC) and the thermo-hydraulic distributor - header (THR) or the buffer tank (AN).

Description of operating modes:

a) Heating mode – priority of heating set by the user (Fig. 8a)

The heat pump (TC) is interconnected with the header (THR) or the buffer tank (AN). The C2 circulation pump provides heating medium circulation between TC and THR (AN). The C1 circulation pump provides heating medium circulation between THR (AN) and the heating system (OS). Operation is controlled according to the temperature of the heating medium returning from OS. Mode change for the „water warming mode“ is made by means of a change in three-way valve (TV) position.

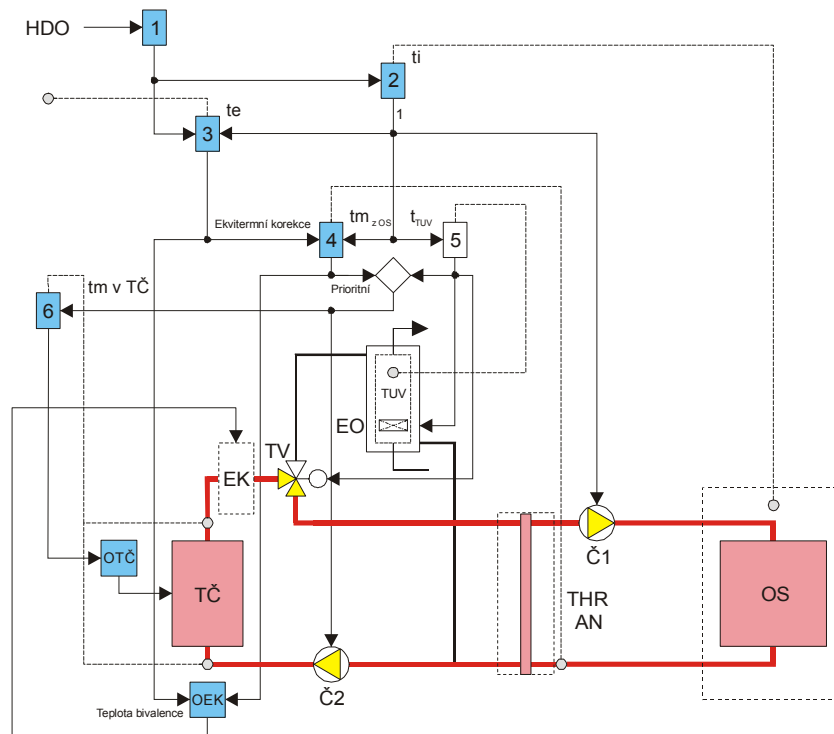


Fig. 8a Example of domestic hot water warming (pre-warming) during heating system idle condition
Pre-warming in a double-jacket heater – Heating mode

b) DHW warming (pre-warming) mode – priority of DHW warming set by the user (Fig. 8b)

- DHW warming (pre-warming) mode for HP with an electric boiler

The heat pump (TC) is interconnected with the heater (EO) preparing domestic hot water. The (C2) circulation pump provides heating medium circulation between the heat pump and the heater after the route is changed over by means of the three-way valve. The (C1) circulation pump of the heating system is shut down. Operation controlled according to water temperature **at the HP outlet**. Mode change for the „heating mode“ is made by means of a change in three-way valve (TV) position as well.

- DHW warming (pre-warming) mode for TCLM KOMPLET HP

The heat pump (TC) is interconnected with the heater (EO) preparing domestic hot water. The (C2) circulation pump provides heating medium circulation between the heat pump and the heater after the route is changed over by means of the three-way valve. The (C1) circulation pump of the heating system is shut down. Operation controlled according to water temperature **at the cylinder**. Mode change for the „heating mode“ is made by means of a change in three-way valve (TV) position as well.

Heating performance concordance as to the heater (at operation temperatures of the heat pump) and the heat pump must be ensured in the design in order to provide pre-warming in TC continuous operation.

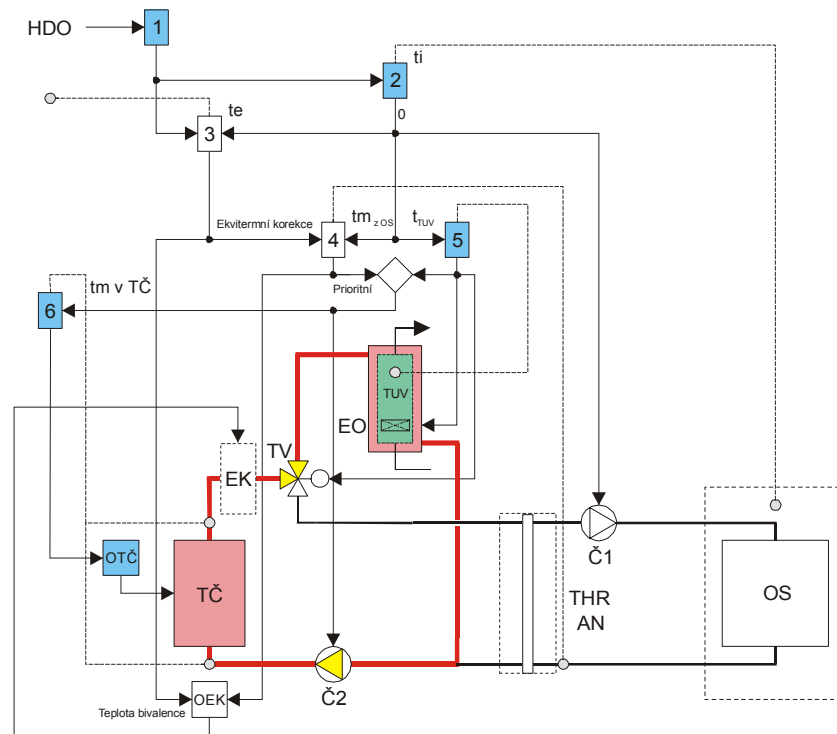


Fig. 8b Example of domestic hot water warming (pre-warming) during heating system idle condition
Pre-warming in a double-jacket heater
The mode of domestic hot water warming (pre-warming)

Explanation to the schematics:

AN	...	buffer tank	OTČ	...	heat pump control
THR	...	thermo-hydraulic distributor - header	OEK	...	electric boiler control
Č1	...	circulation pump in the heating system circuit	TV	...	three-way valve
Č2	...	circulation pump in the heat pump circuit	te	...	external temperature – outside temperature
EK	...	electric boiler	ti	...	internal temperature – heated room temperature
OS	...	heating systém	tm	...	heating medium temperature
TČ	...	heat pump	t _{TUV}	...	temperature TUV
TUV	...	Pre-warming in a double-jacket heater			
EO	...	electric water heater (only for TCLM KOMPLET)			

c) Recommendation for three-way valve connection and selection

In case we use for domestic hot water warming (pre-warming) the system connection shown in the Fig. 8a, 8b, it is necessary to use a servo-driven three-way valve to change over the heating medium circuit. The three-way valve (hereinafter only valve) is to be connected as a distributor, see the figure below. This connection is verified through operation and practice trials. In the case of a different valve connection when changing over the valve, a remarkable flow drop on the heat pump plate exchanger could occur in certain events, which is inadmissible. The connection described above complies with the condition of constant flow.

The correct position of the adjustable slide-valve must be observed when assembling the valve and the servo-drive. Never may occur the situation when the slide-valve closes the heating medium flow completely during changing over from one limit position to the other !!! The slide-valve must rotate in the way shown in the figure. Adherence to correct dimensions of the heater interconnecting pipelines is important as pressure loss may not grow excessively causing thereby drop in the flow through the heat pump.

Suitable three-way valves will be recommended or delivered by the heat pump manufacturer.

Example of domestic hot water warming (pre-warming) during an idle condition of heating.

Pre-warming in a heating cartridge heater

Due to a substantially higher pressure loss on the heating cartridge in comparison with the loss in e.g. a double-jacket heater, it is not convenient to connect it as shown in the previous examples. The suitable connection comprises a separate circulation pump (C3).

The heater is integrated in the take-off section of the heating system, i.e. between the thermo-hydraulic distributor - header (THR) or the buffer tank (AN) and the heating system (OS). In order the circulation pump branches (C1 and C3) cannot influence each other, namely no flow can occur in the shut down circuit, non-return flaps must be set to both pumps. Provided the pumps (C1 and C2) are correctly dimensioned and adjusted, the connection does not influence the heating system in any undesirable way. Concordance of the heater heating performance (at operation temperatures of the heat pump) and the heat pump heating performance must be ensured in the design in order to provide pre-warming in TC continuous operation.

Description of the operating modes:

a) Heating mode (Fig. 9a)

The heat pump (TC) is interconnected with the thermo-hydraulic distributor - header (THR) or the buffer tank (AN). The (C2) circulation pump provides heating medium circulation between TC and THR (AN). The (C1) circulation pump provides heating medium circulation between THR (AN) and the heating system (OS). Operation is controlled (in the equithermic way) according to the temperature of the heating medium returning from the heating system (OS).

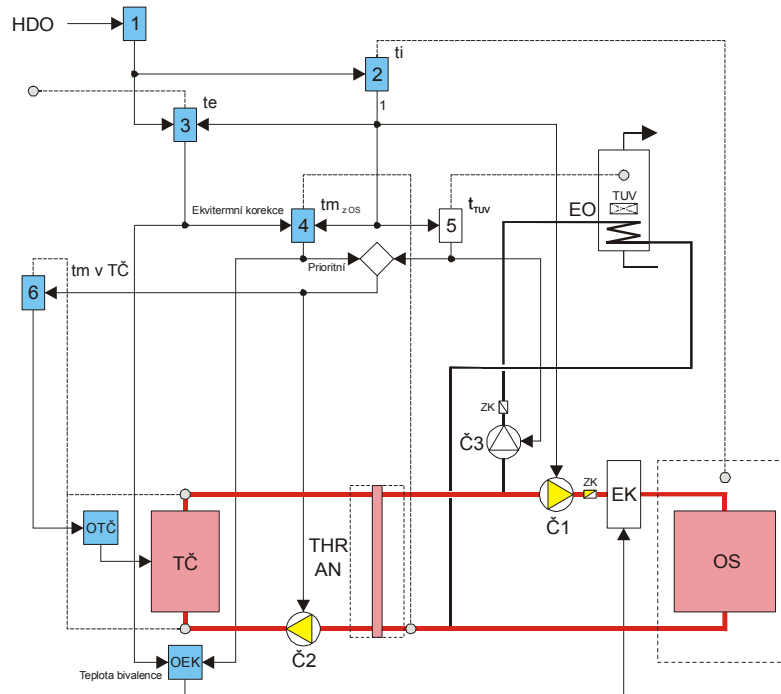


Fig. 9a Example of domestic hot water warming (pre-warming) during heating system idle condition
Pre-warming in a heating cartridge heater – Heating mode

b) The mode of domestic hot water warming (pre-warming) (Fig. 9b)

The connection between the heat pump (TC) and (THR) or (AN) remains unchanged. The circulation pump (C3) is in operation, it provide heating medium circulation between (THR) or (AN) and the heater heating cartridge. Operation is controlled according to the water temperature in the heater. A change in mode is made by change in the functions of the circulation pumps (C1 and C3).

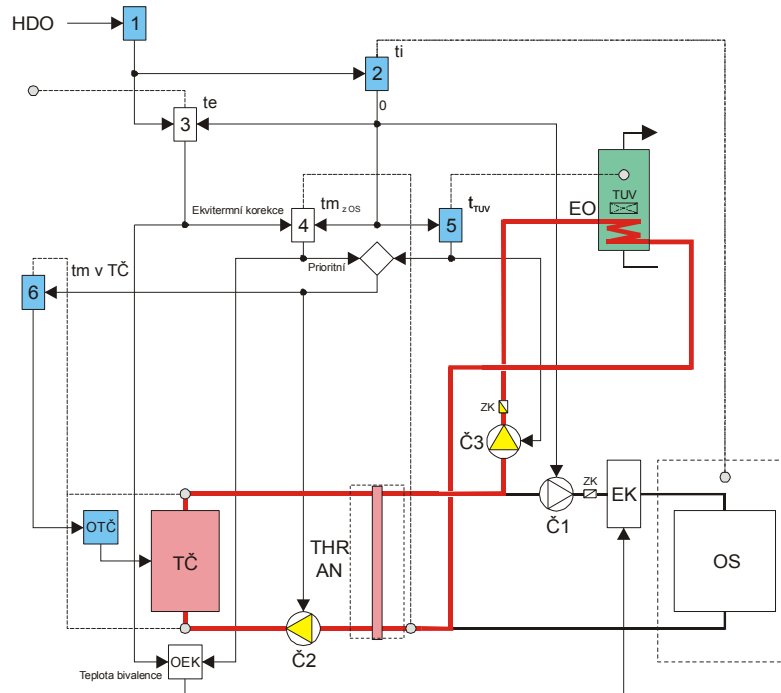


Fig. 9b Example of domestic hot water warming (pre-warming) during heating system idle condition
Pre-warming in a heating cartridge heater – The mode of domestic hot water warming (pre –warming)

Explanation to the schematics:

AN	...	buffer tank	OTČ	...	heat pump control
THR	...	thermo-hydraulic distributor - header	OEK	...	electric boiler control
Č1	...	circulation pump in the heating system circuit	EO	...	electric water heater
Č2	...	circulation pump in the heat pump circuit	ZK	...	non return valve
Č3	...	circulation pump	te	...	external temperature – outside temperature
EK	...	electric boiler	ti	...	internal temperature – heated room temperature
OS	...	heating system	tm	...	heating medium temperature
TČ	...	heat pump	t _{TUV}	...	temperature TUV
TUV	...	Pre-warming in a heating cartridge heater			

Example of domestic hot water warming (pre-warming) during an idle condition of heating

Pre-warming in a heat exchanger

This connection is suitable when concordance of the heat pump performance and the heater warming performance cannot be ensured in the case of the heat pump with high heating performance.

The heat exchanger is integrated in the take-off section of the heating system, i.e. between the thermo-hydraulic distributor - header (THR) or the buffer tank (AN) and the heating system (OS). In order the circulation pump branches (C1 and C3) cannot influence each other namely no flow can occur in the shut down circuit, non-return flaps must be set to both pumps. Provided the pumps (C1 and C2) are correctly dimensioned and adjusted, the connection does not influence the heating system in any undesirable way.

Concordance of the heat exchanger warming performance (at operation temperatures of the heat pump) and the heat pump heating performance must be ensured in the design in order to provide pre-warming in TC continuous operation

Description of the operating modes:

a) Heating mode (Fig. 10a)

The heat pump is interconnected with the thermo-hydraulic distributor - header (THR) or the buffer tank (AN). The (C2) circulation pump provides heating medium circulation between TC and THR (AN). The (C1) circulation pump provides heating medium circulation between THR (AN) and the heating system (OS). Operation is controlled (in the equithermic way) according to the temperature of the heating medium returning from the heating system (OS).

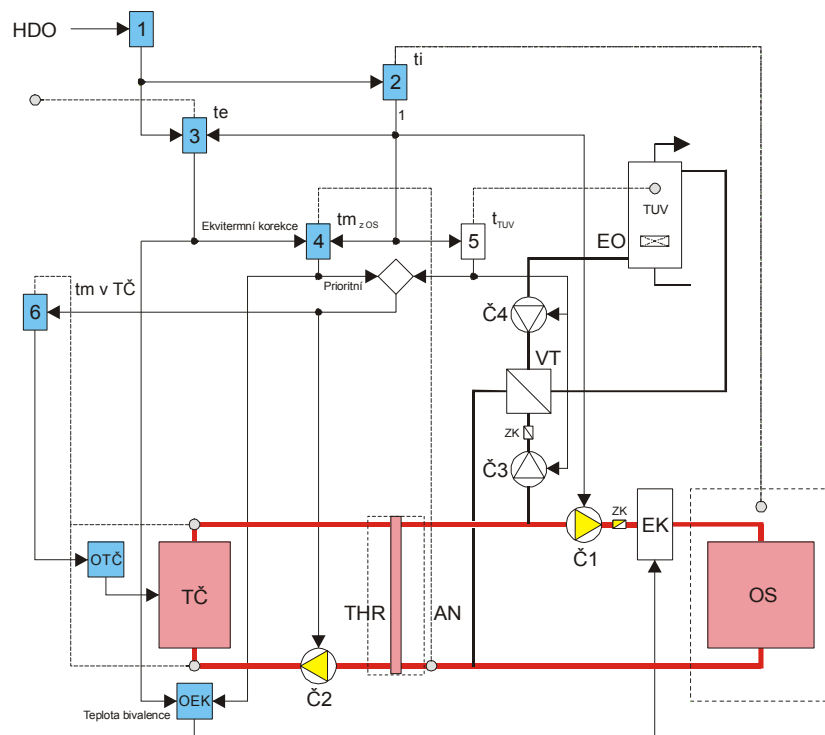


Fig. 10a Example of domestic hot water warming (pre-warming) during heating system idle condition
Pre-warming in a heat exchanger – Heating mode

b) The mode of domestic hot water warming (pre-warming) (Fig. 10b)

The connection between the heat pump (TC) and (THR) or (AN) remains unchanged. The (C1) circulation pump is put out of operation. The (C3) circulation pump is in operation, it provides heating medium circulation between (THR) or (AN) and the heat exchanger. Operation is controlled according to the water temperature in the heater. A change in mode is made by change in the functions of the (C1) and (C3 + C4) circulation pumps.

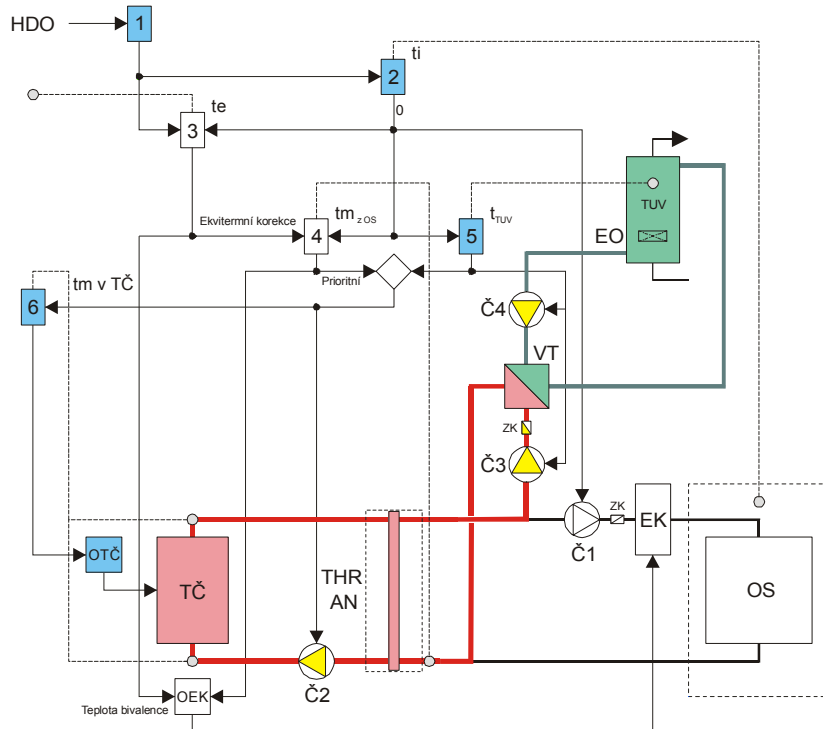


Fig. 10b Example of domestic hot water warming (pre-warming) during heating system idle condition
Pre-warming in a heat exchanger – The mode of domestic hot water warming (pre –warming)

Explanation to the schematics:

AN	...	buffer tank	VT	...	heat exchanger
THR	...	thermo-hydraulic distributor - header	OTČ	...	heat pump control
Č1	...	circulation pump in the heating system circuit	EO	...	electric water heater
Č2	...	circulation pump in the heat pump circuit	ZK	...	non return valve
Č3	...	circulation pump	te	...	external temperature – outside temperature
Č4	...	circulation pump	ti	...	internal temperature – heated room temperature
EK	...	electric boiler	tm	...	heating medium temperature
OS	...	heating system	t _{TUV}	...	temperature TUV
TČ	...	heat pump			
TUV	...	heater for water additional warming			

4. A heating system comprising the heat pump and a gas boiler as a complementary heat source

The previous paragraphs deal primarily with the connections of the heating systems with the heat pump where an electric boiler (electric heating element) is used as a complementary-bivalence heat source. In the case of gas boiler use as that complementary source, the connection must be adapted to specific features of this boiler. With respect to a row of different models of gas boilers, the following is applicable:

The heat pump manufacturer must approve any connection comprising a gas boiler.

Figure 11 shows a general solution, which is to be adapted to specific features of each gas boiler. The general solution is based on several fundamental prerequisites:

- a) the gas boiler is equipped with its own circulation pump;
- b) the amount of the heating medium circulating through the gas boiler is smaller than that in the heating system (as a rule, working temperature difference in the gas boiler is higher than that in the heat pump);
- c) the gas boiler control system is employed without any modification;
- d) an initiating pulse ensures coordinated boiler operation inclusive the circulation pump;
- e) gas boiler operation is released only if:
 - temperature is lower than the bivalence condition temperature;
 - a heat pump failure occurs

Through its inlet as well as outlet, the gas boiler is connected to the „through“ header (thr) providing independent heating medium flow both in the heating system and in the gas boiler and eliminating disproportions both in flow rates and in heating medium temperatures (working differences in temperatures) by means of mixing.

Figure 11a shows the operating mode in the case when outside temperatures is „higher than the bivalence condition temperature“.

Figure 11b shows the operating mode in the case when outside temperatures is „lower than the bivalence condition temperature“.

In this connection, domestic hot water warming (pre-warming) possibilities are quite analogous to the pre-warming possibilities in the heat pump + electric boiler systems.

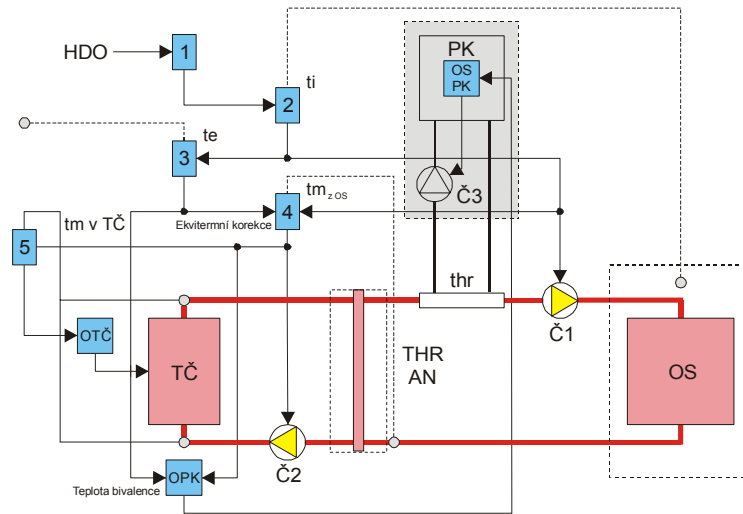


Fig. 11a General design of the heating system comprising the heat pump and a gas boiler as a complementary-bivalence source
Operating mode in the case of outside temperatures higher than the "bivalence condition temperature"

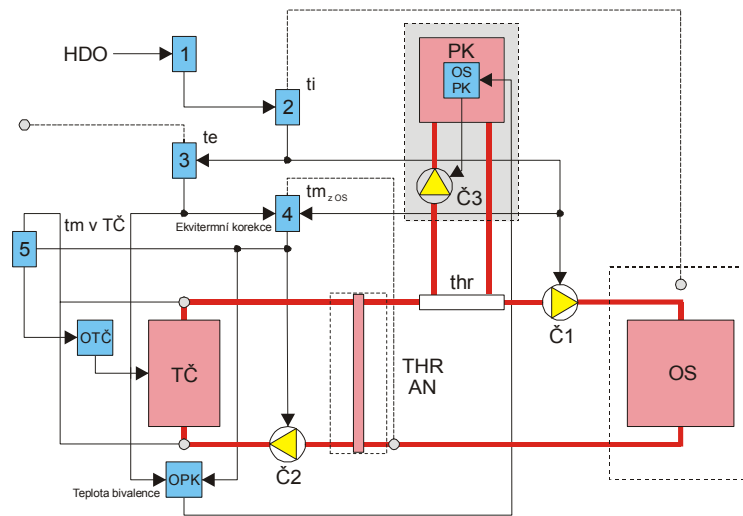


Fig. 11b General design of the heating system comprising the heat pump and a gas boiler as a complementary-bivalence source
Operating mode in the case of outside temperatures lower than the "bivalence condition temperature"

Explanation to the schematics:

AN	...	buffer tank	THR	...	thermo-hydraulic distributor - header
Č1	...	circulation pump in the heating system circuit	OTČ	...	heat pump control
Č2	...	circulation pump in the heat pump circuit	OPK	...	gas boiler control
Č3	...	circulation pump	OSPK	...	gas boiler control system
EK	...	electric boiler I	te	...	external temperature – outside temperature
OS	...	heating system	ti	...	internal temperature – heated room temperature
TČ	...	heat pump	tm	...	heating medium temperature
PK	...	gas boiler			

5. Working difference in heating medium temperatures

The principle of temperature regulation of the heating medium in the case of the „air-water“ heat pump

The working difference in heating medium temperatures on the bivalence source (heat pump + electric boiler) is important for heating system design.

For the „air-water“ heat pump, changes in the working temperature difference on the bivalence source during a heating period, i.e. as depending on outside environment temperature, are indicated in the 12a figure.

The following factors influence the changes in the working temperature difference:

- When the heating medium flow through the source (primarily the heat pump) is constant, temperature difference alters with the heat pump performance change, i.e. depending on outside temperature (environment temperature) or the temperature of the primary circuit heating medium.
- When the environment temperature drops below the bivalence condition temperature, the bivalence source is connected as needed. A step-by-step increase (in stages) in working temperature difference relates to a step-by-step increase (in stages) in source performance. When changing over EK in stages, two bivalence condition temperatures (BB and BB2) can be employed.
- At the outside calculating temperature, the aggregate working temperature difference depends on relative heat pump size, i.e. on the ratio of performances provided by the heat pump and the electric boiler at the calculating temperature. Below the bivalence condition temperature (BB), the electric boiler operation is controlled according to the temperature of the heating medium returning from the heating system, in the same way as heat pump operation.

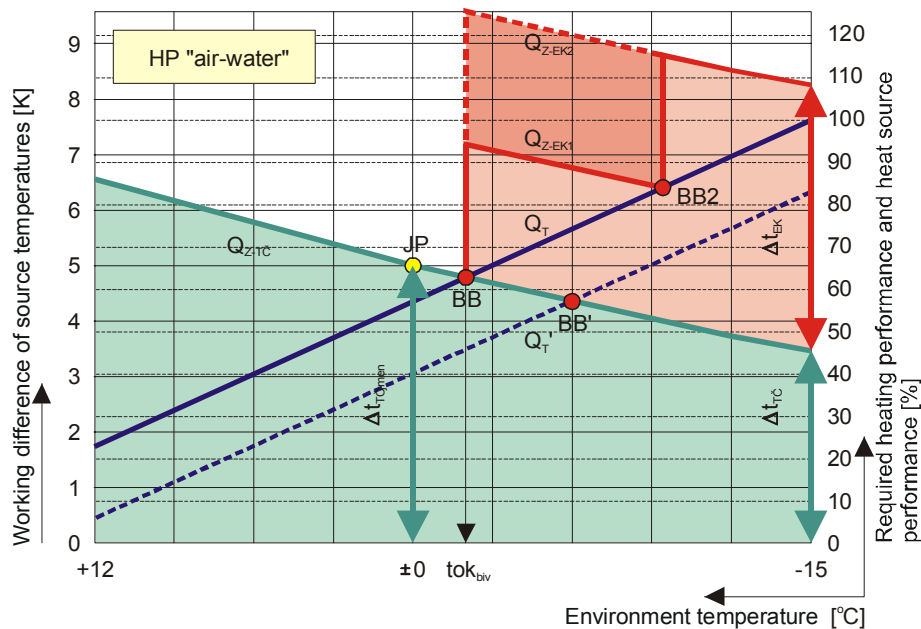


Fig. 12a Dependence of source working temperature difference on environment temperature

Explanation :

BB	...	bivalence condition temperature
JP	...	nominal working conditions
Q _T	...	required heating performance
Q _{Z-Tc}	...	source heating performance in the heat pump temperatures
Q _{Z-EK}	...	source heating performance in the electric boiler part
Δt _{Tc}	...	working difference of heat pump temperatures
Δt _{EK}	...	working difference of electric boiler temperatures

The control working on the principle of multistage thermostat is shown in Fig. 12b. It is obvious from the figure that the highest operating difference of temperatures is not reached at the highest temperature of heating medium. All those facts must be taken into consideration when designing a heating system.

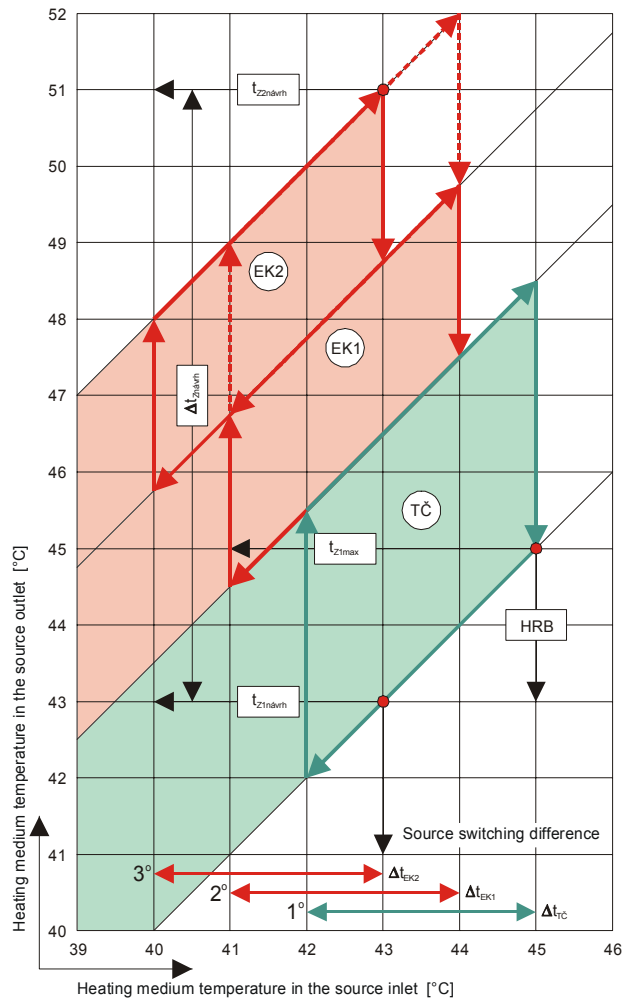


Fig. 12b Dependence of the principle of heating medium temperature control in stages in the bivalence source

Explanation :

- TČ ... Heat pump
- EK1 ... Electric boiler 1st stage
- EK2 ... Electric boiler 2nd stage
- HRB ... The main regulation point – required temperature