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(54) Title: METHOD FOR OPERATING A TEMPERATURE-CONTROLLED CIRCULATION SYSTEM, AND THE TEMPERATURE-CONTROLLED CIRCULATION SYSTEM

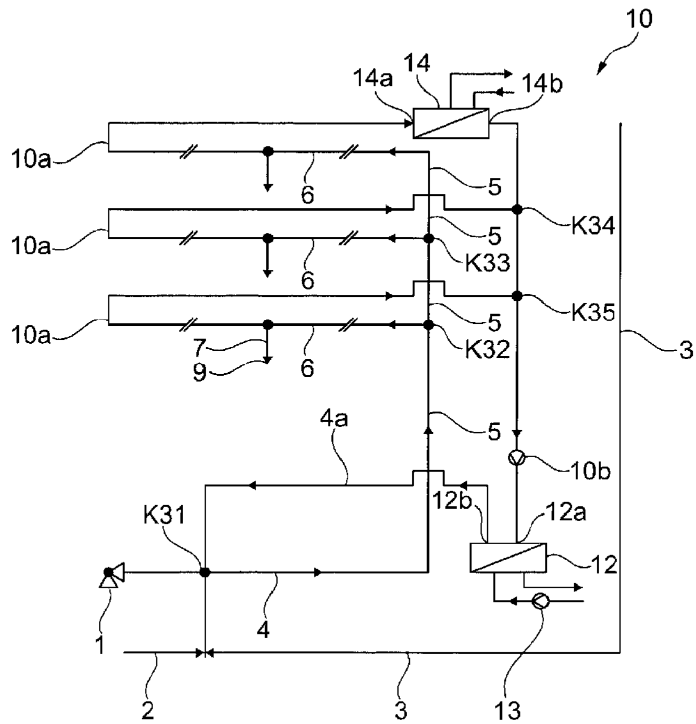

Fig. 3

(57) Abrégé/Abstract:
The invention relates to a method for operating a circulation system (10) comprising a heating device having an inlet port and an outlet port for controlling the temperature of water, and comprising a pipe system having a plurality of strings which include one or

(57) Abrégé(suite)/Abstract(continued):
more sections of a given thermal coupling to the surroundings and are connected by means of nodes, one or more of the pipes of the pipe system being designed as a supply pipe (4, 5, 6), at least one individual delivery pipe (7) connected to a removal point (9) and at least one pipe designed as a circulation pipe (10a) being connected to the supply pipe(s) (4, 5, 6), said method comprising the steps: - setting a water temperature at the outlet port to a value Ta by means of the heating device; - setting a volumetric flow rate at the inlet port to a value Vz, and comprising the following steps: - determining, in particular calculating, a temperature change of the water between the start region and the end region according to a model of the axial temperature change for the first section connected to the outlet port, starting from a temperature start value TMA* and a volumetric flow rate start value Vz*; - determining, in particular calculating, a temperature change of the water between the start region and the end region for each further given section according to the model of the temperature change, subject to the boundary condition that the water temperature in the start region of the given section is the same as the water temperature in the end region of the section to which the given section is connected; and - selecting the value Ta of the water temperature and the value Vz of the volumetric flow rate at the outlet port in such a way that in the end region of each section the water temperature TME is in a specified temperature range around Tsoll, in particular at the inlet port (12a, 14b) the water temperature $Tb < Tsoll$ is set with $Tsoll - Tb < \Theta$, where $\Theta > 0$ is a specified value. Furthermore, the invention also relates to a circulation system for carrying out the method.

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(54) Title: METHOD FOR OPERATING A TEMPERATURE-CONTROLLED CIRCULATION SYSTEM AND TEMPERATURE-CONTROLLED CIRCULATION SYSTEM

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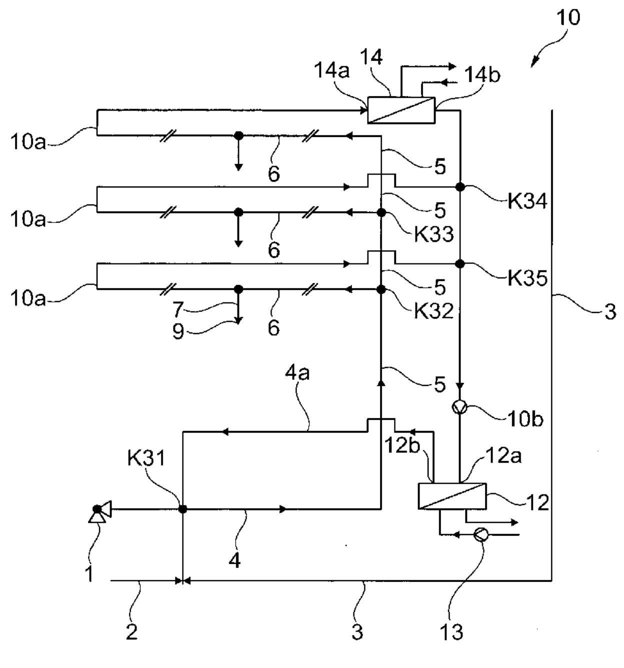

Fig. 3

(57) Abstract: The invention relates to a method for operating a circulation system (10) comprising a heating device having an inlet port and an outlet port for controlling the temperature of water, and comprising a pipe system having a plurality of strings which include one or more sections of a given thermal coupling to the surroundings and are connected by means of nodes, one or more of the pipes of the pipe system being designed as a supply pipe (4, 5, 6), at least one individual delivery pipe (7) connected to a removal point (9) and at least one pipe designed as a circulation pipe (10a) being connected to the supply pipe(s) (4, 5, 6), said method comprising the steps: - setting a water temperature at the outlet port to a value Ta by means of the heating device; - setting a volumetric flow rate at the inlet port to a value Vz, and comprising the following steps: - determining, in particular calculating, a temperature change of the water between the start region and the end region according to a model of the axial temperature change for the first section connected to the outlet port, starting from a temperature start value TMA* and a volumetric flow rate start value Vz*; - determining, in particular calculating, a temperature change of the water between the start region and the end region for each further given section according to the model of the temperature change, subject to the boundary condition that the water temperature in the start region of the given section is the same as the water temperature in the end region of the section to which the given section is connected; and - selecting the value Ta of the water temperature and the value Vz of the volumetric flow rate at the outlet port in such a way

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Veröffentlicht:
— *mit internationalem Recherchenbericht (Artikel 21 Absatz 3)*
— *mit Informationen über die Einbeziehung von fehlenden Teilen und/oder Bestandteilen durch Verweis (Regel 20 Absatz 6)*

that in the end region of each section the water temperature TME is in a specified temperature range around Tsoll, in particular at the inlet port (12a, 14b) the water temperature Tb < Tsoll is set with Tsoll - Tb < Θ, where Θ > 0 is a specified value. Furthermore, the invention also relates to a circulation system for carrying out the method.

(57) Zusammenfassung: Verfahren zum Betrieb eines Zirkulationssystem (10) mit einer Heizvorrichtung mit einem Eingangsport und einem Ausgangsport zur Temperierung von Wasser und mit einem Leitungssystem mit mehreren Strängen, welche eine oder mehrere Teilstrecken mit gegebener Wärme Kopplung mit einer Umgebung aufweisen und mittels Knoten verbunden sind, wobei eine oder mehrere der Leitungen des Leitungssystems als Vorlaufleitung (4, 5, 6) ausgebildet sind, zumindest eine mit einer Entnahmestelle (9) verbundene Einzelzuleitung (7) und zumindest eine als Zirkulationsleitung (10a) ausgebildete Leitung mit der oder den Vorlaufleitungen (4, 5, 6) verbunden ist, mit den Schritten - Einstellen einer Wassertemperatur am Ausgangsport auf einen Wert Ta mittels der Heizvorrichtung - Einstellen eines Volumenstroms am Eingangsport auf einen Wert Vz und mit folgenden Schritten - Ermitteln, insbesondere Berechnen, einer Temperaturänderung des Wassers zwischen Anfangsbereich und Endbereich entsprechend einem Modell der axialen Temperaturänderung für die erste an den Ausgangsport angeschlossene Teilstrecke, ausgehend von einem Temperatur - Startwert TMA* und einem Volumenstrom - Startwert Vz*, - Ermitteln, insbesondere Berechnen, einer Temperaturänderung des Wassers zwischen Anfangsbereich und Endbereich für jede weitere gegebene Teilstrecke entsprechend dem Modell der Temperaturänderung, unter der Randbedingung, dass die Wassertemperatur im Anfangsbereich der gegebenen Teilstrecke gleich der Wassertemperatur im Endbereich der Teilstrecke ist, an die die gegebene Teilstrecke angeschlossenen ist und - Wählen des Wertes Ta der Wassertemperatur und des Wertes Vz des Volumenstroms am Ausgangsport, derart, dass im Endbereich jeder Teilstrecke die Wasser - Temperatur TME in einem vorgegeben Temperaturintervall um Tsoll liegt, insbesondere sich am Eingangsport (12a, 14b) die Wassertemperatur Tb < Tsoll mitTsoll - Tb < Θ einstellt, wobei Θ > 0 ein vorgegebener Wert ist. Darüber hinaus gibt es auch ein Zirkulationssystem zur Ausführung des Verfahrens.

Specification

Method for operating a temperature-controlled circulation system, and the temperature-controlled circulation system

The invention relates to a method for operating a circulation system, as well as the circulation system, each time according to the features of the preambles of the independent claims.

In order to prevent microbial growth in cold water networks, DIN EN 806 as well as VDI Guideline 6023 require for potable water installations in buildings a limiting of the temperature of the cold potable water (PWC) in all lines of the installations at all times to a value of not more than +25° C. According to DIN EN 806-2,3.6, the water temperature for cold water locations should not go beyond +25° C within 30 seconds of the full opening of a tapping point. Moreover, in order to prevent a stagnation of the water, the cold water installation should be designed so that, under normal operating conditions, the potable water is regularly replenished in all lines of the installation. Similarly, the VDI Guideline 6023 also contains the recommendation of holding the temperature of the potable water as much as possible below +25° C. Naturally, a limiting of the temperature of water is often also seen as necessary for other water installations, such as installations for industrial process water.

The occurrence of high PWC temperatures is favored by the solitary or combined occurrence of various circumstances, including:

- high PWC temperatures already at the household junction,
- thermal influencing of the regions of the installation, for example by the position and orientation of the building or the regions of the installation within the building,
- inadequate insulation of the PWC pipelines to keep out heat,
- installation of PWC pipelines in rooms and equipment spaces with heat sources, in common installation areas such as shafts, ducts, suspended ceilings and installation walls with heat-producing media (such as heating system pipelines, potable hot water (PWH) and potable hot water circulation systems (PWH-C), air intake and air exhaust ducts, lamps),
- phases of the stagnation in the aforesaid installation regions,
- highly branching PWC installations with concomitant large installation volumes,
- overly large dimensioned PWC pipelines.

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The method of preference in the effort to meet the mandated rules in stagnation phases is thus far the forced flushing of the installations in order to simulate the desired operation in these phases.

In order to provide cold potable water, various cooled circulation systems have already been proposed for the cold water network.

A cooled circulation system is already known from EP 1 626 034 A1, in which a controlled adding of a disinfectant to the water is proposed.

From DE 10 2014 013 464 A1 there is known a method for the operating of a circulation system with a heat storage, a circulation pump, a regulating unit, and at least two branches, and having an otherwise unknown pipe network structure. The branches, each possessing a valve adjustable by a driving motor, are matched up with temperature sensors, which are situated upstream from each mixing point between the branches. The driving motors and/or the circulation pump are connected for the data exchange to the regulating unit in wireless or wired manner. The regulating unit is designed to carry out a thermal and hydraulic balancing and a thermal disinfecting by limiting the range of metered temperatures and/or by adapting the pump power in dependence on a difference between an actual temperature value and a target temperature value.

From DE 20 2015 007 277 U1 there is known a potable water and service water supply arrangement of a building having a household junction for cold water, which is connected to the public supply network. The supply arrangement comprises at least one circulation conduit, which is provided with a pump and which leads to at least one consumer. A heat exchanger, extracting heat from the water, is provided in the circulation conduit.

Moreover, there is described in EP 3 159 457 A1 a potable water and service water supply arrangement of the kind known from DE 20 2015 007 277 U1, wherein the heat exchanger is formed by a latent heat storage and comprises a motorized flushing valve provided in the circulation conduit, being connected to a control device for control purposes. The flushing valve is arranged between the latent heat storage and the point where the household junction enters the circulation conduit, being situated downstream from the latent heat storage in the flow direction.

The known circulation systems with cooling of the water do not assure, or do not effectively assure, that the water temperature remains below the desired temperature for all partial sections and for all times during the operation of the circulation system.

In PCT/EP2019/062547 of the applicant of the present application, a method is already described for operating a circulation system with a cooling device, involving the steps:

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- determining, especially calculating, a temperature change of the water between a starting range and an ending range, corresponding to a model of the axial temperature change for the first partial section connected to the outlet port (12b, 14b), starting from a starting temperature value $T_{MA}* < T_{soll}$ and a starting volume flow value V_z*,

- determining, especially calculating, a temperature change of the water between a starting range and an ending range for each given additional partial section corresponding to the model of the temperature change, under the boundary condition that the water temperature in the starting range of the given partial section is equal to the water temperature in the ending range of the partial section to which the given partial section is connected, and

- selecting the value T_a of the water temperature and the value V_z of the volume flow at the outlet port (12b, 14b) such that, in the ending range of each partial section, the water temperature is $T_{ME} < T_{soll}$ and at the inlet port (12a, 14b) the water temperature is set at $T_b < T_{soll}$ with $T_{soll} - T_b < \theta$, where $\theta > 0$ is a predetermined value.

The content of the above cited PCT/EP2019/062547 is taken over entirely by reference in the disclosure of the present application.

A similar problem for a cold water network also exists in the case of a hot water network. Here, the operating temperatures will change, but instead of a cooling device there is an accumulator or heater. The temperatures in the hot water network should be between 60° C at the accumulator outlet and 55° C at the accumulator inlet. By contrast with the cold water network, where a temperature rise results from heat uptake from the surroundings, heat losses result in a temperature drop in the hot water network.

The problem which the present invention proposes to solve is therefore to ensure in effective manner that the water temperature remains in a desired temperature range for all partial sections and for all times during the operation of a circulation system.

Moreover, one problem which the present invention proposes to solve is to effectively ensure that the water temperature remains above a nominal temperature for all partial sections and for all times during the operation of a circulation system.

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The problem is solved according to the invention with the features of the independent patent claims.

In general, therefore, the invention also includes the case, with corresponding adaptations of the formulas used for the calculation per the model, that a temperature-control device such as a heat exchanger is used in place of a cooling device, which can heat or cool the water. Preferably, the temperature-control device is configured as a heating device.

The method according to the invention relates in particular to a circulation system having a temperature-control device with an input port and an output port for the cooling of water and having a pipeline system with multiple branches comprising one or more partial sections with given thermal coupling to the surroundings and being connected by means of nodes, wherein one or more of the lines of the pipeline system are configured as a flow pipe, at least one as a single supply line connected to a tapping point, and at least one line configured as a circulation conduit connected to the flow pipe or pipes.

The method according to the invention for operating the circulation system is characterized in that a temperature change of the water between the initial region and the end region is determined according to a model of the axial temperature change for the first partial section connected to the output port, starting from a temperature start value $T_{MA}^* < T_{soll}$ and a volume flow start value V_z^*, a temperature change of the water between the initial region and the end region is determined for each further given partial section connected to the first partial section according to the model of the temperature change, under the boundary condition that the water temperature in the initial region of the given partial section is equal to the water temperature in the end region of the partial section to which the given partial section is connected in the flow direction of the water, and the value T_a of the water temperature and the value V_z of the volume flow at the output port are chosen such that, in the end region of each partial section of the circulation system, the water temperature is $T_{ME} < T_{soll}$ and at the input port the water temperature is set at $T_b < T_{soll}$ with $T_{soll} - T_b < \theta$, where $\theta > 0$ is a given value.

Preferably, the determining consists in a calculating, according to the model, of the axial temperature change of the water between the initial region and the end region of the partial section, i.e., the corresponding piece of conduit, based on heat uptake from the surroundings of the partial section. Thus, beginning with the first partial section connected to the temperature-control device, one moves successively through the entire system of partial sections and therefore calculates the temperature in the overall system.

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According to the invention, the value T_a of the water temperature and the value V_z of the volume flow at the output port are determined in the method for which the water temperature is $T_{ME} < T_{soll}$ in the end region of each partial section of the circulation system and the water temperature $T_b < T_{soll}$ at the input port is $T_{soll} - T_b < \theta$, where $\theta>0$ is a given value, by means of a modeling of temperature and volume flows of the circulating water in the conduit system, preferably by a calculation. This is done preferably for a state with steady Vz.

The temperature-control device and possibly a circulation pump of the circulation system are then adjusted so that the water temperature and the volume flow take on the ascertained values of T_a and the value of V_z.

It is proposed according to the invention that a temperature is set at an output port, and temperature changes are calculated based on this and used for the modeling according to the characterizing passage of claim 1.

The advantage of a calculation is that no sensor is needed to measure anything, and one can evaluate and vary factors of influence and possibly also make predictions.

Calculation offers the advantage over a two-point regulating system and/or a cascade control of building floors or a control by pipeline branches that fewer metering points are required and the system as a whole is less prone to oscillations.

Thus, the regulation according to the invention, as opposed to the prior art, is accomplished by means of a setpoint operation at the output port, although the design of the regulator is based on the overall water conduit system with distributed parameters and a calculation of multiple temperatures TME. Hence, basically only one regulator and only one temperature setting are required to provide the temperature Ta.

The following formula holds for both the temperature drop in a hot water network and the temperature rise in a cold water network.

$$\Delta\vartheta = \dot{q}\frac{l}{\dot{\mathrm{m}} \cdot cw} = \dot{q}\ \frac{l}{\dot{\mathrm{V}} \cdot p \cdot cw}$$

$\dot{q}$ = specific heat flux in W / m

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$\Delta\vartheta = \vartheta_{\text{medium start}} - \vartheta_{\text{medium end}}$ hot water

$\Delta\vartheta = \vartheta_{\text{medium end}} - \vartheta_{\text{medium start}}$ cold water

The invention therefore also encompasses the similar instance of a hot water network, where a reservoir or heater is used in place of a temperature-control device.

Moreover, the above given formulas also hold in a cold water network if the temperature of the water is higher than the ambient temperature.

In general, therefore, the invention encompasses, al already mentiond, with corresponding adaptations of the formulas used for the calculation according to the model, the case of using a heat exchanger in place of a temperature-control device, which can heat or cool the water.

The term branch signifies a line consisting of a partial section or multiple partial sections between two nodes, with no further nodes lying between them. The branches are connected across nodes.

Preferably, the boundary condition that the water temperature in the initial region of the given partial section is equal to the water temperature in the end region of the partial section to which the given partial section is connected pertains only to the partial sections of a respective branch.

The temperature and the magnitude of the volume flow emerging from one node into an adjacent partial section depends on the temperatures and magnitudes of the incoming volume flows. The invention preferably assumes these to be given by the design of the pipeline system.

The apportionment of the volume flows exiting from a node among the different outgoing lines or partial sections is preferably assumed by the invention as being given by the design of the pipeline system.

Preferably, mix temperatures when branches join together and the temperatures when branches are divided are calculated based on a percentage volume flow apportionment.

In the method according to the invention, the pipeline system is assumed as given, it being understood that the pipeline system is designed in accordance with the rules of DIN 1988-300 for the design of pipe networks, specifying in particular certain nominal widths of the PWC (Potable Water Cold) lines and values for the thermal coupling of the circulating water to the

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surroundings. It is understood that the designs of the pipe network specified or recommended in other countries or regions can also be generally heeded.

Preferably, the highest permissible value according to the design of the pipeline system is chosen as the volume flow start value V_z*. This value is decreased until such time as the temperature of the circulating water is close to T_{soll}, since with diminishing volume flow the temperature of the circulating water increases and therefore the temperature at the input port increases.

Preferably, the value T_{MA}* is varied and the highest value T_a of the water temperature is chosen for which the water temperature at the input port is $T_b < T_{soll}$ with $T_{soll} - T_b < \theta$, where $\theta > 0$ is a predetermined value.

Given $T_{soll} - T_b < \theta$, it is ensured that the water temperature in the circulation system is not set too cold and the system is not operated in an energy ineffective manner. Typically, θ lies in a range between 1° C and 5° C, but it may also lie in another range.

The determination of the temperature change of the water between the initial and end region of each partial section can be done according to models which are known in themselves, for example by simulation calculations or also appropriate known formulas.

When implementing the method according to the invention, the circulation system is preferably operated in a state in which no water removal and no water uptake occurs, because in this state a greater heating of the water may be expected than in a state in which a water removal occurs, and therefore a safety margin from a state with undesirably high water temperature is assured by using the parameters T_a and V_z as determined by the method.

The parameters T_a and V_z as determined by the method are used advantageously to model a given circulation system, in which the pipeline system is designed in accordance with the legal specifications regarding nominal widths and thermal coupling of the circulating water to the surroundings, and to operate it such that the mandated rules regarding the temperature of the potable water in the circulation system are fulfilled.

Simulations of the applicant for already existing systems have revealed that, by using the parameters set according to the invention: a) the mentioned legal requirements are fulfilled, and b) a greater energy efficiency of the system operation is achieved.

The parameters T_a and V_z as determined by the method are used advantageously in order to determine the design of the temperature-control device in terms of its cooling power in a given

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circulation system, in which the pipeline system is designed in accordance with the legal specifications regarding nominal widths and thermal coupling of the circulating water to the surroundings. Moreover, the design of a circulation pump may be determined in regard to its pumping power.

The following terms shall be used in this text with a specific meaning, the definition relying on the standard DIN EN 806.

The circulation conduit of the circulation system denotes a conduit downstream from a tapping point in the circulation, in which water runs from the output port of a temperature-control device back to the input port of the temperature-control device, if no further tapping point is connected to this conduit.

The term node is used for a conduit element to which conduits are connected. Either at least two volume flows may enter a node and exactly one volume flow depart from it, or exactly one volume flow may enter and at least two volume flows may depart from it. A node corresponds to a branching point.

Preferably, exactly two volume flows enter a node of the circulation system and one volume flow departs from it, or exactly one volume flow enters and exactly two volume flows depart from it, for example, in the manner of a T-piece.

Kirchhoff's first law applies to the nodes of the circulation system, by analogy with electrical circuits, whereby the sum of the incoming volume flows is equal to the sum of the outgoing volume flows.

Preferably, the outgoing volume flows at each node point are apportioned in departing volume flows of equal size. It is to be understood that other apportionments are also possible.

For a node with exactly one departing volume flow with different temperatures and exactly one entering volume flow it is preferably assumed that the temperature t_m and the mass flow m_m of the mix water of the departing volume flow are related by the following equation to the temperature tk and mass flow mk of the colder flow or the temperature tw and mass flow mw of the warmer flow:

$$t_m = \frac{t_k * m_k + t_w * m_w}{m_m}$$

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t_m = Temperature of mix water (°C)
t_k = Temperature of colder water (°C)
t_w = Temperature of warmer water (°C)
m_m = Mass/volume (flow) of mix water (kg; m³; kg/h; m³/h or %)
m_k = Mass/volume (flow) of cold water (kg; m³; kg/h; m³/h or %)
m_w = Mass/volume (flow) of warm water (kg; m³; kg/h; m³/h or %)

For the determination of the temperature change of the water between the initial and end region of a partial section, the following parameters can be used preferably, along with the length of the partial section

T_{Luft} = the temperature of the ambient air(°C)
k_R = the heat transfer coefficient of the pipeline (W/(m*K))
m_M = the mass flow of the water in the partial section (kg/ s)
$c_{p,m}$ = the spec. heat capacity of the water (J/(kg*K)
V_M = the volume flow of the water in the partial section (m^3/s)
p_M = the density of the water (kg/m^3)

Advantageously, a temperature change of the water between the initial region and the end region can be determined for each partial section of the circulation system during a stationary volume flow, wherein the water temperature in the end region of a given partial section is chosen equal to the water temperature in the initial region of the partial section to which the given partial section is connected in the flow direction of the circulating water. Therefore, for each partial section of the circulation system it is possible to determine the temperature of the water in the end region of the respective partial section by starting from the temperature in the initial region.

Advantageously, starting from a temperature at the output port during a stationary volume flow it is possible to determine the temperature of the circulating water for each partial section, i.e., it is also possible to determine a value T_a of the water temperature at the output port as the initial temperature of the partial section adjacent to the output port such that the water temperature is $T_{ME} < T_{soll}$ for the end regions of all partial sections.

In a further embodiment of the invention it is proposed that the values T_a and V_z are determined in an iterative approximation procedure, wherein the water temperature T_{ME} in the end region is calculated for each given partial section, starting from a temperature start value $T_{MA}* < T_{soll}$ and a volume flow start value V_z* for the first partial section connected to the output port, the water

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temperature T_{MA}' in the initial region of the next connected partial section being chosen equal to the water temperature T_{ME} in the end region of the given partial section.

In a further embodiment of the invention it is proposed that the partial sections are designed axially uniformly in regard to their thermal coupling to the surroundings along the length between their initial region and their end region, i.e., they do not change axially. This enables a simplification of the computations.

In a further embodiment of the invention it is proposed that the water temperature T_{ME} in the end region of at least one partial section with length L is determined by means of the formula

$$T_{ME} = (T_{MA} - T_{Luft}) * e^{-\varepsilon * L} + T_{Luft}$$

$$\varepsilon = \frac{k_R}{m_M * c_{pm}} = \frac{k_R}{V_M * p_M * C_{pm}}$$

where

L	= the length (m) of the uniform partial section (T_{S1})
T_{MA}	= the water temperature in the initial region (°C)
T_{ME}	= the water temperature in the end region (°C)
T_{Luft}	= the temperature of the ambient air(°C)
k_R	= the heat transfer coefficient of the pipeline (W/(m*K))
m_M	= the mass flow of the water in the partial section (kg/ s)
$c_{p,m}$	= the spec. heat capacity of the water (J/(kg*K)
V_M	= the volume flow of the water in the partial section (m^3/s)
p_M	= the density of the water (kg/m^3)

This formula allows a good approximation of the temperature change for uniform partial sections.

In another embodiment of the invention, it is proposed that the heat transfer coefficient of the partial sections is determined by the formula

$$\frac{1}{k_R} = \frac{1}{d_i * \alpha_i * \pi} + \frac{1}{\Lambda_R} + \frac{1}{d_a * \alpha_a * \pi}$$

where

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$1/k_R$ = the heat transmission resistance of the pipeline (m * K/W)

αi = the inward heat transfer coefficient (W/(m² * K))

$1/\Lambda R$ = the thermal resistance (m * K/W)

α_a = the outward heat transfer coefficient (W/(m² * K))

d_a = the outer diameter (m)

d_i = the inner diameter (m)

and

$$\frac{1}{\Lambda_R} = \frac{1}{2*\pi} * \left(\frac{1}{\lambda_r} * ln\frac{d_{aR}}{d_{iR}} + \frac{1}{\lambda_D} * ln\frac{d_{aD}}{d_{iD}}\right)$$

In the following, equations 1-4 shall be used to determine the temperature changes and the heat gain in the water due to the temperature difference from the surroundings.

For this, equation 1 for the thermal resistance is inserted into equation 2 and thus the heat transition resistance is found. The heat transfer coefficient, equation 3, is calculated using the reciprocal of equation 2.

Thermal resistance $\frac{1}{\lambda_{ges}}$ of a pipeline incl. insulation

$$\frac{1}{\lambda_{ges}} = \frac{1}{2 \cdot \pi} \cdot \left(\frac{1}{\lambda_R} \cdot \ln\frac{d_{aR}}{d_{iR}} + \frac{1}{\lambda_D} \cdot \ln\frac{d_{aD}}{d_{iD}}\right)$$ Equation 1, see VDI 2055, 2008

Heat transition resistance $\frac{1}{U_R}$ of the insulated pipeline

$$\frac{1}{U_R} = \frac{1}{d_{iR} \cdot \alpha_i \cdot \pi} + \frac{1}{\lambda_{ges}} + \frac{1}{d_{aD} \cdot \alpha_a \cdot \pi}$$ Equation 2, see VDI 2055, 2008

$$\frac{1}{U_R} = \frac{1}{2 \cdot \pi} \cdot \left(\frac{1}{\lambda_R} \cdot \ln\frac{d_{aR}}{d_{iR}} + \frac{1}{\lambda_D} \cdot \ln\frac{d_{aD}}{d_{iD}}\right) + \frac{1}{d_{aD} \cdot \alpha_a \cdot \pi}$$

Heat transfer coefficient U_R of the insulated pipeline

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$$U_R = \frac{\pi}{\frac{1}{2} \cdot \left(\frac{1}{\lambda_R} \cdot \ln\frac{d_{aR}}{d_{iR}} + \frac{1}{\lambda_D} \cdot \ln\frac{d_{aD}}{d_{iD}}\right) + \frac{1}{d_{aD} \cdot \alpha_a}}$$ Equation 3

The heat transfer coefficient is the central component of equation 4 for calculating a temperature at the end of a partial section.

With the aid of equation 4, the respective starting and end temperatures of the cold water are found for all relevant partial sections. The deriving of the forumla for the axial heating of water in a pipeline starts with equation 5:

$$\vartheta_{ME} = \Delta\vartheta_a \cdot e^{\frac{-U_R \cdot l}{m \cdot c_W}} + \vartheta_{Luft}$$ Equation 4

$$\Delta\vartheta = \Delta\vartheta_a \left(1 - e^{\frac{-U_R \cdot l}{m \cdot c_W}}\right)$$ Equation 5, see VDI 2055, 2008

$$\Delta\vartheta = \vartheta_{MA} - \vartheta_{ME}$$

$$\vartheta_{MA} - \vartheta_{ME} = \Delta\vartheta_a \left(1 - e^{\frac{-U_R \cdot l}{m \cdot c_W}}\right)$$

$$\vartheta_{ME} = - \Delta\vartheta_a \left(1 - e^{\frac{-U_R \cdot l}{m \cdot c_W}}\right) + \vartheta_{MA}$$

$$\vartheta_{ME} = - \Delta\vartheta_a + \Delta\vartheta_a \, e^{\frac{-U_R \cdot l}{m \cdot c_W}} + \vartheta_{MA}$$

insert $\Delta\vartheta_a = \vartheta_{MA} - \vartheta_{Luft}$ and then combine.

$$\vartheta_{ME} = \Delta\vartheta_a \, e^{\frac{-U_R \cdot l}{m \cdot c_W}} + \vartheta_{Luft}$$

In an iterative calculation with incremental/stepwise increasing of the volume flow, one seeks that volume flow which operates the cold water installation with a desired/given spread of 5 K (15° C / 20° C), for example.

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With the aid of this solution, it is possible to determine not only a volume flow of the circulation system, which is the primary consideration, but also a water temperature for any given point in the particular pipeline network.

Preferably, the iterative approximation method is the known Excel target value search; see Excel and VBA: an introduction with practical applications in the natural sciences, by Franz Josef Mehr, María Teresa Mehr, Wiesbaden 2015, section 8.1.

According to the invention, key data of the pipeline system including the above indicated parameters of the partial sections are entered into the program and the target value search is used to determine the volume flow V_z for which the potable water target temperature T_b is achieved; for example, as follows

3.1.1 Material values, water

No. MT	**Designation**		**Value/ units**
MT1	Potable water input temperature after output port		15.0° C
MT2	Target potable water temperature		20.0° C
MT3	Density of water at 17.5° C		998.8 kg/m³
MT4	Volume flow V_z		**0.022 m³/h**
MT5	Specific heat capacity		1.163 Wh/(Kg*K)

3.1.2 Heat transmission coefficients

No. W	**Designation**			**(W/(m²*K))**
Wi	Heat transmission coefficients outward	α_a		5
Wa	Heat transmission coefficients inward	α_i		0

3.1.3 Ambient temperatures

No. UT	**Designation**	**Temperature t_{Luft} in °C**
UT1	Boiler room	30° C
UT2	Basement corridor	20° C

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UT3	Shaft	30° C
UT4	Hallway suspended ceiling	33° C
UT5	Bathroom front wall	26° C
UT6	Return shaft	26° C

3.1.4 Insulation

No.			**Thermal conductivity coefficient**
DA	**Designation**	**Material**	**λ_{DA} in W/(m*K)**
DA1	Rockwool with PVC	Boiler room	0.035
DA2	Rockwool aluminum lined	Basement corridor	0.035
DA3	Rockwool aluminum lined	Riser	0.035
DA4	Rockwool aluminum lined	Hallway ceiling	0.035
DA5	Flex EL-Conel 24x18	Bathroom front wall	0.032
DA6	with 9 mm insulation in the floor	Bathroom floor	0.04

3.1.5 Pipe materials

No.		**Nominal width**	**Wall thickness**	**Thermal conductivity coefficient**
DA	**Designation**	**mm**	**mm**	**λ_R in W/(m*K)**
R1	Viega Raxofix	16 x 2.2	2.2	0.4
R2	Viega Raxofix	20 x 2.8	2.8	0.4
R3	Viega Raxofix	25 x 2.7	2.7	0.4
R4	Viega Raxofix	32 x 3.2	3.2	0.4
R5	Viega Raxofix with insulation	16 x 2.2	2.2	0.35
R6	Viega Raxofix with insulation	20 x 2.8	2.8	0.35
R7	Viega Raxofix with insulation	25 x 2.7	2.7	0.35
R8	Viega Raxofix with insulation	32 x 3.2	3.2	0.35
R9	Viega Sanpress	15 x 1.0	1	23
R10	Viega Sanpress	18 x 1.0	1	23
R11	Viega Sanpress	22 x 1.2	1.2	23
R12	Viega Sanpress	28 x 1.2	1.2	23
R13	Viega Sanpress	35 x 1.5	1.5	23
R14	Viega Sanpress	42 x 1.5	1.5	23
R15	Viega Sanpress	54 x 1.5	1.5	23

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R16	Viega Sanpress	64 x 2	2	23

In this example, the calculated volume flow V_z for which a target temperature Tb of 20° is achieved for an input temperature T_a of 15° C is indicated in row MT4.

In a further embodiment of the invention it is proposed that a circulation pump is integrated in the circulation system, so that a desired volume flow can be set.

Of course, several temperature-control devices and/or circulation pumps can also be provided.

In the following, embodiments shall be described with pipeline structures such as are used typically for potable water installations in buildings.

A connection line is a line between a supply line and a potable water installation or the circulation system.

A consumer line is a line which takes the water from the main shutoff valve to the junctions of the tapping points and optionally to appliances. A collective feed line is a horizontal consumer line between the main shutoff valve and a riser pipe. A riser pipe (downpipe) leads from one floor to another, and the building floor lines or single supply lines branch off from it. A building floor line is the line branching off from the riser pipe (downpipe) within a building floor and the single supply lines branch off from it. A single supply line is the line leading to a tapping point.

In one embodiment of the invention it is proposed that at least one flow pipe is connected to at least one loop line.

In a further embodiment of the invention it is proposed that at least one branch of the circulation conduit departs from the at least one flow pipe.

In a further embodiment of the invention it is proposed that at least one branch of the at least one circulation conduit departs from the at least one loop line.

In a further embodiment of the invention it is proposed that the at least one flow pipe comprises at least one riser line and/or a building floor line.

In a further embodiment of the invention it is proposed that the at least one flow pipe comprises a collective feed line, which is connected by a junction to a water supply network.

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In a further embodiment of the invention it is proposed that the junction is connected to at least one connection line and/or at least one consumer line.

In a further embodiment of the invention it is proposed that at least one static or dynamic flow divider is arranged in the at least one flow pipe and/or the at least one loop line, by which preferably one tapping point for water is connected. Preferably, a percentage apportionment of the volume flows of 95% at the exit and 5% passing through is accomplished.

In a further embodiment of the invention it is proposed that the temperature-control device for the cooling of the circulating water is used to transfer thermal energy from the circulating water to another material flow, preferably by means of a heat transfer agent, which can achieve an optimization of the cooling process by suitable choice of the other material flow, such as propane, and a lessening of the energy required for the operation of the cooling device.

In a further embodiment of the invention it is proposed that the cooling device is thermally coupled to a cold generator, preferably a heat pump, a water chiller or a cold supply network, which can likewise accomplish a lessening of the energy required for the cooling process.

In a further embodiment of the invention, it is proposed to determine a consumer characteristic of the circulation pump in dependence on the delivered volume flow of the circulation pump and to determine a consumer characteristic of the cooling device in dependence on a water temperature at the output port and to adjust a volume flow V_z and a water temperature T_a at the output port such that the power consumption of the circulation pump and the cooling device takes on a relative or absolute minimum value, thereby improving the energy efficiency of the method.

In a further embodiment of the invention it is advisedly proposed that a value of 20° C +/- 5° C is chosen for the temperature T_{soll} and a value of 15° C +/-5° C is chosen for the water temperature T_a at the output port.

In a further embodiment of the invention it is proposed that at least one partial section of the pipeline system is designed as an outer circulation conduit, since outer circulation conduits are usually installed particularly in already existing circulation systems.

In a further embodiment of the invention it is proposed that at least one partial section is designed as an inliner circulation conduit, since these are often installed in newer or new circulation systems.

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Further benefits will be evident from the following description of the drawings.

The drawings show exemplary embodiments in the specification. The drawing, the specification, and the claims contain many features in combination. The skilled person will also advisedly consider the features individually and combine them into further meaningful combinations.

There are shown, as an example:

Figure 1a: in schematic representation, a circulation system according to the invention
Figure 1b: a representation of a circulation system according to the invention
Figure 2: a further embodiment of a circulation system according to the invention
Figure 3a – 3c: further embodiments of a circulation system
Figure 4: a further embodiment of a circulation system according to the invention
Figure 5: a further embodiment of a circulation system according to the invention
Figure 6: a further embodiment of a circulation system according to the invention
Figure 7: a further embodiment of a circulation system according to the invention
Figure 8: a further embodiment of a circulation system according to the invention
Figure 9: a further embodiment of a circulation system according to the invention
Figure 10: a further embodiment of a circulation system according to the invention

The circulation systems represented in Figures 1 to 8 are merely examples, the invention not being limited to these systems. In all the systems shown, exactly two volume flows enter a node and one volume flow departs from it, or exactly one volume flow enters and exactly two volume flows depart from it, as in the case of a T-piece. However, the invention is not limited to systems with such nodes. Basically, all of the lines represented between nodes and between nodes and input port, as well as nodes and output port, may consist of one or more partial sections, as defined above.

Similar components are given the same reference numbers.

First of all, for a better understanding of the invention, a circulation system already described in PCT/EP2019/062547 shall be described by contrast in Figure 1a.

In the circulation system represented in Figure 1a, one node K1 is connected across a flow pipe 4a to an output port 12b of a cooling device 12. The cooling device 12 has connections on the refrigeration side and a refrigeration pump 13.

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At the node K1 there is provided a branching point to a collective line 4, a connection line to a junction 1 at a water supply network and a consumer line 3, the latter and the connection line not being part of the circulation system. Therefore, no volume flow apportioning occurs at the node K1.

The collective feed line 4 is connected to a riser pipe 5, which empties into a node K2. The node K2 branches into a building floor line 6 and a riser pipe 5, which empties into a node K3 and at which there occurs a branching to a building floor line 6 and a riser pipe 5, [which] is connected to a building floor line 6, which empties into a node K4. The node K2 is connected by a building floor line 6 to a node K6. The node K3 is connected by a building floor line 6 to a node K5.

Two partial sections TS1 and TS2, explicitly characterized as such, are connected across the node K4, TS1 representing a partial section of the building floor line 6 and TS2 representing a circulation conduit.

Moreover, at node K4 there occurs a branching across a single supply line 7 to a tapping point 9. To simplify matters, the single supply lines and tapping points connected to the nodes K2 and K3 are not given reference numbers. Since the circulation system according to the invention is operated in order to carry out the method according to the invention in a state in which no water removal occurs, the nodes which are coordinated with the tapping points are not considered in the following and, accordingly, not given reference numbers in the drawings, except for node K4.

The partial section TS2 is connected to a vertical circulation conduit 10a, which empties into the node K5. The node K5 is connected to a circulation conduit 10a, which empties into the node K6. The node K6 is connected to a vertical circulation conduit 10a, which is connected to a horizontal circulation conduit 10a, which in turn is connected across a vertical circulation conduit to the circulation pump 10b.

The circulation system according to the invention for hot potable water PWC as represented in Figure 1b has a similar structure to the system represented in Figure 1a, but the reference number 12 denotes a heating device which is connected across a connection line 4‘ for cold potable water PWC to the inlet port 12a. The outlet port 12b is connected to a riser line 5. Reference number 9 denotes the last tapping point for hot water PWH. The circulation line 10a of the circulation system PWH-C
is connected across the circulation pump 10b to the inlet port 12a. The heating device has ports for the heating circuit as well as a pump 13 for the heating circuit.

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In a further embodiment of the invention, in Figure 1a a valve is provided at nodal point K1, which can temporarily block the water supply from port 1, so that potable water can be heated, while reference number 12 denotes a heating device or a temperature-control device.

The circulation system represented in Figure 2 has a similar structure to the system of Figure 1a, but loop lines are provided in the building floor lines 6, and to simplify matters a reference number 8 is used only for the uppermost loop line represented in Figure 2. The loop line 8 is coordinated with an optional flow divider 8a. Loop lines are coordinated with nodes K21 to K32. It is understood that such systems in which only one loop line is present are also covered by the invention.

Figure 3 shows another system with nodes K31 to K34, but here the circulation conduits 10a emptying into the nodes K34 and K35 are led in parallel with the building floor lines 6 departing from the nodes K32 and K33.

Moreover, an optional decentralized cooling device 14 with an input port 14a and an output port 14b is arranged in the uppermost building floor line 6, while to simplify the representation the existing junctions of a cold-side circuit and a corresponding pump are not shown.

Similarly, further decentralized cooling devices can be arranged in the other building floor lines, as shown in Fig. 3a..

In another embodiment similar to Figure 3, the heat exchanger 12 may be omitted; in this case, one cooling device 14 or multiple cooling devices 14 are necessary, as shown in Fig. 3b.

Similar to the embodiment of Figure 3, cooling devices can be provided in the riser pipes 5 and the building floor line of the embodiments of Figures 1, 2 and 4 to 8, for example with a cooling device 12' as in Fig. 3.

Figure 4 shows a system with nodes K41 to K51 as in Figure 3, but loop lines 8 are provided in the building floor lines.

Figure 5 shows a system with nodes K51 to K55, in which circulation conduits 10 are led in parallel with the riser pipes 5 connected to the nodes K52, K53.

Figure 6 shows a system with the nodes K61 to K69b, where loop lines are provided between the nodes K63, K64, K66, K67 and K68, K69.

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Figure 7 shows a system with the nodes K71 to K75, where riser pipes 5 are connected to the nodes K72 and K73.

Figure 8 shows a system with nodes K81 to K89b similar to Figure 7, but with loop lines arranged between the nodes K89a, K89b, K88, K89 and K84 and K85.

Figure 9 shows a system with a device 12‘ which is connected by a line 2‘ to the inlet port 12a‘ of a water supply 1. The outlet port 12b‘ is connected by a collecting line 4a to the node K91 and riser lines 5.
The circulation line 10a is connected at the inlet port 12a‘.

The device 12‘ may be designed as a cooling device, a heating device, or a temperature-control device.

Figure 10 shows a system with a device 20, which is connected by a line 2‘to the inlet port 20a‘of a water supply 1. The outlet port 20b‘is connected by a collecting line 4 to the node K101 and riser lines 5.
The circulation line 10a is connected downstream from the outlet port 20b‘.

The device 20 may be designed as a cooling device, a heating device, or a temperature-control device.

Moreover, the system comprises the device 12, the output port 12b of which is connected by a collecting line 4a to the node K101 and riser lines 5.
The circulation line 10a is connected to the inlet port 12a.

The device 12 may be designed as a cooling device, a heating device, or a temperature-control device.

The embodiments represented in Figures 1, 3, 5, 7 can also allow only partial regions to have a circulation. Thus, the partial sections may also represent installations in dwellings, for example, which are not permitted to circulate together on account of different requirements (account metering of the water consumption). A water exchanging to maintain the desired temperature could be possible here with automatic flushing.

The method according to the invention is implemented in the systems of Figures 1 to 8 in the above-described manner: starting from a temperature start value $T_{MA}* < T_{soll}$ and a volume flow start value V_z* for the first partial section connected to the output port (12b), a temperature

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change of the water between the initial region and the end region is determined according to a model of the temperature change.

Moreover, a temperature change of the water between the initial region and the end region for each further given partial section is determined according to the model of the temperature change, under the boundary condition that the water temperature in the initial region of the given partial section is equal to the water temperature in the end region of the partial section to which the given partial section is connected.

Preferably, one uses the above-described model of the axial temperature change, according to which the water temperature T_{ME} in the end region of a partial section of length L is calculated by the formula

$$T_{ME} = (T_{MA} - T_{Luft}) * e^{-\varepsilon * L} + T_{Luft}$$

$$\varepsilon = \frac{k_R}{m_M * c_{pm}} = \frac{k_R}{V_M * \rho_M * c_{pm}}$$

The value T_a of the water temperature and the value V_z of the volume flow at the output port 12b are chosen such that, in the end region of each partial section of the circulation system, the water temperature is $T_{ME} < T_{soll}$ and at the input port 12a the water temperature is $T_b < T_{soll}$ with $T_{soll} - T_b < \theta$, where $\theta > 0$ is a predetermined value.

It is understood that the circulation pump 10b is not always operated with a constant volume flow, i.e., regardless of whether the port inlet temperature 12a has exactly the setpoint value or even lies below it.

If the port inlet temperature 12a for various reasons should lie at 17° C for example, where a max. of 20° C is given, the delivery volume flow of the circulation pump 10b could be reduced. This can be done automatically, for example, under temperature control. As a result, energy savings will be achieved.

Likewise, in such a case the delivery volume flow of the pump 13 can be reduced by temperature control.

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If the port inlet temperature for various reasons should lie at 17° C for example (where a max. of 20° C is given for example), the flow temperature in the refrigeration circuit could likewise be adjusted. As a result, energy savings would be achieved.

Table 1

Symbol	Unit	Designation	Explanation
c_W	kJ(kg K)	Specific heat capacity of the	Heat for the heating of 1 kg of
ρ	kg/m³	Density of the water	Quotient of mass and volume of water at given temperature
a_a	W(m² K)	Outward heat transmission coefficient	Heat loss of a 1 m^2 surface for a temperature difference between the surface and air of 1 K
λD	W(m K)	Thermal conductivity of the	
λR	W(m K)	Thermal conductivity of the	
λges	W(m K)	Thermal conductivity of a structural piece, here a pipeline incl. multilayered	insulation
$\frac{1}{\lambda_{ges}}$	(m K)W	Thermal resistance	
$\frac{1}{U_R}$	(m K)W	Heat transition resistance	
U_R	W(m K)	Heat transfer coefficient for the pipe	Heat loss of a 1 m long insulated hot water pipe at a temperature difference between the water and the air of 1 K
d_a	mm	Pipe outer diameter	Outer diameter of a hot water line
D	mm	Pipe outer diameter	Outer diameter of an insulated hot water line
L	m	Pipeline length	Length of a partial section

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ϑ_{Luft}	°C	Air/surrounding temperature	
$\Delta\vartheta a$	K	Starting temperature difference	Temperature difference between surroundings and medium at the start of a partial section
ϑ_{MA}	°C	Medium temperature at start	Temperature of a medium at the start of a partial section
ϑ_{ME}	°C	Medium temperature at end	Temperature of a medium at the end of a partial section

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List of reference numbers

1	Connection to a water supply network
2	Connection line
3	Consumer line
4	Collective feed line
4a	Collective feed line
5	Riser (down pipe)
6	Building floor line
7	Single supply line
8	Loop line
8a	Static or dynamic flow division
9	Tapping point
10	Circulation system
10a	Circulation conduit
10b	Circulation pump
12	Temperature-control device, cooling device, heat exchanger
12a	Input port
12b	Output port
13	Pump
13’	Pump
14	Temperature-control device, cooling device, heat exchanger
14a	Input port
14b	Output port
14’	Temperature-control device, cooling device, heat exchanger
15	Pump
20	Temperature-control device, cooling device, heat exchanger
20a	Input port
20b	Output port
21	Pump
21a	Input port
21b	Output port

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Patent claims

1. Method for operating a circulation system (10) having a heating device with an input port and an output port for the temperature control of water and having a pipeline system with multiple branches comprising one or more partial sections with given thermal coupling to the surroundings and being connected by means of nodes, wherein one or more of the lines of the pipeline system are configured as a flow pipe (4, 5, 6), at least one as a single supply line (7) connected to a tapping point (9), and at least one line configured as a circulation conduit (10a) connected to the flow pipe or pipes (4, 5, 6),

   with the steps

   - setting a water temperature at the output port to a value T_a by means of the heating device

   - setting a volume flow at the input port to a value V_z

   characterized by the following steps

   - determining, in particular calculating, a temperature change of the water between the initial region and the end region according to a model of the axial temperature change for the first partial section connected to the output port, starting from a temperature start value T_{MA}* and a volume flow start value V_z*,

   - determining, in particular calculating, a temperature change of the water between the initial region and the end region for each further given partial section according to the model of the temperature change, under the boundary condition that the water temperature in the initial region of the given partial section is equal to the water temperature in the end region of the partial section to which the given partial section is connected, and

   - selecting the value T_a of the water temperature and the value V_z of the volume flow at the output port such that, in the end region of each partial section, the water temperature T_{ME} lies in a given temperature interval around T_{soll}, in particular, at the input port (12a, 14b) the water temperature is set at $T_b < T_{soll}$ with $T_{soll} - T_b < \theta$, where $\theta > 0$ is a given value.

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2. The method according to claim 1, characterized in that the values T_a and V_z are determined in an iterative approximation procedure, wherein the temperature change of the water between the initial region and the end region is calculated starting from a temperature start value T_{MA}* and a volume flow start value V_z* for the first partial section connected to the output port (12b, 14b) for each further given partial section under the boundary condition that the water temperature in the initial region of the given partial section is equal to the water temperature in the end region of the partial section to which the given partial section is connected.

3. The method according to claim 1 or 2, characterized in that the partial sections are designed uniformly in regard to their thermal coupling to the surroundings along the length between their initial region and their end region.

4. The method according to claim 3, characterized in that the water temperature T_{ME} in the end region of at least one partial section with length L is determined by means of the formula

$$T_{ME} = (T_{MA} - T_{Luft}) * e^{-\varepsilon * L} + T_{Luft}$$

$$\varepsilon = \frac{k_R}{m_M * c_{pm}} = \frac{k_R}{V_M * P_M * C_{pm}}$$

where

L = the length of the uniform partial section (T_{S1}) (m)
T_{MA} = the water temperature in the initial region (°C)
T_{ME} = the water temperature in the end region (°C)
T_{Luft} = the temperature of the ambient air(°C)
k_R = the heat transfer coefficient of the pipeline (W/(m*K))
m_M = the mass flow of the water in the partial section (kg/ s)
$c_{p,m}$ = the spec. heat capacity of the water (J/(kg*K)
V_M = the volume flow of the water in the partial section (m^3/s)
p_M = the density of the water (kg/m^3)

5. The method according to claim 4, characterized in that the heat transfer coefficient of the partial sections is determined by the formula

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$$\frac{1}{k_R} = \frac{1}{d_i * \alpha_i * \pi} + \frac{1}{\Lambda_R} + \frac{1}{d_a * \alpha_a * \pi}$$

where

$1/k_R$ = the heat transmission resistance of the pipeline (m * K/W)
αi = the inward heat transfer coefficient (W/(m² * K))
$1/\Lambda R$ = the thermal resistance (m * K/W)
α_a = the outward heat transfer coefficient (W/(m² * K))
d_a = the outer diameter (m)
d_i = the inner diameter (m)

and

$$\frac{1}{\Lambda_R} = \frac{1}{2*\pi} * \left(\frac{1}{\lambda_r} * ln\frac{d_{aR}}{d_{iR}} + \frac{1}{\lambda_D} * ln\frac{d_{aD}}{d_{iD}}\right)$$

6. The method according to one of the preceding claims, characterized in that a circulation pump (10b) is integrated in the circulation system (10).

7. The method according to one of the preceding claims, characterized in that the temperature control device (12, 14) is used to control the temperature of the circulating water by transferring thermal energy from the circulating water to another material flow, preferably by means of a heat transfer agent.

8. The method according to claim 7, characterized in that the temperature control device (12, 14) is thermally coupled to a cold generator, preferably a heat pump, a water chiller or a cold supply network.

9. The method according to one of claims 6 to 8, characterized by

- determining a consumer characteristic of the circulation pump (10b) in dependence on a delivered volume flow of the circulation pump (10b)

- determining a consumer characteristic of the temperature control device (12, 14) in dependence on a water temperature at the output port (12b, 14b)

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- setting a volume flow V_z and a water temperature T_a at the output port (12b, 14b) such that the power consumption of the circulation pump (10b) and the temperature control device (12, 14) takes on a relative or absolute minimum value.

10. The method according to one of the preceding claims, characterized in that a value of 20° C is chosen for the temperature T_{soll} and a value of 15° C is chosen for the water temperature T_a at the output port (12b, 14b).

11. A circulation system having a temperature control device (12, 14) with an input port (12a, 14a) and an output port (12b, 14b) for the cooling of water and having a pipeline system with multiple branches comprising one or more partial sections with given thermal coupling to the surroundings and being connected by means of nodes,

- wherein, for a given apportionment of the volume flows emerging from the nodes, a mixed water temperature is determinable from t he volume flows emerging from the nodes in dependence on the volume flows entering the nodes,

- wherein one or more of the lines of the pipeline system are configured as a flow pipe (4, 5, 6), at least one as a single supply line (7) connected to a tapping point (9), and at least one line configured as a circulation conduit (10a) connected to the flow pipe or pipes (4, 5, 6),

having

- means of setting the water temperature at the output port (12b, 14b) to a value T_a by means of the temperature control device (12, 14)

- means of setting a stationary volume flow of circulating water at the input port (12a, 14a) to a value V_z

characterized by

- device means for determining a temperature change of the water between the initial region and the end region of each partial section under the boundary condition that the water temperature in the end region of a given partial section is chosen equal to the water temperature in the initial region of the partial section

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connected to the given partial section in the flow direction of the circulating water and

- device means for selecting the value T_a of the water temperature and the value V_z of the volume flow at the output port (12b, 14b) such that, in the end region of each partial section, the water temperature T_{ME} lies in a given temperature interval around T_{soll}, in particular, at the input port (12a, 14a) the water temperature is set at $T_b < T_{soll}$ with $T_{soll} - T_b < \theta$, where $\theta>0$ is a given value.

12. The circulation system according to claim 11, characterized in that device means are provided for determining the values T_a and V_z in an iterative approximation procedure, wherein the water temperature T_{ME} is calculated for each given partial section in its end region, starting from a temperature start value $T_{MA}* < T_{soll}$ and a volume flow start value V_z* for the first partial section connected to the output port (12b), wherein the water temperature $T_{MA}‘$ in the initial region of the next attached partial section is chosen equal to the water temperature TME in the end region of the given partial section.

13. The circulation system according to claims 11 to 12, characterized in that the partial sections are designed uniformly in regard to their thermal coupling to the surroundings along the length between their initial region and their end region.

14. The circulation system according to claims 11 to 13, characterized in that a circulation pump (7) is integrated in the circulation system (10).

15. The circulation system according to one of the preceding claims, characterized in that at least one flow pipe (4, 5, 6) is connected to at least one loop line (8).

16. The circulation system according to one of the preceding claims, characterized in that at least one line of the circulation conduit (10a) departs from the at least one flow pipe (4, 5, 6).

17. The circulation system according to one of the preceding claims, characterized in that at least one line of the at least one circulation conduit (10a) departs from the at least one loop line (8).

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18. The circulation system according to one of the preceding claims, characterized in that the at least one flow pipe (4, 5, 6) comprises at least one riser line (5) and/or a building floor line (6).

19. The circulation system according to one of the preceding claims, characterized in that the at least one flow pipe (4, 5, 6) comprises a collective feed line (4), which is connected by a junction (1) to a water supply network.

20. The circulation system according to one of the preceding claims, characterized in that the junction (1) is connected to at least one connection line (2) and/or at least one consumer line (3).

21. The circulation system according to one of the preceding claims, characterized in that at least one static or dynamic flow divider (8a) is arranged in the at least one flow pipe (4, 5, 6) and/or the at least one loop line (8).

22. The circulation system according to one of the preceding claims, characterized in that the temperature control device (12, 14) is used to transfer thermal energy from the circulating water to another material flow, preferably by means of a heat transfer agent.

23. The circulation system according to claim 22, characterized in that the temperature control device (12, 14) is thermally coupled to a cold generator, preferably a heat pump, a water chiller or a cold supply network.

24. The circulation system according to claim 23, characterized in that at least one partial section of the pipeline system is designed as an outer circulation conduit.

25. The circulation system according to claim 24, characterized in that at least one partial section is designed as an inliner circulation conduit.

26. The circulation system according to one of claims 11 to 25, characterized in that the temperature control device (12) is connected by its output port (12b) to a flow pipe (4a) and by its input port (12a) to a vertical circulation conduit.

27. The circulation system according to one of claims 11 to 26, characterized in that the temperature control device (14) is integrated in a riser line (5) and/or a building floor line (6).

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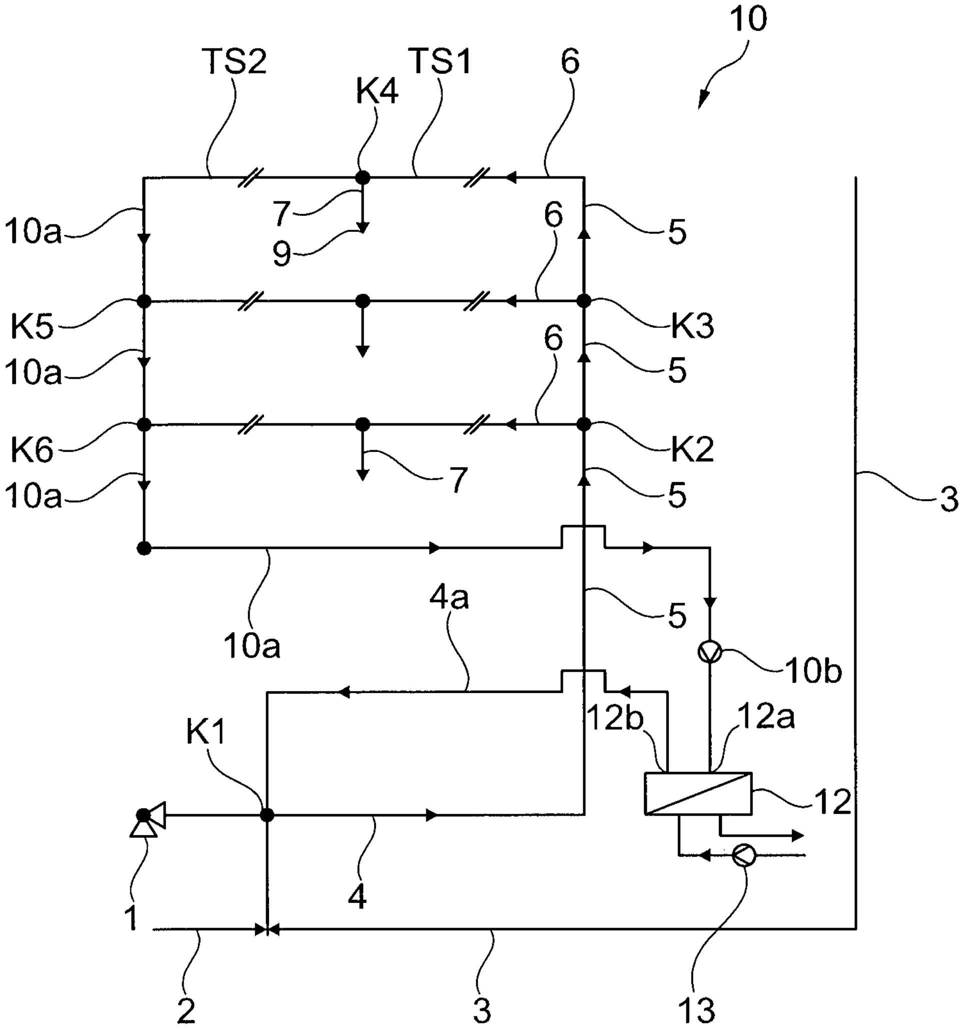

Fig. 1a

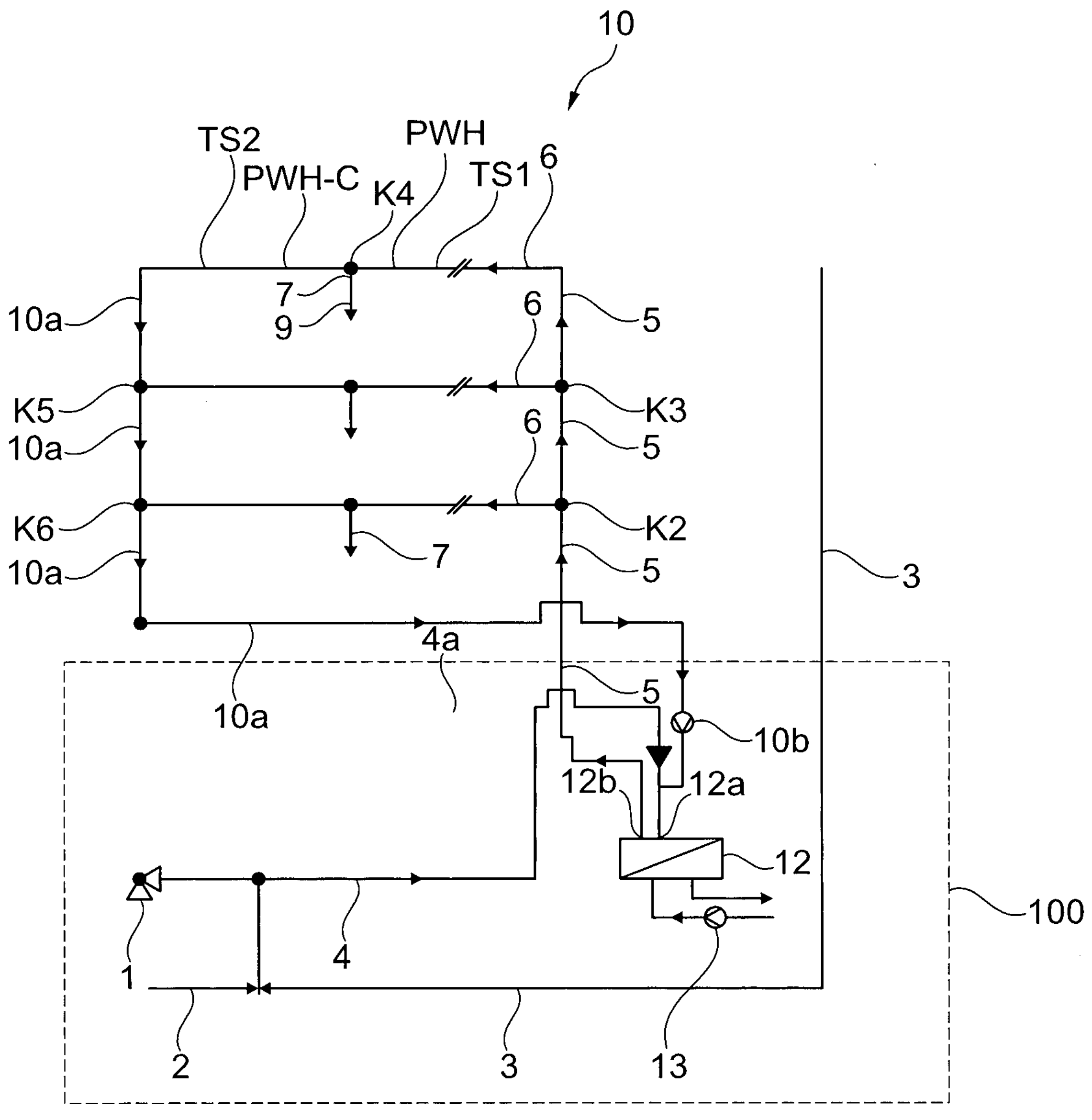
10
TS2
PWH
PWH-C
K4
TS1
6
7
9
10a
5
6
K5
K3
10a
6
5
K6
K2
10a
7
5
3
4a
10a
5
10b
12b
12a
12
100
1
4
2
3
13

Fig. 1b

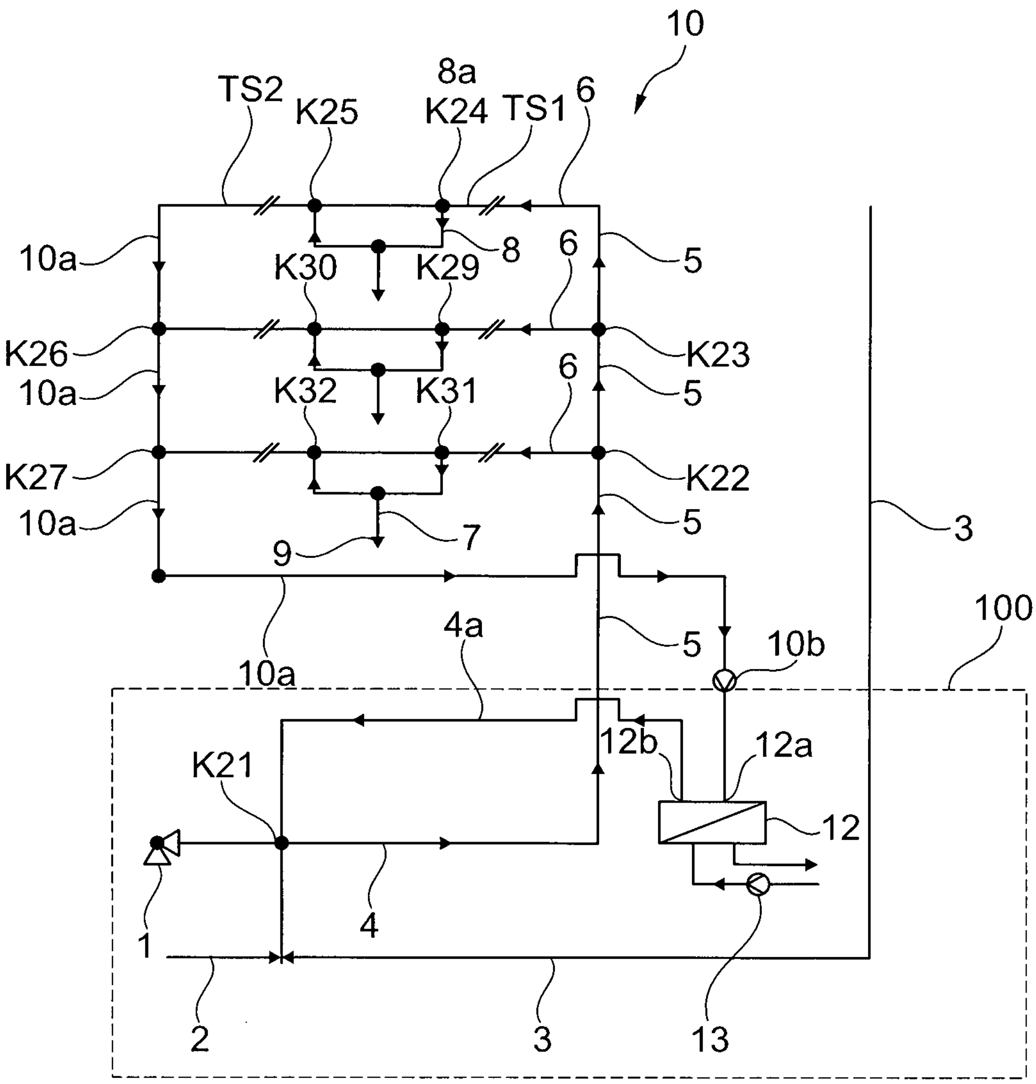
10
TS2
K25
8a
K24
TS1
6
10a
8
K30
K29
6
5
K26
K23
10a
6
K32
K31
5
K27
K22
10a
9
7
5
3
100
4a
5
10b
10a
12b
12a
K21
12
1
4
2
3
13

Fig. 2

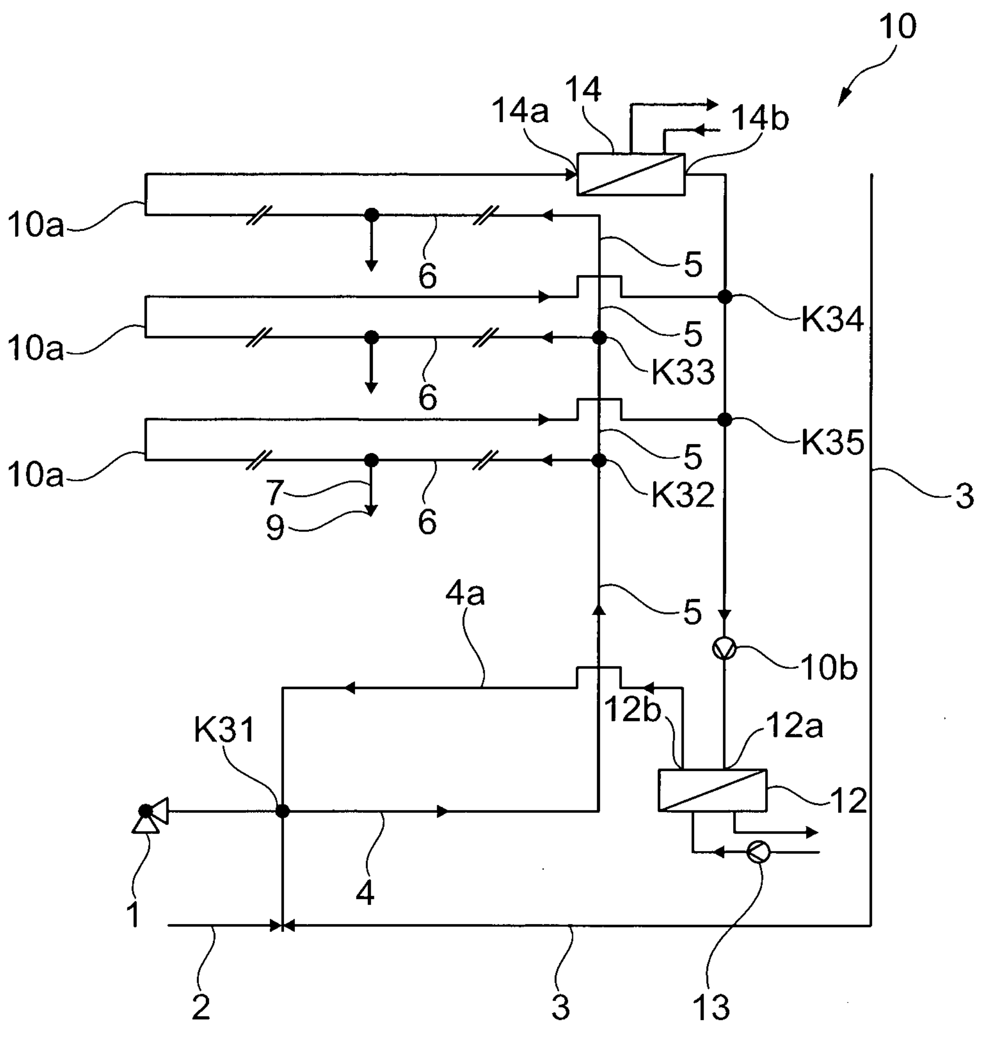
10
14
14a
14b
10a
6
5
K34
10a
5
K33
6
10a
5
K35
K32
7
9
6
3
4a
5
10b
12b
12a
K31
12
1
4
2
3
13

Fig. 3

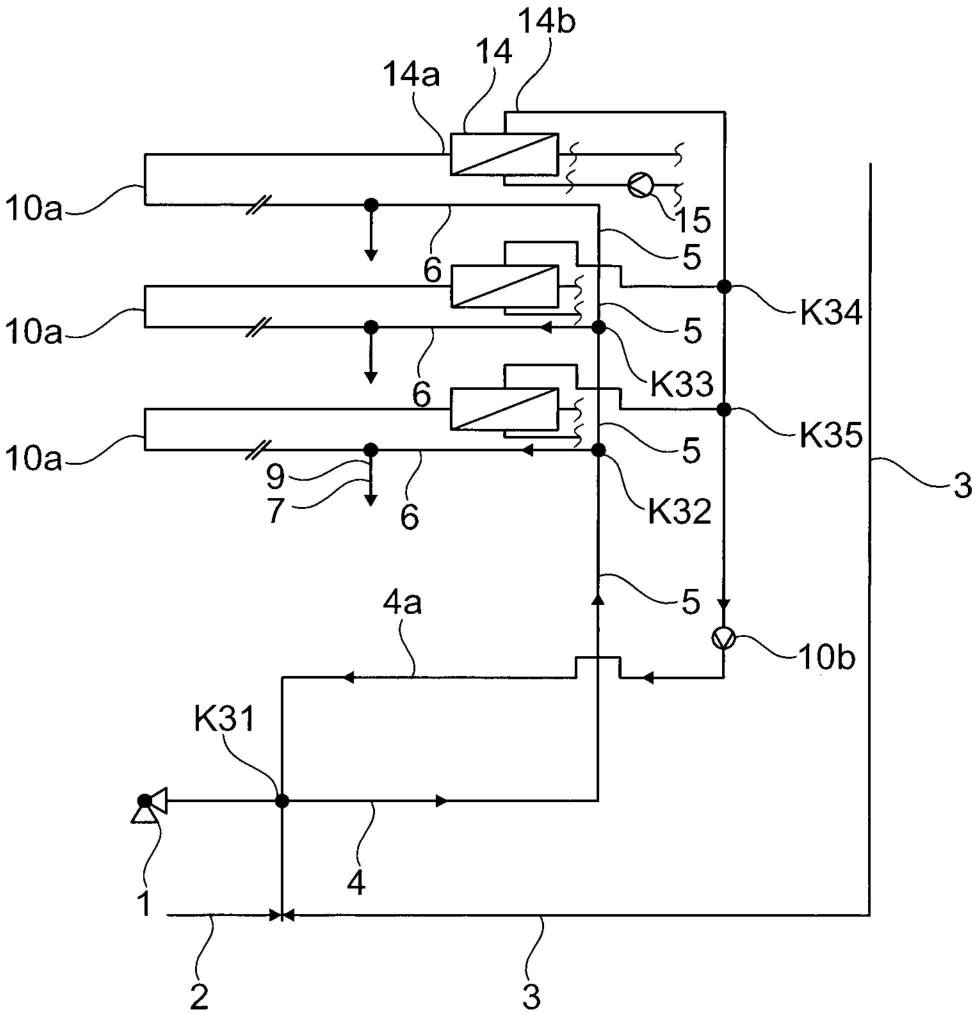
14b
14
14a
10a
15
5
6
K34
10a
5
6
K33
6
10a
5
K35
9
7
6
K32
3
4a
5
10b
K31
1
4
2
3

Fig. 3b

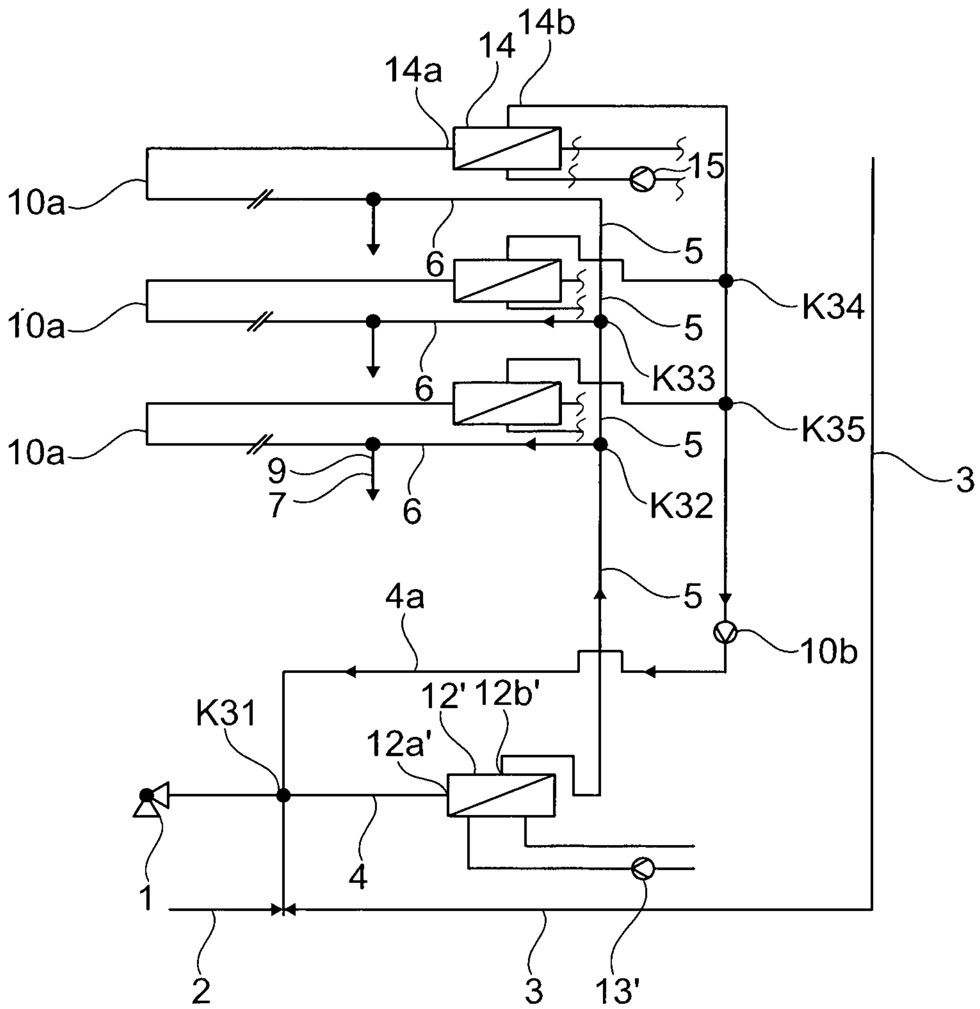
14b
14
14a
15
10a
5
6
K34
10a
5
K33
6
K35
10a
5
9
7
6
K32
3
5
4a
10b
K31
12'
12b'
12a'
1
4
2
3
13'

Fig. 3c

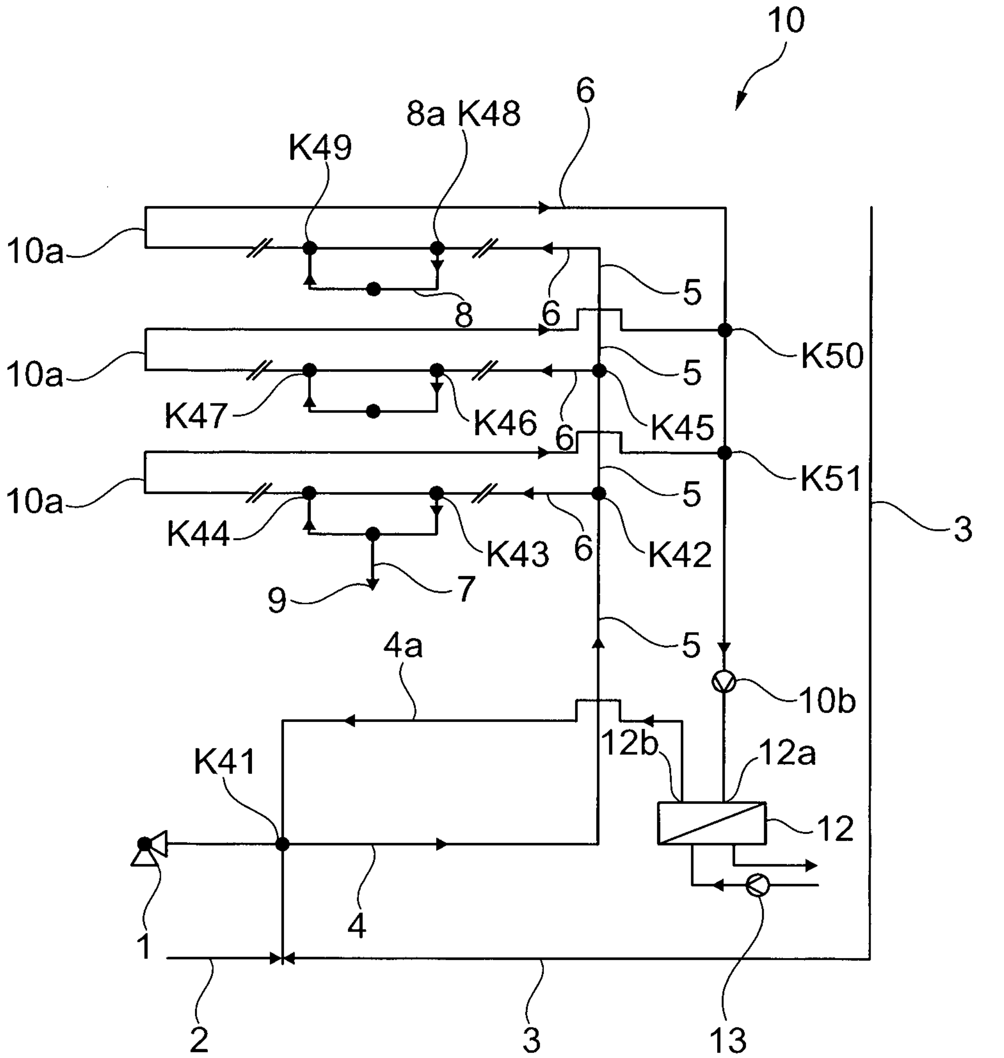
10
6
8a K48
K49
10a
8
6
5
K50
10a
K47
K46
K45
6
5
K51
10a
K44
K43
6
K42
3
9
7
5
4a
10b
12b
12a
K41
12
1
4
2
3
13

Fig. 4

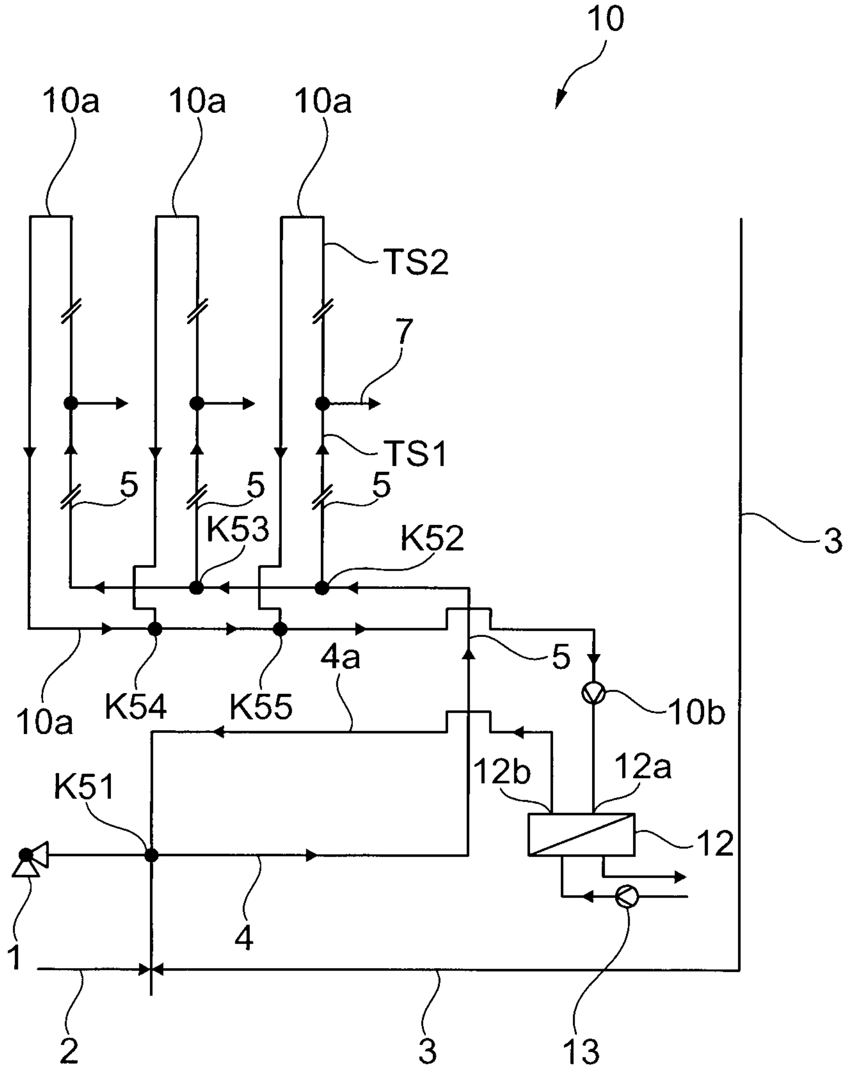
10
10a
10a
10a
TS2
7
TS1
5
5
5
K53
K52
3
5
10a
K54
K55
4a
10b
12a
12b
K51
12
1
4
2
3
13

Fig. 5

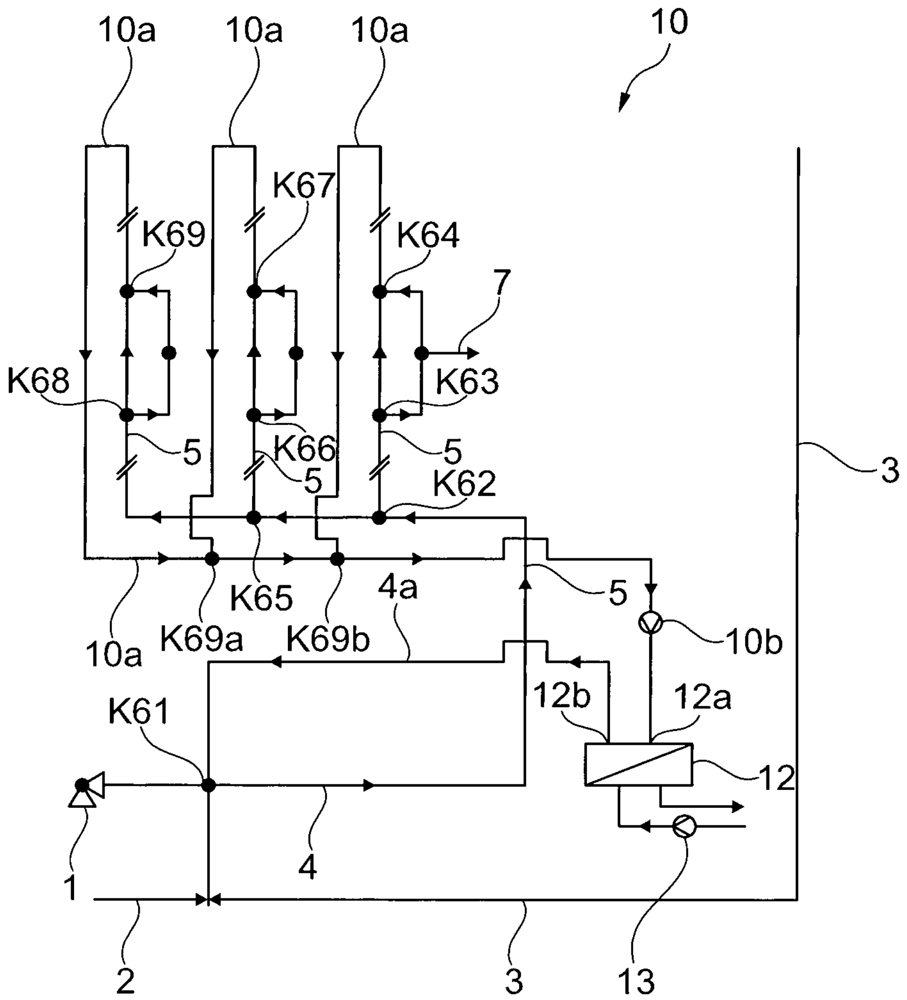
10a
10a
10a
10
K67
K69
K64
7
K68
K63
K66
5
5
5
K62
3
5
K65
4a
5
10a
K69a
K69b
10b
12b
12a
K61
12
1
4
2
3
13

Fig. 6

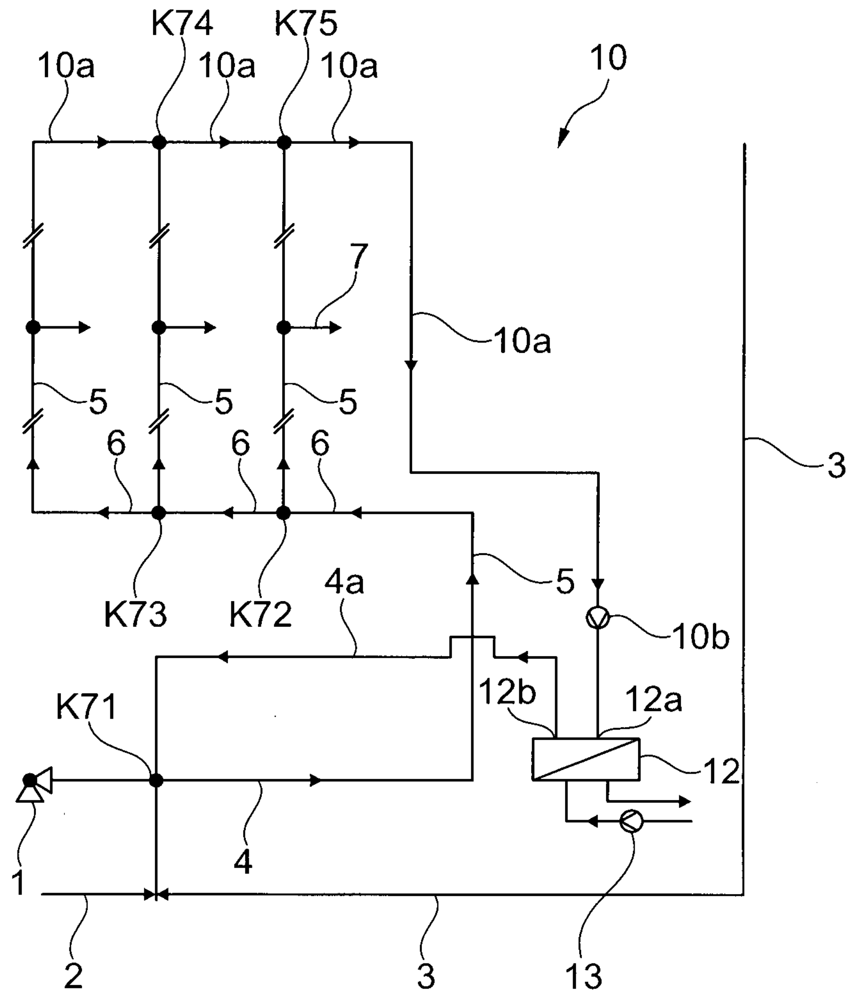
K74
K75
10a
10a
10a
10
7
10a
5
5
5
6
6
6
3
K73
K72
4a
5
10b
12b
12a
K71
12
1
4
2
3
13

Fig. 7

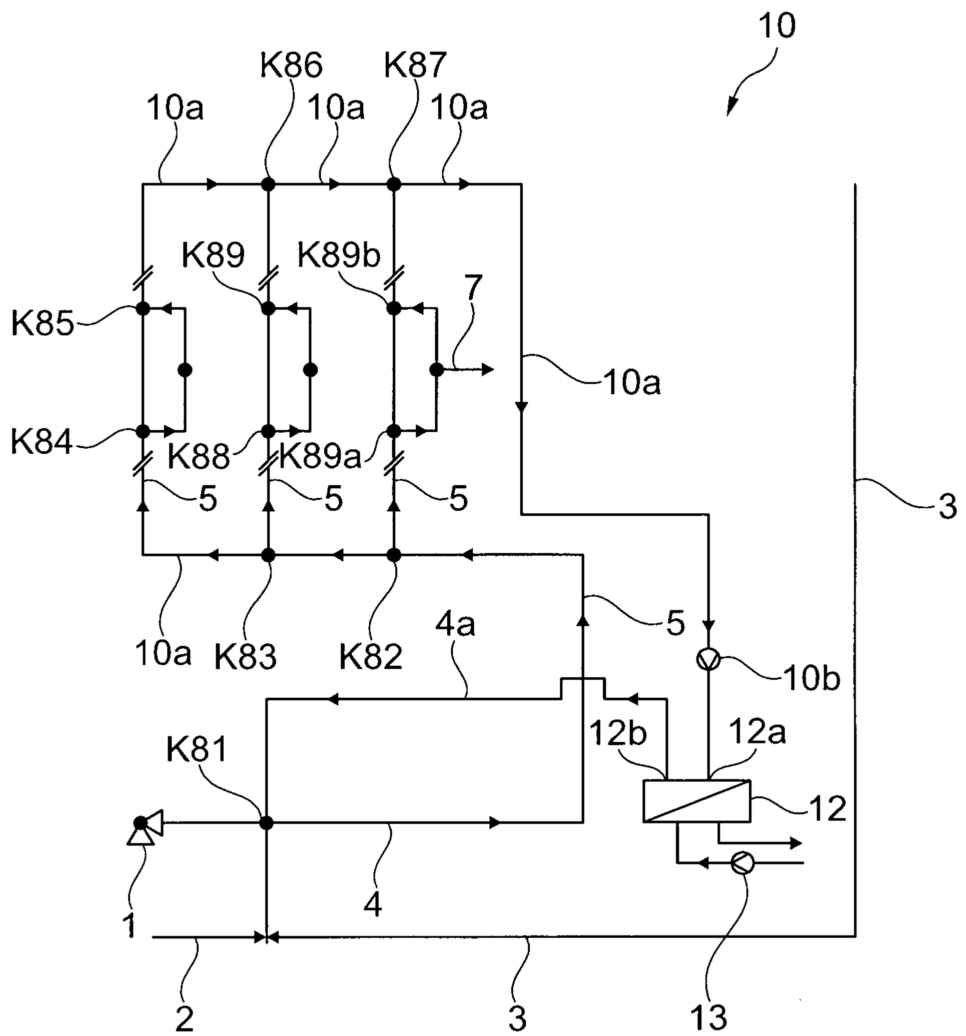
10
K86
K87
10a
10a
10a
K89
K89b
7
K85
10a
K84
K88
K89a
5
5
5
3
10a
K83
K82
4a
5
10b
12b
12a
K81
12
1
4
2
3
13

Fig. 8

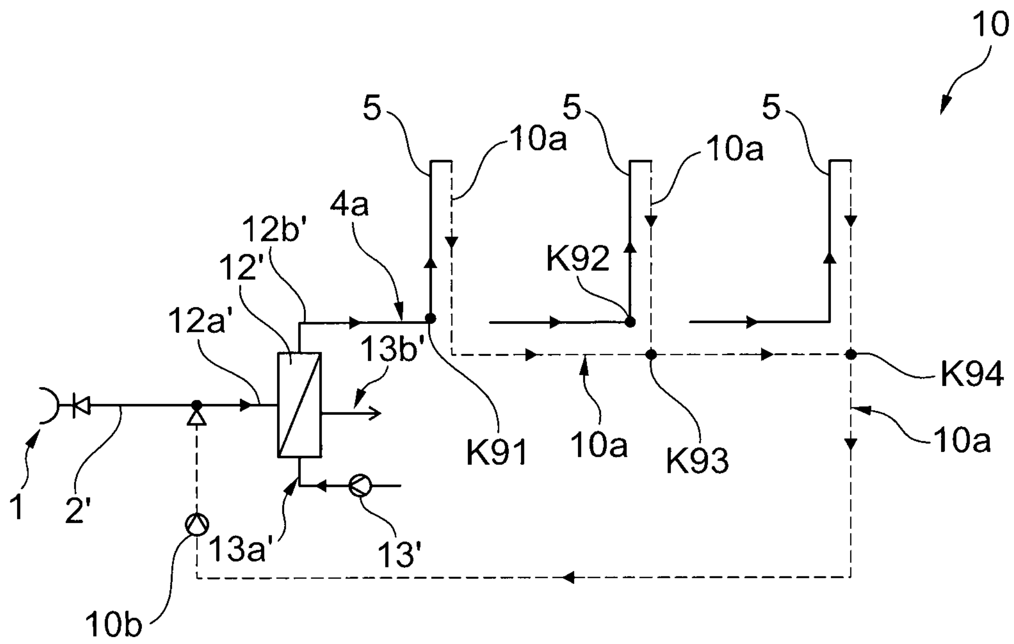
10
5
5
5
10a
10a
4a
12b'
12'
12a'
K92
13b'
K94
K91
10a
K93
10a
1
2'
13a'
13'
10b

Fig. 9

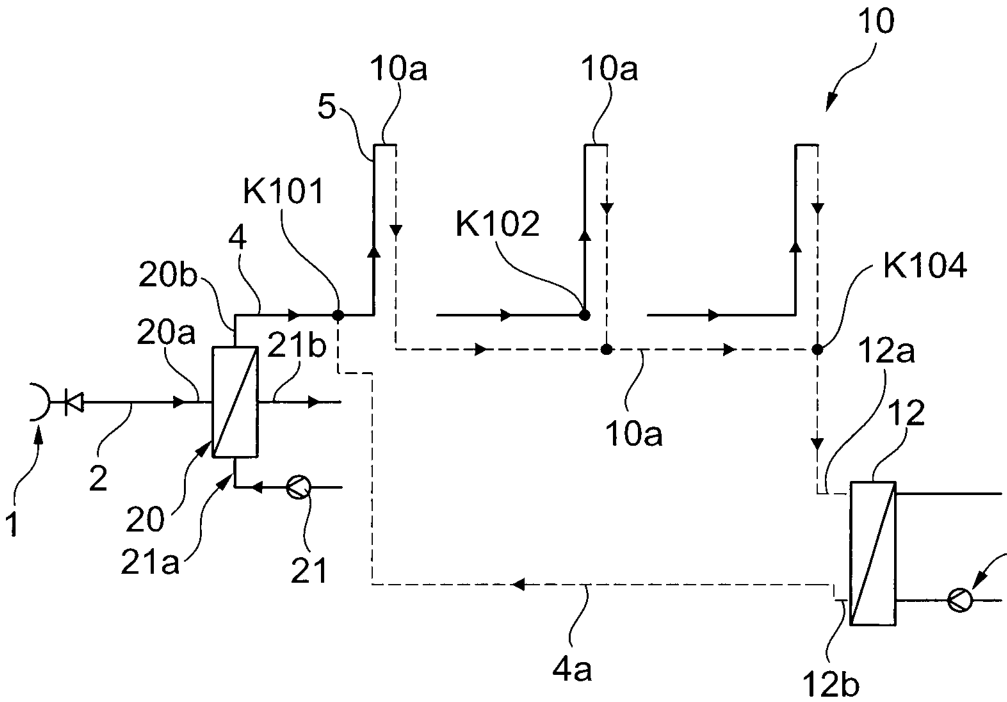
10
10a
10a
5
K101
K102
K104
4
20b
20a
21b
12a
12
10a
2
1
20
21a
21
13
4a
12b

Fig. 10

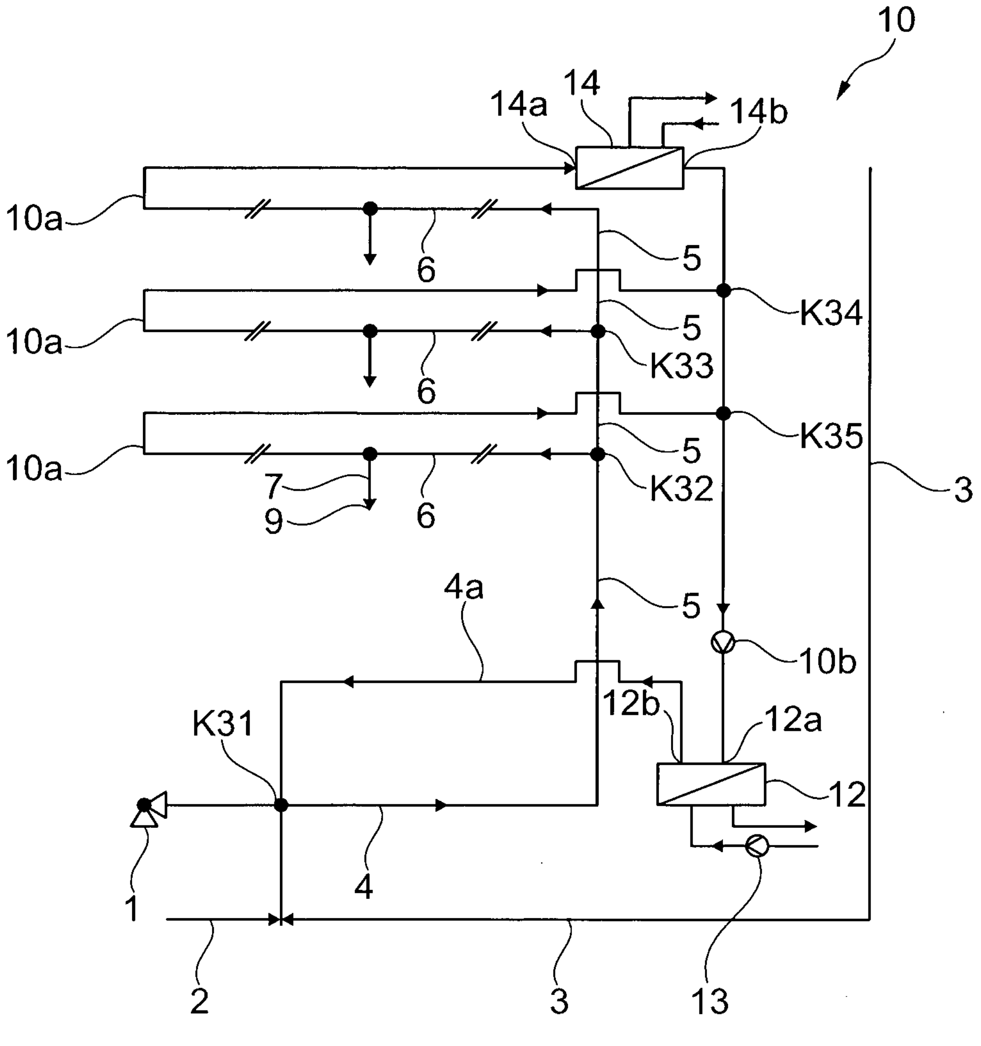
10
14
14a
14b
10a
6
5
10a
5
K34
K33
6
10a
5
K35
K32
7
9
6
3
4a
5
10b
12b
12a
K31
12
1
4
2
3
13

Fig. 3