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(54) **HEAT PUMP SYSTEM AND METHOD FOR CONTROLLING PUMP SPEED BASED ON LEAKAGE DETECTION DATA AND WATER FLOW RATE DATA**

(57) The present invention concerns a heat pump system and method of controlling said system which does not require the complete shutdown of said system should refrigerant be detected inside the heat medium circuit. In particular, the invention relates to the identifica-

tion and operation of the system within a safety threshold for heat medium flow, which safety threshold is commensurate with the capability of the system to cope with the leaked refrigerant.

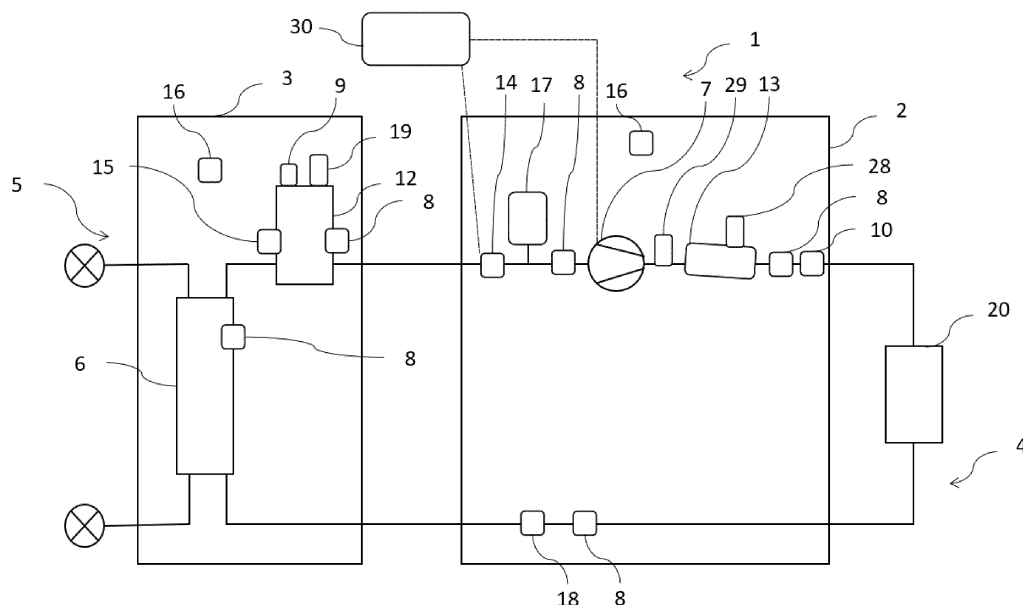


FIG. 1

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## Description

### FIELD OF THE INVENTION

[0001] The present invention relates to a device and control method of a temperature control system. More in particular, the present invention relates to a heat pump system and a method for the control of said system.

### BACKGROUND

[0002] JP2001208392A discloses a heat pump device including a safety feature configured to stop the circulation pump of the system when a refrigerant leak is detected in the heat medium piping. The operation of the system according to JP '392 includes also a step of purging the system of any refrigerant contaminated water.

[0003] Another method is disclosed in EP2759787A1, wherein, upon detection of a refrigerant leakage in the heat medium circuit, the circulation of refrigerant towards an intermediate heat exchanger is stopped by means of two valves.

[0004] EP3764073A1 discloses a method including steps of detection and stopping a heat pump system when a leakage of refrigerant is detected in a heat medium circuit.

[0005] WO2019/239556 discloses an air-conditioning device includes a refrigerant circuit including a compressor, a heat source-side heat exchanger, an expansion unit, and an intermediate heat exchanger connected by a refrigerant pipe, through which refrigerant circulates; and a heat medium circuit including a pump, the intermediate heat exchanger, and a load-side heat exchanger connected by a heat medium pipe, through which heat medium circulates. A discharge unit connected downstream of the intermediate heat exchanger in the heat medium circuit discharges fluid flowing through the heat medium pipe, depending on pressure of the fluid. A refrigerant concentration detector detects concentration of the refrigerant contained in the fluid discharged from the discharge unit. A notification device notifies leakage of the refrigerant. A controller activates the notification device depending on the concentration of the refrigerant detected.

[0006] EP3734198 discloses a refrigerant separation device, in particular an air / refrigerant separation device for a heat pump system, comprising a separation container with at least one fluid inlet and at least one fluid outlet and a deflection device which is arranged and configured in this way that a direct path for a fluid flowing in the separation container during operation is at least partially, in particular completely, blocked.

[0007] These known methods require the heat pump system to stop, and in the case of JP '392, the disposal of heat medium, further increasing the time until operation of the system can be resumed. The delay between the shutdown of the heat pump system and the restarting of

its operation is particularly relevant in cold weather conditions, more in sub-zero temperatures. Under such temperatures, ice is likely to form on at least the outdoor elements of the system, thereby compromising the restarting of the system and most likely damaging some of the elements of said system.

[0008] The present invention aims to resolve at least some of the problems and disadvantages mentioned above. The aim of the invention is to provide a method which eliminates those disadvantages. The present invention targets at solving at least one of the aforementioned disadvantages.

### SUMMARY OF THE INVENTION

[0009] The present invention aims to resolve at least some of the problems and disadvantages mentioned above.

[0010] The invention thereto aims to provide a heat pump system and method of controlling said system which does not require the complete shutdown of said system should refrigerant be detected inside the heat medium circuit.

[0011] The present invention and embodiments thereof serve to provide a solution to one or more of above-mentioned disadvantages. To this end, the present invention relates to a heat pump system according to claim 1. Such a heat pump system comprises:

- a refrigerant circuit comprising a compressor, a heat-source side heat exchanger, a refrigerant side of an intermediate heat exchanger located downstream from the compressor;
- a controller for controlling at least the pump;
- a heat medium circuit comprising a heat medium side of the intermediate heat exchanger, a liquid-gas separator, a pump and a load side heat exchanger.

[0012] The heat medium circuit comprises a means for detecting refrigerant in the heat medium circuit, said means being configured to provide first information relating to the presence of refrigerant in the heat medium circuit to the controller. Said controller controls the pump during operation, taking into account the first information relating to the presence of refrigerant in the heat medium circuit. By preference, said means is capable of providing said first information at a frequency of at least 1Hz, more preferably 10Hz, 24Hz, 50Hz, most preferably 100Hz. In this way, it is possible to not only detect but also to monitor the presence of refrigerant in the heat medium circuit for the whole duration of the operation of the system. By preference, the means is capable of providing information related to the refrigerant leak flowrate into the heat medium circuit, said information being the first information.

[0013] In this context, the controller is to be understood a device configured by a memory that stores predetermined control programs, a processor that runs on the

control programs to perform various controls, and the like.

**[0014]** In an embodiment, the controller comprises a memory section for storing second information about a relationship between a separation efficiency of the liquid-gas separator and flowrate of the heat medium, wherein, the controller is configured to control the flowrate of the heat medium based on the second information so that the amount of refrigerant flowing to the load-side heat exchanger without being separated in the liquid-gas separator is below a predetermined amount.

**[0015]** In an embodiment, the controller comprises a memory section for storing a third information, wherein said third information represents a relationship between a flowrate of the heat medium and a measured presence of the refrigerant in the heat medium circuit, taking into account a known separation efficiency of the liquid-gas separator, wherein said relationship defines ranges for said flowrate of the heat medium and said measured presence of the refrigerant, and wherein the controller is configured to control the flowrate of the heat medium based on the third information. This information enables the controller to take immediate action upon detection of refrigerant in the heat medium circuit, reaching a safe flow for the heat medium, and without the need to shut down the system.

**[0016]** In an embodiment, the third information further defines ranges for said flowrate of the heat medium and said measured presence of the refrigerant for which the controller is configured to control one or more pressure relief valves to reduce the presence of the refrigerant in the heat medium. This information enables the controller to take immediate action upon detection of higher amounts refrigerant in the heat medium circuit, reaching a safe state, and without the need to shut down the system. The opening of one or more pressure relief valves advantageously permits also the operation of the system to maintain a higher flow of heat medium in case of less severe refrigerant leaks, while still maintaining safe operation of the system.

**[0017]** In an embodiment, the predetermined amount of refrigerant allowable into the load-side heat exchanger depends on the lower flammable limit of the refrigerant used in the system. In this way, even if refrigerant escapes into an indoor space, the resulting concentration will not be enough start combusting. By preference, the maximum allowable amount of refrigerant reaching the load-side heat exchanger is determined taking into account the toxicity of the refrigerant. More preferably, the dimensions of the rooms reached by any element of the heat pump are considered as well when determining maximum allowable amount of refrigerant reaching the load-side heat exchanger. Most preferably, the maximum allowable amount of refrigerant reaching the load-side heat exchanger cannot exceed a value that, if released in the smallest room reached by any element of the heat pump, the refrigerant concentration would reach the lower flammable limit and/or toxic levels.

**[0018]** In an embodiment, the controller is configured to determine an intended flowrate of the heat medium based on the second information recorded in the memory about the relationship between the separation efficiency of the liquid-gas separator and the flowrate of the heat medium when the controller detects that the refrigerant has leaked into the heat medium circuit, and wherein the controller controls the pump to generate said intended flowrate for the heat medium in the heat medium circuit.

**[0019]** In an embodiment, when the controller detects that the refrigerant has leaked into the heat medium circuit while the pump is being driven, the controller is configured to control the rotation speed of the pump based on the second information about the relationship between the separation efficiency of the liquid-gas separator and the flowrate of the heat medium. In this way, the flow of heat medium is maintained sufficiently within the separation capability of said liquid-gas separator to lower the amount of refrigerant in the heat circuit below the predetermined amount of refrigerant allowable.

**[0020]** In an embodiment, when the controller detects that the refrigerant has leaked into the heat medium circuit while the pump is being driven, the controller is configured to adjust the rotation speed of the pump to a rotation speed lower than the rotation speed of the pump before the detection of the refrigerant leakage. In this way, the flow of the heat medium is immediately and preventively reduced, allowing the speed of the pump to be raised in small increments until the reaching and stabilizing on an allowable amount of refrigerant in the heat medium circuit. This approach is advantageously suitable when the separation efficiency of the liquid-gas separator is not known, or has varied over time, with changes to the system or conditions external to the system e.g. temperature, humidity. In this way, it is possible to determine the maximum speed of the pump for a known refrigerant leakage rate. This is particularly advantageous if paired with a machine learning algorithm in order to create and update a model containing the maximum pump speed for a range of range of refrigerant leakage rates. In this way any deterioration of the heat pump system is advantageously compensated for as said system ages.

**[0021]** In an embodiment, the heat medium circuit comprises an expansion vessel upstream from the pump. This allows the system to cope not only with the expansion of the heat medium, but also with the increase of pressure inside the heat medium circuit in the event of a refrigerant leakage into the circuit. In this way, damage to the piping and/or any of the elements in the system.

**[0022]** In an embodiment, the means is located downstream from the liquid-gas separator and upstream from the expansion vessel. In this way, the detection and measurement of the refrigerant in the heat medium circuit is made more accurate as the expansion vessel may accumulate some gas which may cause false positive or even an error in the measured values.

**[0023]** In an embodiment, the heat medium circuit

comprises a flow sensor capable of measuring flowrate of the heat medium in the heat medium circuit, said flow sensor being positioned downstream of the pump, said flow sensor being configured to send fourth information relating to flowrate of the heat medium to the controller, wherein the controller takes into account the fourth information received from said flow sensor for controlling at least the pump.

**[0024]** In an embodiment, the liquid-gas separator comprises a gas purge outlet and a first pressure relief valve for releasing leaked refrigerant out of the system. The outlet and valve advantageously permit purging the liquid-gas separator of any accumulated refrigerant. If the liquid level in the separator vessel exceeds a certain point, it could lead to carryover of liquid into the gas outlet, which could cause damage to other equipment and/or facilities. Additionally, if the liquid level in the separator vessel drops below a certain point, it could be used as a means for detecting that refrigerant is leaked into the heat medium circuit.

**[0025]** In an embodiment, the liquid-gas separator comprises a level switch. The level switch allows monitoring of the liquid level inside the liquid-gas separator. Thus, by using the level switch, it is possible to detect refrigerant leakage into the heat medium circuit. Shutoff valves are provided on the heat medium circuit on the inlet side and the outlet side of the heat medium circuit of the liquid-gas separator, and when refrigerant leakage into the heat medium circuit is detected, the shutoff valves can be programmed to automatically shut off at least one of the shutoff valves. Also, when refrigerant leakage into the heat medium circuit is detected, the pump speed can be lowered.

**[0026]** In an embodiment, the heat medium circuit comprises at least one temperature sensor. More preferably, one of said at least one temperature sensor is located immediately before or immediately after the ultrasonic sensor. More preferably, the system includes a pressure sensor immediately before or after said temperature sensor or ultrasonic sensor. These sensors permit the measurement of the volume of refrigerant, its temperature and the pressure inside the heat medium piping at the same point of said piping. In this way, it is possible to accurately determine the mass of refrigerant passing by these three sensors. This advantageously permits determining how much refrigerant can potentially be released indoor via at least one load-side heat exchanger, thereby allowing for a more accurate risk assessment.

**[0027]** In an embodiment, the heat medium circuit comprises a backup heater, said backup heater being located downstream from the pump. The backup heater permits ensuring the delivery of heat to the heating medium even if the refrigerant circuit fails. The heater is advantageously positioned after the pump, as in this way, the heating medium is only heated after it leaves the pump, thereby reducing the temperature inside the pump and greatly extending its service life.

**[0028]** In an embodiment, the heat medium circuit comprises a second pressure relief valve upstream from any load side heat exchanger. In this way, excessive pressure is advantageously kept from reaching any load side heat exchanger.

**[0029]** In an embodiment, at least one of the pressure relief valves has an adjustable aperture, said aperture being adjustable by the controller. In this way, release of refrigerant gas is advantageously increased. This is particularly advantageous, for example, if the separation efficiency of the liquid-gas separator has been exceeded.

**[0030]** The invention relates also to a method for controlling a heat pump system according to claim 13. Said heat pump having a refrigerant circuit and a heat medium circuit in fluid connection with an intermediate heat exchanger, the method comprising the steps of:

detecting refrigerant in the heat medium circuit via a means for detecting refrigerant in the heat medium circuit;

providing first information regarding the presence of the refrigerant in the heat medium circuit from the means to a controller;

**[0031]** The method further includes a step of controlling at least a pump during operation in the heat medium circuit by means of the controller, wherein the pump is controlled taking into account the first information relating to the presence of the refrigerant in the heat medium circuit, for driving the flowrate of the heat medium in the heat medium circuit.

**[0032]** In an embodiment, the method further includes a step of determining an allowable speed of rotation of the pump, said determination being based on a third information, wherein said third information represents a relationship between a flowrate of the heat medium and a measured presence of the refrigerant in the heat medium circuit, taking into account a known separation efficiency of the liquid-gas separator, wherein said relationship defines ranges for said flowrate of the heat medium circuit..

**[0033]** In an embodiment, the method includes a step wherein the controller issues a signal to at least one pressure relief valve located on the heat medium circuit and/or a liquid-gas separator located on the heat medium circuit, causing said at least one valve to open further. Said signal is sent, for example though not exclusively, if the speed of the pump has been reduced and the amount of refrigerant in the heat medium circuit is still high, the pressure inside the liquid-gas separator is too high, if the pressure inside the backup heater is too high.

## DESCRIPTION OF FIGURES

**[0034]** The following description of the figures of specific embodiments of the invention is merely exemplary in nature and is not intended to limit the present teachings, their application or uses. Throughout the drawings, cor-

responding reference numerals indicate like or corresponding parts and features.

**Fig. 1** schematically shows a first embodiment of the heat pump system.

**Fig. 2** presents a graphical representation of leak rate to heat medium flow.

**Fig. 3** presents a flow chart depicting a methodology according to an embodiment of the invention to control the heat pump system.

## DETAILED DESCRIPTION OF THE INVENTION

**[0035]** The invention is further described by the following non-limiting examples which further illustrate the invention, and are not intended to, nor should they be interpreted to, limit the scope of the invention.

**[0036]** The present invention concerns a heat pump system and method of controlling said system which does not require the complete shutdown of said system should refrigerant be detected inside the heat medium circuit. In particular, the invention relates to the identification and operation of the system within a safety threshold for heat medium flow, which safety threshold is commensurate with the capability of the system to cope with the leaked refrigerant. In this way, the system and method permit resuming the operation of the system under a number of safety constraints. This permits not only maintaining an acceptable indoor temperature but permit also preventing damage to the system.

**[0037]** Unless otherwise defined, all terms used in disclosing the invention, including technical and scientific terms, have the meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. By means of further guidance, term definitions are included to better appreciate the teaching of the present invention.

**[0038]** As used herein, the following terms have the following meanings:

"A", "an", and "the" as used herein refers to both singular and plural referents unless the context clearly dictates otherwise. By way of example, "a compartment" refers to one or more than one compartment.

**[0039]** "Comprise", "comprising", and "comprises" and "comprised of" as used herein are synonymous with "include", "including", "includes" or "contain", "containing", "contains" and are inclusive or open-ended terms that specifies the presence of what follows e.g. component and do not exclude or preclude the presence of additional, non-recited components, features, element, members, steps, known in the art or disclosed therein.

**[0040]** Furthermore, the terms first, second, third and the like in the description and in the claims, are used for distinguishing between similar elements and not necessarily for describing a sequential or chronological order, unless specified. It is to be understood that the terms so

used are interchangeable under appropriate circumstances and that the embodiments of the invention described herein are capable of operation in other sequences than described or illustrated herein.

**[0041]** The recitation of numerical ranges by endpoints includes all numbers and fractions subsumed within that range, as well as the recited endpoints.

**[0042]** Whereas the terms "one or more" or "at least one", such as one or more or at least one member(s) of a group of members, is clear *per se*, by means of further exemplification, the term encompasses *inter alia* a reference to any one of said members, or to any two or more of said members, such as, e.g., any  $\geq 3$ ,  $\geq 4$ ,  $\geq 5$ ,  $\geq 6$  or  $\geq 7$  etc. of said members, and up to all said members.

**[0043]** Unless otherwise defined, all terms used in disclosing the invention, including technical and scientific terms, have the meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. By means of further guidance, definitions for the terms used in the description are included to better appreciate the teaching of the present invention. The terms or definitions used herein are provided solely to aid in the understanding of the invention.

**[0044]** Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment, but may. Furthermore, the particular features, structures or characteristics may be combined in any suitable manner, as would be apparent to a person skilled in the art from this disclosure, in one or more embodiments. Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the invention, and form different embodiments, as would be understood by those in the art. For example, in the following claims, any of the claimed embodiments can be used in any combination.

**[0045]** With as a goal illustrating better the properties of the invention the following presents, as an example and limiting in no way other potential applications, a description of a number of preferred embodiment of the heat pump system based on the invention, wherein:

### First embodiment

**[0046]** **FIG. 1** schematically shows a first embodiment of the heat pump system (1). The system (2) is shown comprising an outdoor unit (3) and an indoor unit (2). The heat pump system (2) comprises a refrigerant circuit and a heat medium circuit. The refrigerant circuit comprises a compressor (not shown), a heat-source side heat exchanger (not shown) and a refrigerant side of an inter-

mediate heat exchanger (6) located downstream from the compressor. The heat medium circuit comprises a heat medium side of the intermediate heat exchanger (6), a liquid-gas separator (12), a pump (7) and a load side heat exchanger (20). The outdoor unit (3) comprises at least part of a refrigerant circuit (5), and the intermediate heat exchanger (6) equipped with a temperature sensor (8) and a liquid-gas separator (12) equipped with a first pressure relief valve (19) and a first gas/air purge valve (9). In the first embodiment, the first pressure relief valve (19) is a mechanical valve. In other words, the first pressure relief valve (19) is automatically opened when the pressure in the heat medium circuit becomes a pressure greater than a predetermined pressure threshold. Also, when the pressure of the heat medium circuit becomes smaller than the predetermined pressure threshold, it is automatically closed. When refrigerant escapes from the system and mixes with the heat medium liquid (such as water or brine), it needs to be separated to prevent potential issues. The type of liquid-gas separator (12) is also commonly known as a refrigerant separator or refrigerant recovery unit. The liquid-gas separator (12) works by utilizing the difference in physical properties between the refrigerant gas and the heat medium liquid. When refrigerant leaks into the heat medium circuit during operation of the heat pump system, under the pressure of the heat medium circuit, the refrigerant is typically a gas, while the heat medium liquid remains in a liquid state, the liquid-gas separator (12) capitalizes on this difference to separate the two components. When a liquid-gas separator (12) is in operation, pressure differentials may occur due to factors such as changes in flow rates, temperature fluctuations, or system malfunctions. These pressure differentials can potentially lead to an increase in pressure within the liquid-gas separator (12). The first pressure relief valve (19), also known as a release valve or safety valve, is designed to protect the liquid-gas separator (12) from excessive pressure buildup. It acts as a safety mechanism by opening at the predetermined pressure threshold and allowing the excess pressure to escape from the separator (12). This release of excess refrigerant has the advantageous effect of liberating some of the internal volume of the liquid-gas separator (12), making room for any further refrigerant gas to more effectively be separated from the heat medium, therefore maximizing the separation performance of the liquid-gas separator (12). Furthermore, the pressure relief valve (19) advantageously protects other elements of the system from overpressure, ensuring a safe and long operational life.

**[0047]** The refrigerant circuit (5) is shown passing through one side of the intermediate heat exchanger (6), the second side of said heat exchanger being in fluid contact with a heat medium circuit (4). The liquid-gas separator (12) is shown in fluid connection with the outlet of the intermediate heat exchanger (6) and a first of two pipes connecting the outdoor unit (3) with the indoor unit (2). The indoor unit (2) is only traversed by the heat

medium circuit (4), which heat medium circuit (4) includes a 2-phase sensor (14) capable of detecting refrigerant bubbles inside the heat medium circuit (4) on the piping reaching an expansion vessel (17). In the first embodiment, the 2-phase sensor (14) corresponds to a means for detecting refrigerant in the heat medium circuit in the claims. The expansion vessel (17) placed upstream and in fluid connection with the inlet side of a pump (7) by means of piping equipped with a temperature sensor (8). The 2-phase sensor (14) may be, for example but not limited to, an ultrasonic flow-meter or vortex flow sensor. Ultrasonic flow meters can be used to measure the flow of the heat medium within the pipes. If gas is present in the heat medium, it can alter the flow characteristics, causing disruptions or changes in the ultrasonic signal. Vortex flow sensor also can be used to measure the flow of the heat medium within the pipes. If gas is present in the heat medium, it can alter the flow characteristics, causing disruptions or changes in the vortex frequency. By analyzing these disturbances, it may be possible to detect the presence of gas bubbles within the heat medium. Also, by analyzing these disturbances, it may be possible to detect the amount of change in gas bubbles per unit time, that is, the refrigerant leak flowrate into the heat medium circuit. These sensors can use various methods such as optical, acoustic, or conductive principles to identify the bubbles. The means, for example 2-phase sensor (14) is in communication with a controller (30) such that it can send a first information related to the presence of refrigerant in the heat medium circuit, said controller being configured to control the pump (7), as illustrated by the dashed lines. The controller (30) is of course typically also in communication (not shown on Fig. 1) with other components, for instance the flow sensor (10), the temperature sensor (8), the leakage detection sensor (16), the pressure sensor (18), and others.

**[0048]** The controller may comprise one or more processing units or modules (e.g. a central processing unit (CPU) such as a microprocessor, or a suitably programmed field programmable gate array (FPGA) or application-specific integrated circuit (ASIC)). Additionally, or alternatively, the controller may be provided with any memory sections necessary to perform its function of controlling operation of the heat pump system. Such memory sections may be provided as part of (comprised in) the controller (e.g. integrally formed or provided on the same chip) or provided separately, but electrically connected to the controller. By way of example, the memory sections may comprise both volatile and non-volatile memory resources, including, for example, a working memory (e.g. a random access memory). In addition, the memory sections may include an instruction store (e.g. a ROM in the form of an electrically-erasable programmable read-only memory (EEPROM) or flash memory) storing a computer program comprising computer-readable instructions which, when executed by the controller, cause the controller to perform various functions described herein. In an embodiment, the controller has

instructions, causing it to send a signal to the pump, said signal comprising instructions which alter the operation of the pump (7). These instructions, which will be explained in more detail in the descriptions of FIG. 2 and FIG. 3, advantageously limit the volume of refrigerant reaching the load side of the heat medium circuit.

**[0049]** The outlet side of the pump (7) is shown in fluid connection with a second pressure relief valve (29) located upstream of a backup heater (13) equipped with a second gas/air purge valve (28). In the first embodiment, the second pressure relief valve (29) is a mechanical valve. In other words, the second pressure relief valve (29) is automatically opened when the pressure in the heat medium circuit becomes a pressure greater than a predetermined pressure threshold. Also, when the pressure of the heat medium circuit becomes smaller than the predetermined pressure threshold, it is automatically closed. The outlet side of the backup heater (13) is in fluid connection with a load-side heat exchanger (20) by means of piping equipped with a temperature sensor (8) and a flow sensor (10) capable of measuring flowrate of the heat medium. The flow sensor (10) is configured to send fourth information relating to flowrate of the heat medium. The 2-phase sensor (14) send first information relating to the presence of refrigerant in the heat medium circuit to the controller. This fourth and first information advantageously permits assessing if the liquid-gas separator (12) provides sufficient separation. By preference, this piping is fitted with a pressure sensor (18 not shown), allowing the controller to calculate the refrigerant mass passing through the piping. In an embodiment, a pressure sensor (18 not shown) may be fitted after the 2-phase sensor (14). This allows the controller to compare the volume of refrigerant passing in the heat medium piping before and after the liquid-gas separator (12). This permits to assess if the separation efficiency of the liquid-gas separator (12) is sufficient for the measured heat medium flow. This estimated efficiency of the liquid-gas separator (12) relative to the flowrate of the heat medium is expressed as a second information to be stored in the memory of the controller. This is particularly useful if the efficiency of the liquid-gas separator (12) is not known and/or to assess if the performance of the liquid-gas separator (12) has deteriorated. The second information establishes the allowable upper flowrate of the heat medium in function of the refrigerant leak flowrate into the heat medium circuit. The second information can then be used as reference information, based on which the controller controls the speed of the pump (7). By preference, a third information relative to the allowable upper flowrate of the heat medium in function of the refrigerant leak flowrate into the heat medium circuit when liquid-gas separation is performed only by the liquid-gas separator (12) or performed by the liquid-gas separator (12) in combination with one or more of the pressure relief valves (19, 29). The outlet side of the load-side heat exchanger (20) is in further fluid connection with a pressure sensor (18) and a temperature

sensor (8) before continuing via a second pipe connecting the indoor unit (2) with the outdoor unit (3). Inside the outdoor unit (3) is in fluid connection with the intermediate heat exchanger (6).

**[0050]** FIG. 2 presents a graphical representation of leak rate to heat medium flow (21). The graph has a first axis corresponding to heat medium flowrate (25) and a second axis corresponding to refrigerant leak flowrate (26). This graph is a graph showing a separation efficiency of the liquid-gas separator. In other words, it shows whether the liquid-gas separator can separate refrigerant from heat medium at a certain refrigerant leak flowrate and a certain heat medium flowrate. This graph corresponds to the second information in the claim 2. The second information is stored in the memory sections. Fig. 2 shows a first area (22) corresponding to combination of heat medium flowrate and refrigerant leak flowrate at which the gas separator alone can sufficiently reduce the refrigerant in the heat medium circuit. A second area (23) is shown, which contains the combined values of heat medium flowrate and refrigerant leak flowrate require the use of both the liquid-gas separator (12) as well as a pressure relief valve (19) to sufficiently achieve a separation efficiency of the liquid-gas separator. A third area (24) shows the combined heat medium flowrate and refrigerant leakage flowrate that cannot be addressed by the gas separator (12) and pressure relief valve alone. The first area (22) and the second area (23) correspond to the third information in the claim 3 and 4, which are stored in the memory sections.

**[0051]** FIG. 3 shows a diagram of the method (27) for controlling the heat pump. This method (27) requires the determining an upper safe limit for the refrigerant flowing to the load side (S1). By preference, this step takes into account the toxicity of the refrigerant, more preferably also the lower flammability limit of the refrigerant, most preferably, the step S1 takes into consideration the volume of the rooms potentially affected in case a refrigerant leakage occurs. While the system (1) is running, the controller is configured to poll at least one means for detecting refrigerant in the heat medium circuit (S2). As explained above, the means for detecting refrigerant may be chosen from the 2-phase sensor (14) such as the ultrasonic flow-meter and the vortex flow sensor, and serves to check for presence of refrigerant in heat medium piping (S3). If the controller receives a first information, the controller calculates the refrigerant leak flowrate into the heat medium circuit (S4). In order to determine if the efficiency of the liquid-gas (12) separator is sufficient, the fourth information related to the flowrate of the heat medium and the estimated refrigerant leak flowrate are used in combination with the second information as shown in FIG. 2. If it is determined that the system is operating within area (22) of FIG. 2 (S5 is yes), it is checked by the controller whether or not the system is operating at a lower pump speed than a first predetermined pump speed (S6). If it is determined that the system is operating at a lower pump speed than the first

predetermined pump speed (S6 is yes), it is determined that the efficiency of the liquid-gas separator is sufficient and the controller maintains the pump speed (S7). In essence, as long as the system operates within area (22), the separation efficiency of the liquid-gas separator is sufficient, so the amount of refrigerant flowing to the load-side heat exchanger without being separated in the liquid-gas separator is below a predetermined amount that could cause ignition when it leaks into a room where the load-side heat exchanger is installed.

**[0052]** If it is determined that the system is operating at a higher pump speed than the first predetermined pump speed (S6 is no), the controller controls the pump to reduce the pump speed below the first predetermined pump speed (S8). Since the higher the pump speed is, the lower separation efficiency by the gas-liquid separator becomes, in reducing the pump speed to a speed below the first predetermined pump speed, will result in a sufficient separation efficiency. This in turn reduces the amount of refrigerant flowing to the load-side heat exchanger without being separated in the liquid-gas separator.

**[0053]** In the area (22), the pressure relief valves (19, 29) do not open, because the refrigerant leak flowrate is small in this area, so the pressure in the heat medium circuit does not exceed a predetermined pressure threshold.

**[0054]** If it is determined that the system is not operating within area (22) of FIG. 2 (S5 is no), it is checked whether or not the system is operating within area (23) of FIG. 2 (S9). If it is determined that the system is operating within area (23) of FIG. 2 (S9 is yes), it is checked by the controller whether or not the system is operating at a lower pump speed than a second predetermined pump speed (S10). If it is determined that the system is operating at a lower pump speed than the second predetermined pump speed (S10 is yes), the controller maintains the pump speed (S11). The area (23) is an area where the pressure in the heat medium circuit can reach the predetermined pressure threshold or higher. In the area (23), when the pressure in the heat medium circuit reaches the predetermined pressure threshold or higher, the mechanical pressure relief valve (19, 29) is automatically opened.

**[0055]** Thus, since the pressure in the heat medium circuit is kept at a pressure lower than the predetermined pressure threshold by opening the mechanical pressure relief valve, the separation efficiency of the liquid-gas separator is sufficient.

**[0056]** If it is determined that the system is operating at a higher pump speed than the second predetermined pump speed (S10 is no), the controller controls the pump to reduce the pump speed below the second predetermined pump speed (S12). The second predetermined pump speed may be the same as the first predetermined pump speed. Also, the reason this system has the second predetermined pump speed is the same as for the first predetermined pump speed. That is, as long as the

system operates within area (23), the separation efficiency of the liquid-gas separator (12) used in combination with one or more pressure relief valves (19, 29) is sufficient. Therefore, the amount of refrigerant flowing to the load-side heat exchanger without being separated in the liquid-gas separator is below a predetermined amount that could cause ignition when it leaks into a room where the load-side heat exchanger is installed.

**[0057]** If it is determined that the system is not operating within area (23) of FIG. 2 (S9 is no), it is checked whether or not the system is operating within area (24) of FIG. 2 (S13). If it is determined that the system is operating within area (24) of FIG. 2 (S13 is yes), the controller issues a signal to the pump (7) to cause a reduction of the speed of said pump (7) below a third predetermined pump speed (S14). The third predetermined pump speed may be the same as the first predetermined pump speed and the second predetermined pump speed. Thus, in the first embodiment, even when refrigerant leaks into the heat medium circuit, the controller controls the pump speed by considering information on the presence of refrigerant in the heat medium circuit. Also, in the first embodiment, the pump speed is determined based on the second information about a relation between the separation efficiency of the liquid-gas separator and the flowrate of the heat medium. Thus, the system can continue operation even after refrigerant has leaked into the heat carrier circuit.

## 30 Second embodiment

**[0058]** In the second embodiment, the first and second pressure relief valve (19, 29) are configured by control valves. That is, the first and second pressure relief valves (19, 29) are controlled by the controller. In the second embodiment, the controller is configured to perform a variation on S11 of the first embodiment. In the variation of S11, the controller maintains the pump speed and issues a signal to the at least one pressure relief valves (19, 29), causing said at least one valve to open (variation of S11). Also, the controller is configured to perform a variation on S12-1 of the first embodiment. In the variation on S12, the controller controls the pump so that the pump speed is below the second predetermined pump speed and issues a signal to the at least one pressure relief valves (19, 29), causing said at least one valve to open (variation on S12). Also, the controller is configured to perform a variation on S14 of the first embodiment. That is, the controller controls the pump so that the pump speed is below the third predetermined pump speed and issues a signal to the at least one pressure relief valves (19, 29), causing said at least one valve to open (variation of S14). The other actions are the same as in embodiment 1.

## 55 List of numbered items:

**[0059]**



|     |                                                                                                  |    |
|-----|--------------------------------------------------------------------------------------------------|----|
| 1   | system                                                                                           |    |
| 2   | indoor unit                                                                                      |    |
| 3   | outdoor unit                                                                                     |    |
| 4   | heat medium circuit                                                                              |    |
| 5   | refrigerant circuit                                                                              | 5  |
| 6   | intermediate heat exchanger                                                                      |    |
| 7   | pump                                                                                             |    |
| 8   | temperature sensor                                                                               |    |
| 9   | first gas/air purge valve                                                                        |    |
| 10  | flow sensor                                                                                      | 10 |
| 12  | liquid-gas separator                                                                             |    |
| 13  | backup heater                                                                                    |    |
| 14  | 2-phase sensor                                                                                   |    |
| 15  | level switch                                                                                     |    |
| 16  | leakage detection sensor                                                                         | 15 |
| 17  | expansion vessel                                                                                 |    |
| 18  | pressure sensor                                                                                  |    |
| 19  | pressure relief valve                                                                            |    |
| 20  | load-side heat exchanger                                                                         |    |
| 21  | graphic representation of leak rate to heat medium flow                                          | 20 |
| 22  | area where gas separator is sufficient                                                           |    |
| 23  | area where gas separator and pressure relief is sufficient                                       |    |
| 24  | area of excessive refrigerant leak                                                               | 25 |
| 25  | heat medium flowrate axis                                                                        |    |
| 26  | leak flowrate axis                                                                               |    |
| 27  | method for controlling the heat pump                                                             |    |
| 28  | second gas/air purge valve                                                                       |    |
| 29  | second pressure relief valve                                                                     | 30 |
| 30  | controller                                                                                       |    |
| S1  | establishing an upper safe limit for the refrigerant flowing to the load side                    |    |
| S2  | polling means for detecting refrigerant                                                          |    |
| S3  | checking for presence of refrigerant in heat medium piping                                       | 35 |
| S4  | calculating refrigerant leakage rate                                                             |    |
| S5  | System is operating within area 22                                                               |    |
| S6  | System is operating at a lower pump speed than a first predetermined pump speed                  | 40 |
| S7  | Controller keeps the pump to control with the pump speed                                         |    |
| S8  | Controller controls the pump so that the pump speed is below the first predetermined pump speed  | 45 |
| S9  | System is operating within area 23                                                               |    |
| S10 | System is operating at a lower pump speed than a second predetermined pump speed                 |    |
| S11 | Controller keeps the pump to control with the pump speed                                         | 50 |
| S12 | Controller controls the pump so that the pump speed is below the second predetermined pump speed |    |
| S13 | System is operating within area 24                                                               |    |
| S14 | Controller issues a signal to the pump (7) to cause a reduction of the speed of said pump        | 55 |

more details, referring to examples that are not limitative.

## Claims

### 1. A heat pump system comprising:

a refrigerant circuit comprising a compressor, a heat-source side heat exchanger, a refrigerant side of an intermediate heat exchanger located downstream from the compressor;  
a controller for controlling at least the pump;  
a heat medium circuit comprising a heat medium side of the intermediate heat exchanger, a liquid-gas separator, a pump and a load side heat exchanger;

**characterized in that**, the heat medium circuit comprises a means for detecting refrigerant in the heat medium circuit, said means being configured to provide first information relating to the presence of refrigerant in the heat medium circuit to the controller;  
wherein said controller controls the pump during operation, taking into account the first information relating to the presence of refrigerant in the heat medium circuit.

2. The system according to claim 1, **characterized in that**, the controller comprises a memory section for storing second information about a relationship between a separation efficiency of the liquid-gas separator and flowrate of the heat medium, wherein, the controller is configured to control the flowrate of the heat medium based on the second information so that the amount of refrigerant flowing to the load-side heat exchanger without being separated in the liquid-gas separator is below a predetermined amount.

3. The system according to claim 1 or 2, **characterized in that**, the controller comprises a memory section for storing a third information, wherein said third information represents a relationship between a flowrate of the heat medium and a measured presence of the refrigerant in the heat medium circuit, taking into account a known separation efficiency of the liquid-gas separator, wherein said relationship defines ranges for said flowrate of the heat medium and said measured presence of the refrigerant, and wherein the controller is configured to control the flowrate of the heat medium based on the third information.

4. The system according to claim 3, **characterized in that**, the third information further defines ranges for said flowrate of the heat medium and said measured presence of the refrigerant for which the controller is configured to control one or more pressure relief valves to control reduce the presence of the refrigerant.

[0060] The present invention will be now described in

erant in the heat medium.

5. The system according to any of the previous claims, **characterized in that**, the predetermined amount of refrigerant allowable into the load-side heat exchanger depends on the lower flammable limit of the refrigerant used in the system.
6. The system according to any previous claim 2 or 5, **characterized in that**, the controller is configured to determine an intended flowrate of the heat medium based on the second information recorded in the memory about the relationship between the separation efficiency of the liquid-gas separator and the flowrate of the heat medium when the controller detects that the refrigerant has leaked into the heat medium circuit, and wherein the controller controls the pump to generate said intended flowrate for the heat medium in the heat medium circuit.
7. The system according to previous claim 6, **characterized in that**, when the controller detects that the refrigerant has leaked into the heat medium circuit while the pump is being driven, the controller is configured to control the rotation speed of the pump based on the second information about the relationship between the separation efficiency of the liquid-gas separator and the flowrate of the heat medium.
8. The system according to any of the previous claims 1 to 7, **characterized in that**, when the controller detects that the refrigerant has leaked into the heat medium circuit while the pump is being driven, the controller is configured to adjust the rotation speed of the pump to a rotation speed lower than the rotation speed of the pump before the detection of the refrigerant leakage.
9. The system according to any of the previous claims, **characterized in that**, the means is an ultrasonic sensor for detecting gas bubbles in a liquid medium.
10. The system according to any of the previous claims, **characterized in that**, the heat medium circuit comprises a flow sensor capable of measuring flowrate of the heat medium in the heat medium circuit, said flow sensor being positioned downstream of the pump, said flow sensor being configured to send fourth information relating to flowrate of the heat medium to the controller, wherein the controller takes into account the fourth information received from said flow sensor for controlling at least the pump.
11. The system according to any of the previous claims, **characterized in that**, the liquid-gas separator comprises a gas purge outlet and a first pressure relief valve for releasing leaked refrigerant out of the system.

12. The system according to any of the previous claims, **characterized in that**, the heat medium circuit comprises a second pressure relief valve upstream from any load side heat exchanger.

13. Method for controlling a heat pump system of a heat pump having a refrigerant circuit and a heat medium circuit in fluid connection with an intermediate heat exchanger, the method comprising the steps of:

detecting refrigerant in the heat medium circuit via a means for detecting refrigerant in the heat medium circuit;  
 providing first information regarding the presence of the refrigerant in the heat medium circuit from the means to a controller;  
**characterized in that**, the method further includes a step of controlling at least a pump during operation in the heat medium circuit by means of the controller, wherein the pump is controlled taking into account the first information relating to the presence of the refrigerant in the heat medium circuit, for driving the flowrate of the heat medium in the heat medium circuit.

14. The method according to previous claim 14, **characterized in that**, the method further includes a step of determining an allowable speed of rotation of the pump, said determination being based on a third information, wherein said third information represents a relationship between a flowrate of the heat medium and a measured presence of the refrigerant in the heat medium circuit, taking into account a known separation efficiency of the liquid-gas separator, wherein said relationship defines ranges for said flowrate of the heat medium and said measured presence of the refrigerant.

15. The method according to claim 14 or 15, **characterized in that**, the method includes a step wherein the controller issues a signal to at least one pressure relief valve located on the heat medium circuit and/or a liquid-gas separator located on the heat medium circuit, causing said at least one valve to open further.

#### Amended claims in accordance with Rule 137(2) EPC.

1. A heat pump system comprising:

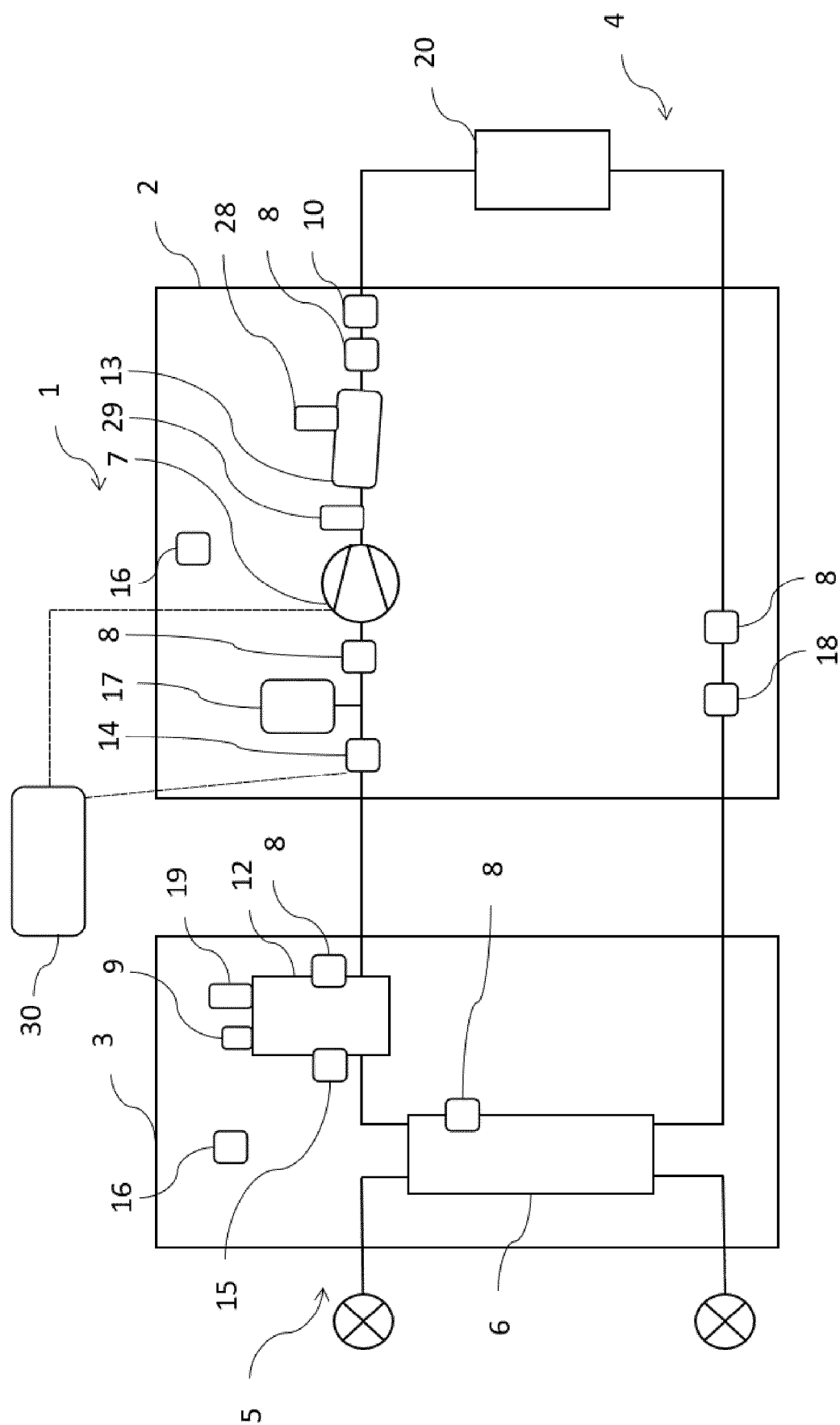
a refrigerant circuit comprising a compressor, a heat-source side heat exchanger, a refrigerant side of an intermediate heat exchanger located downstream from the compressor;  
 a heat medium circuit comprising a heat medium side of the intermediate heat exchanger, a liquid-gas separator, a pump and a load side heat

- exchanger;  
 a controller for controlling at least the pump;  
 wherein the heat medium circuit comprises a means for detecting refrigerant in the heat medium circuit, said means being configured to provide first information relating to the presence of refrigerant in the heat medium circuit to the controller;  
 wherein said controller controls the pump during operation, taking into account the first information relating to the presence of refrigerant in the heat medium circuit,  
 and **characterized in that** the controller comprises a memory section for storing second information about a relationship between a separation efficiency of the liquid-gas separator and flowrate of the heat medium, wherein, the controller is configured to control the flowrate of the heat medium based on the second information so that the amount of refrigerant flowing to the load-side heat exchanger without being separated in the liquid-gas separator is below a predetermined amount.
2. The system according to claim 1, **characterized in that**, the controller comprises a memory section for storing a third information, wherein said third information represents a relationship between a flowrate of the heat medium and a measured presence of the refrigerant in the heat medium circuit, taking into account a known separation efficiency of the liquid-gas separator, wherein said relationship defines ranges for said flowrate of the heat medium and said measured presence of the refrigerant, and wherein the controller is configured to control the flowrate of the heat medium based on the third information.
  3. The system according to claim 1 or 2, **characterized in that**, the third information further defines ranges for said flowrate of the heat medium and said measured presence of the refrigerant for which the controller is configured to control one or more pressure relief valves to reduce the presence of the refrigerant in the heat medium.
  4. The system according to any of the previous claims, **characterized in that**, the predetermined amount of refrigerant allowable into the load-side heat exchanger depends on the lower flammable limit of the refrigerant used in the system.
  5. The system according to any of the previous claims, **characterized in that**, the controller is configured to determine an intended flowrate of the heat medium based on the second information recorded in the memory about the relationship between the separation efficiency of the liquid-gas separator and the flowrate of the heat medium when the controller detects that the refrigerant has leaked into the heat medium circuit, and wherein the controller controls the pump to generate said intended flowrate for the heat medium in the heat medium circuit.
  6. The system according to previous claim 5, **characterized in that**, when the controller detects that the refrigerant has leaked into the heat medium circuit while the pump is being driven, the controller is configured to control the rotation speed of the pump based on the second information about the relationship between the separation efficiency of the liquid-gas separator and the flowrate of the heat medium.
  7. The system according to any of the previous claims, **characterized in that**, when the controller detects that the refrigerant has leaked into the heat medium circuit while the pump is being driven, the controller is configured to adjust the rotation speed of the pump to a rotation speed lower than the rotation speed of the pump before the detection of the refrigerant leakage.
  8. The system according to any of the previous claims, **characterized in that**, the means is an ultrasonic sensor for detecting gas bubbles in a liquid medium.
  9. The system according to any of the previous claims, **characterized in that**, the heat medium circuit comprises a flow sensor capable of measuring flowrate of the heat medium in the heat medium circuit, said flow sensor being positioned downstream of the pump, said flow sensor being configured to send fourth information relating to flowrate of the heat medium to the controller, wherein the controller takes into account the fourth information received from said flow sensor for controlling at least the pump.
  10. The system according to any of the previous claims, **characterized in that**, the liquid-gas separator comprises a gas purge outlet and a first pressure relief valve for releasing leaked refrigerant out of the system.
  11. The system according to any of the previous claims, **characterized in that**, the heat medium circuit comprises a second pressure relief valve upstream from any load side heat exchanger.
  12. Method for controlling a heat pump system of a heat pump having a refrigerant circuit and a heat medium circuit in fluid connection with an intermediate heat exchanger, the heat medium circuit comprising a liquid-gas separator, a pump and a load-side heat exchanger, the method comprising the steps of:
    - detecting refrigerant in the heat medium circuit via a means for detecting refrigerant in the heat

medium circuit;  
 providing first information regarding the presence of the refrigerant in the heat medium circuit from the means to a controller;  
 controlling at least a pump during operation in the heat medium circuit by means of the controller, wherein the pump is controlled taking into account the first information relating to the presence of the refrigerant in the heat medium circuit, for driving the flowrate of the heat medium in the heat medium circuit, 5  
 and **characterized in that** the controller comprises a memory section for storing second information about a relationship between a separation efficiency of the liquid-gas separator and flowrate of the heat medium, comprising a step of controlling the flowrate of the heat medium by the controller based on the second information so that the amount of refrigerant flowing to the load-side heat exchanger without being separated in the liquid-gas separator is below a predetermined amount. 10 15 20

13. The method according to previous claim 12, **characterized in that**, the method further includes a step of determining an allowable speed of rotation of the pump, said determination being based on a third information, wherein said third information represents a relationship between a flowrate of the heat medium and a measured presence of the refrigerant in the heat medium circuit, taking into account a known separation efficiency of the liquid-gas separator, wherein said relationship defines ranges for said flowrate of the heat medium and said measured presence of the refrigerant. 25 30 35

14. The method according to claim 12 or 13, **characterized in that**, the method includes a step wherein the controller issues a signal to at least one pressure relief valve located on the heat medium circuit and/or a liquid-gas separator located on the heat medium circuit, causing said at least one valve to open further. 40 45 50 55



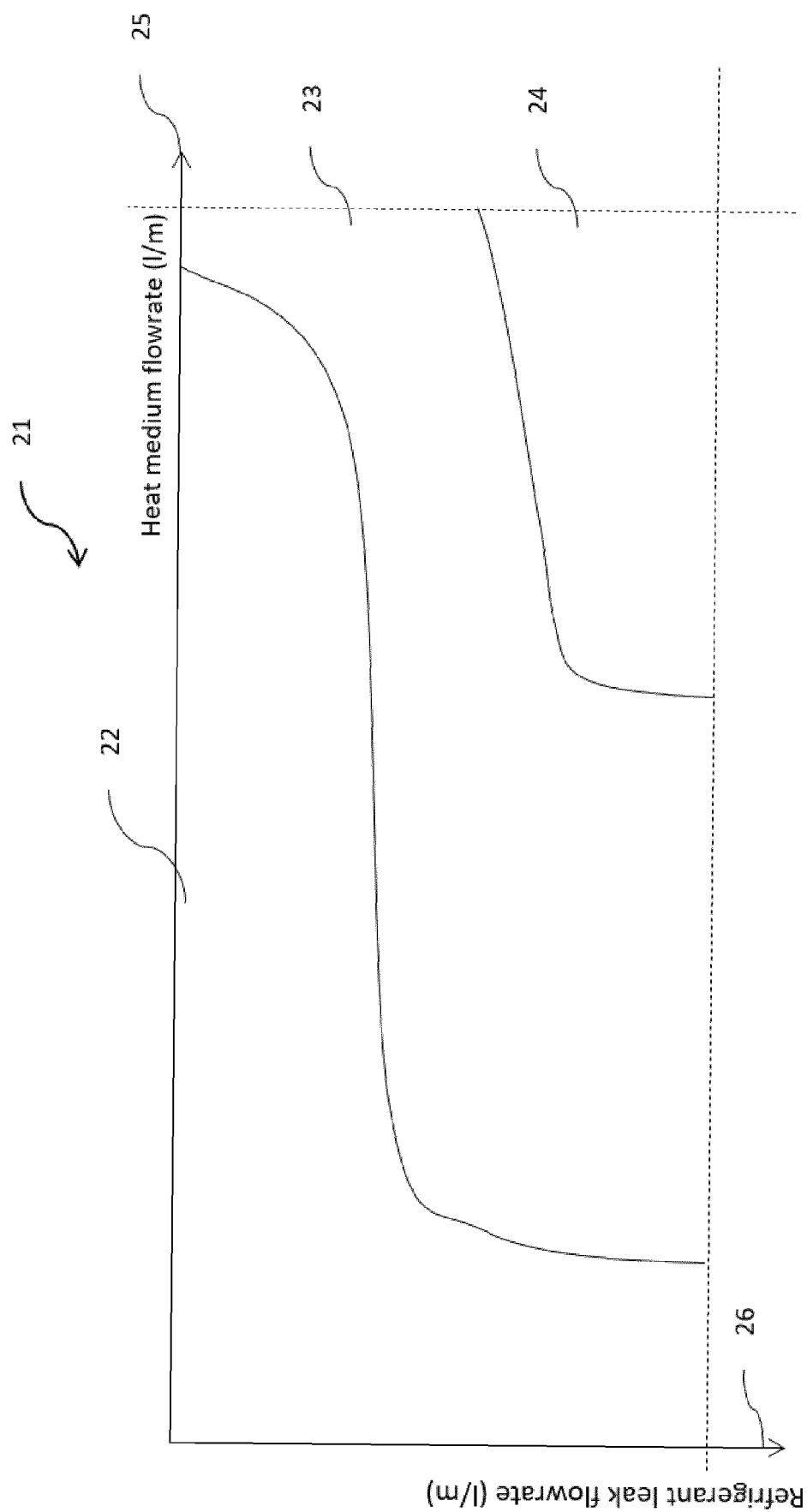


FIG. 2

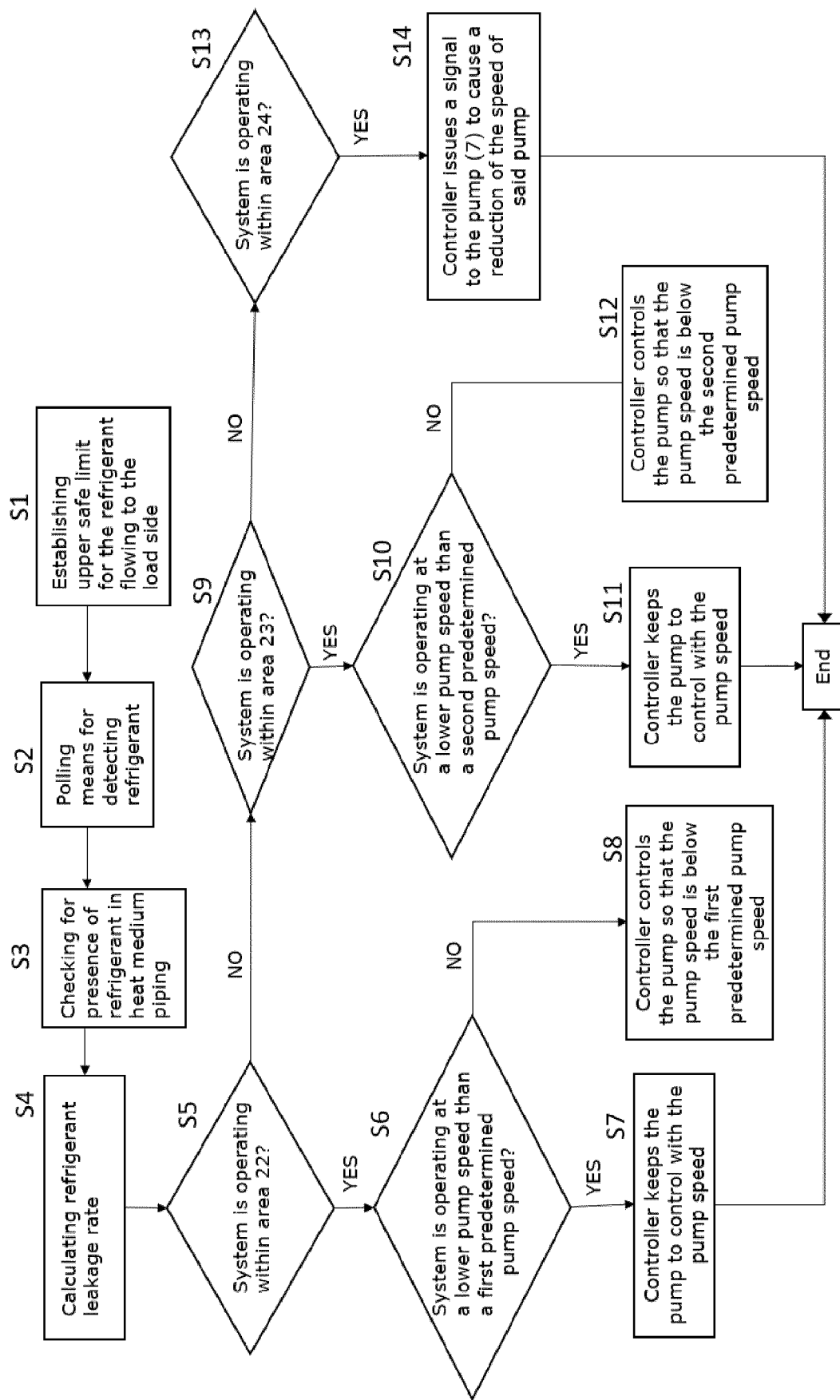


FIG. 3



## EUROPEAN SEARCH REPORT

Application Number

EP 23 19 3310

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| Place of search                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                    | Date of completion of the search | Examiner                                |
| Munich                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                    | 26 January 2024                  | Hoffmann, Stéphanie                     |
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