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(54) A heat pump laundry drying machine and a method for operating a heat pump laundry drying machine

(57) The present invention relates to a laundry drying machine (1; 100; 200; 300; 400) comprising a laundry chamber (9) suitable for receiving the laundry to be dried; an air stream circuit (10) for circulating drying air through said laundry chamber (9); a heat pump system (20) comprising a closed refrigerant circuit (30) for a refrigerant. The refrigerant circuit (30) comprises a compressor (24), a first heat exchanger (21), an expansion device (22) and a second heat exchanger (23) connected in series to form a closed-loop circuit. The air stream circuit (10) comprises the first heat exchanger (21), the laundry chamber (9), the second heat exchanger (23) and at least one blowing device (12) for the air. The second heat exchanger (23) is provided for cooling down and dehumidifying the drying air leaving the laundry chamber (9) and for heating up the refrigerant, wherein the drying air condenses at the second heat exchanger (23) generating condensed water.

The refrigerant circuit (30) further comprises a refrigerant-to-refrigerant heat exchanger (40) having a high-pressure side arranged between the first heat exchanger (21) and the expansion device (22) and a low-pressure side arranged between the second heat exchanger (23) and an inlet (24a) of the compressor (24). The machine (1; 100; 200; 300; 400) further comprises an auxiliary heat exchanging system (60; 160; 360) arranged between the low-pressure side of the refrigerant-to-refrigerant heat exchanger (40) and the compressor inlet (24a).

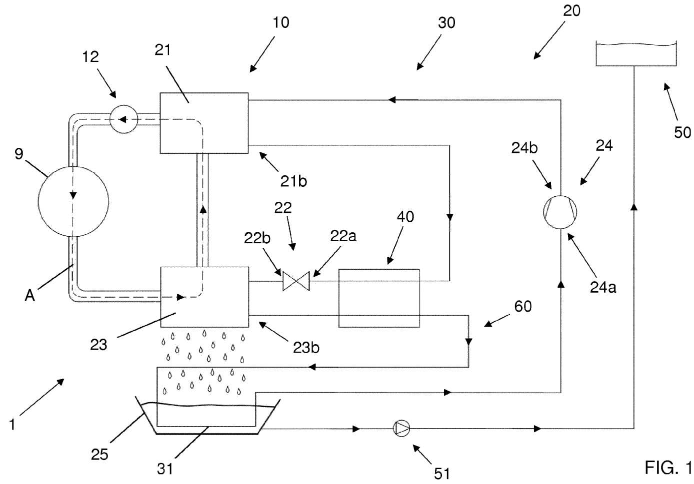

FIG. 1

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Description

FIELD OF THE INVENTION

[0001] The present invention concerns the technical field of laundry treating machines, especially laundry drying machines.

[0002] In particular, the present invention refers to a laundry drying machine with a heat pump system and a method for operating such laundry drying machine.

BACKGROUND ART

[0003] Laundry treating machines capable of carrying out a drying process on laundry, hereinafter simply indicated as laundry dryers, generally comprise a casing that houses a laundry container, like a rotating drum, where laundry to be treated is received. A closed air stream circuit carries out drying operation by circulating hot air through the laundry container containing the wet laundry.

[0004] In laundry dryers, the heat pump technology is the most efficient way to save energy during drying operation. In conventional heat pump laundry dryers a drying air stream flows in a close loop. The drying air stream is moved by a fan, passes a laundry drum and removes water from wet clothes. Then the drying air stream is cooled down and dehumidified and then heated up in a heat pump system and finally reinserted again into the laundry drum.

[0005] The heat pump system comprises a refrigerant flowing in a closed-loop refrigerant circuit constituted by a compressor, a condenser, an expansion device and an evaporator. The condenser heats up the drying air while the evaporator cools and dehumidifies the drying air leaving the drum. The refrigerant flows in the refrigerant circuit where it is compressed by the compressor, condensed in the condenser, expanded in the expansion device and then vaporized in the evaporator. The temperatures of the drying air stream and the refrigerant are strongly correlated to each other.

[0006] The operation cycle of a heat pump laundry dryer includes two phases, namely a transitory phase (or warm-up phase), and a steady state phase. During the transitory phase the temperatures of the drying air stream and the heat pump system, which are usually at the ambient temperature when the laundry dryer starts to operate, increase up to desired levels. During the steady state phase, the temperatures of the drying air stream remain substantially constant and also the temperatures of the heat pump system are kept quiet constant, for example by means of a compressor cooling fan or an auxiliary condenser, until the laundry is dried.

[0007] In laundry dryers of known type, for example in the laundry dryer described in US20050198852, the refrigerant circuit is also provided with an inner heat exchanger for allowing the refrigerant compressed by the compressor and discharged from the condenser to exchange heat with the refrigerant discharged from the evaporator.

[0008] The inner heat exchanger therefore cools down the refrigerant at the outlet of condenser before the expansion device (i.e. on the high-pressure side), and heats up the vapour at the outlet of the evaporator before the compressor (i.e. the low-pressure side).

[0009] This allows the refrigerant to enter in the evaporator in a more favourable conditions therefore increasing the cooling and the dehumidifying capacity of the evaporator.

[0010] Furthermore, the heat transferred to the refrigerant at the outlet of the evaporator assures the absence of liquid in the refrigerant before it reaches the compressor. In a preferred embodiment, the inner heat exchanger substantially performs a complete vaporization of the refrigerant before it reaches the compressor. In other preferred embodiments, the inner heat exchanger substantially performs an overheating of the refrigerant already completely vaporized before it reaches the compressor. In any case, the inner heat exchanger assures the absence of liquid in the refrigerant itself thereby ensuring the correct functioning of the compressor. However, the laundry dryers above described belonging to the known art pose some drawbacks.

[0011] A first drawback posed by this known laundry dryers is constituted by the fact that a too high temperature level of the refrigerant at the compressor inlet can be dangerous for the safety of the compressor itself.

[0012] Therefore, the amount of heat that can be transferred from the high-pressure side to the low-pressure side by the internal heat exchanger is limited by the fact that the temperature of the refrigerant at the compressor inlet can't be higher than a certain level, for compressor safety.

[0013] Another drawback posed by this known technique is constituted by the fact that the excessive heating of the refrigerant, i.e. the vapour, performed by the inner heat exchanger causes a reduction of the refrigerant's density. This cause, in turn, a flow rate reduction of the refrigerant and hence a reduction of the performance of the heat pump system.

[0014] The main object of the present invention is therefore to overcome said drawbacks.

[0015] In particular, it is one object of the present invention to provide a laundry drying machine which may work in safe condition.

[0016] Therefore, an object of the present invention is to provide a laundry drying machine with a lower failure rate with respect to the laundry drying machines of known type.

[0017] Another object of the present invention is to provide a laundry drying machine with higher energy efficiency with respect to the laundry drying machines of known type.

[0018] A further object of the present invention is to provide a laundry drying machine which speed-up the transitory phase with respect to the laundry drying machines of known type.

[0019] Advantages, objects, and features of the invention will be set forth in part in the description and drawings which follow and in part will become apparent to those having ordinary skill in the art upon examination of the following or may be learned from practice of the invention.

DISCLOSURE OF INVENTION

[0020] The applicant has found that by providing a laundry drying machine comprising a laundry chamber suitable for receiving the laundry to be dried, an air stream circuit for circulating drying air through said laundry chamber, a heat pump system comprising a closed refrigerant circuit for a refrigerant, wherein the refrigerant circuit comprises a compressor, a first heat exchanger, an expansion device and a second heat exchanger connected in series to form a closed-loop circuit; wherein the second heat exchanger is provided for cooling down and dehumidifying the drying air leaving the laundry chamber and for heating up the refrigerant, wherein the drying air at least partially condenses at the second heat exchanger generating condensed water, and by providing an auxiliary heat exchanging system associated to the refrigerant circuit and suitable for transferring heat from the refrigerant to the condensed water generated at the second heat exchanger it is possible to obtain a laundry drying machine which may work in safe condition.

[0021] In a first aspect the present invention relates, therefore, to a laundry drying machine comprising:

- a laundry chamber suitable for receiving the laundry to be dried;
- an air stream circuit for circulating drying air through said laundry chamber;
- a heat pump system comprising a closed refrigerant circuit for a refrigerant, wherein said refrigerant circuit comprises a compressor, a first heat exchanger, an expansion device and a second heat exchanger connected in series to form a closed-loop circuit; and wherein:
- said air stream circuit comprises said first heat exchanger, said laundry chamber, said second heat exchanger and at least one blowing device for said air;
- said refrigerant circuit and said air stream circuit are thermally coupled by said first heat exchanger and said second heat exchanger, said second heat exchanger being provided for cooling down and dehumidifying said drying air leaving said laundry chamber and for heating up said refrigerant, wherein said drying air at least partially condenses at said second heat exchanger generating condensed water;
- said first heat exchanger being provided for heating up said drying air and cooling down said refrigerant;
- said refrigerant circuit further comprising a refrigerant-to-refrigerant heat exchanger having a high-pressure side arranged between said first heat exchanger and said expansion device and a low-pressure side arranged between said second heat exchanger and an inlet of said compressor, said refrigerant-to-refrigerant heat exchanger being provided for transferring heat from said high-pressure side to said low-pressure side;

wherein said machine further comprises an auxiliary heat exchanging system arranged between said low-pressure side of said refrigerant-to-refrigerant heat exchanger and said compressor inlet, said auxiliary heat exchanging system being suitable for transferring heat from said refrigerant to said condensed water generated at said second heat exchanger.

[0022] Preferably, the auxiliary heat exchanging system comprises a portion of the refrigerant circuit connecting the low-pressure side of the refrigerant-to-refrigerant heat exchanger to the compressor inlet.

[0023] Preferably, the portion is a portion of pipe of the refrigerant circuit connecting the low-pressure side of the refrigerant-to-refrigerant heat exchanger to the compressor inlet.

[0024] In a preferred embodiment of the invention, the portion of pipe is arranged below the second heat exchanger where the condensed water drips from the second heat exchanger.

[0025] Preferably, the machine further comprises a main container suitable for receiving the condensed water generated at the second heat exchanger.

[0026] In a more preferred embodiment of the invention, the portion of pipe of the refrigerant circuit connecting the refrigerant-to-refrigerant heat exchanger to the compressor inlet is arranged at least partially inside the main container. Preferably, the auxiliary heat exchanging system further comprises a draining pump suitable for draining water from the main container to a collection tank or to the outside.

[0027] In a further preferred embodiment of the invention, the portion of pipe of the refrigerant circuit is arranged at least partially inside an additional container connected to, and receiving the condensed water from, the main container. Preferably, the auxiliary heat exchanging system further comprises a draining pump suitable for draining water from the additional container to a collection tank or to the outside.

[0028] Preferably, the auxiliary heat exchanging system further comprises a draining pump suitable for draining water from the main container to the additional container.

[0029] In a further preferred embodiment of the invention, the auxiliary heat exchanging system comprises an additional heat exchanger having one side arranged in a portion of the refrigerant circuit connecting the refrigerant-to-refrigerant heat exchanger to the compressor inlet and the other side arranged in a condensed water flow flowing out of the main container.

[0030] Preferably, the auxiliary heat exchanging system further comprises a draining pump suitable for draining water from the main container in order to create said condensed water flow and for successively draining the water to a collection tank or to the outside.

[0031] In a further preferred embodiment of the invention, the auxiliary heat exchanging system comprises an additional heat exchanger having one side arranged in a portion of the refrigerant circuit connecting the refrigerant-to-refrigerant heat exchanger to the compressor inlet and the other side arranged in a condensed water flow flowing out of a collector arranged below the second heat exchanger. Preferably, the auxiliary heat exchanging system further comprises a draining pump suitable for draining water from the collector in order to create said condensed water flow and for successively draining the water to a collection tank or to the outside.

[0032] In a preferred embodiment of the invention, the machine further comprises a switching device suitable for selectively connecting the auxiliary heat exchanging system to the refrigerant circuit, so that the refrigerant can flow either through the auxiliary heat exchanging system or from the refrigerant-to-refrigerant heat exchanger to the compressor inlet directly by-passing the auxiliary heat exchanging system.

[0033] Preferably, the switching device comprises a three-way valve.

[0034] Opportunely, the machine comprises a collection tank suitable for collecting the condensed water.

[0035] Preferably, the collection tank is a removable tank suitable to be emptied by a user when necessary.

[0036] In a further aspect the present invention relates to a method for operating a laundry drying machine of the type comprising:

- a laundry chamber suitable for receiving the laundry to be dried;
- an air stream circuit for circulating drying air through said laundry chamber;
- a heat pump system comprising a closed refrigerant circuit for a refrigerant, wherein said refrigerant circuit comprises a compressor, a first heat exchanger, an expansion device and a second heat exchanger connected in series to form a closed-loop circuit; and wherein:
- said air stream circuit comprises said first heat exchanger, said laundry chamber, said second heat exchanger and at least one blowing device for said air;
- said refrigerant circuit and said air stream circuit are thermally coupled by said first heat exchanger and said second heat exchanger, said second heat exchanger being provided for cooling down and dehumidifying said drying air leaving said laundry chamber and for heating up said refrigerant, wherein said drying air at least partially condenses at said second heat exchanger generating condensed water;
- said first heat exchanger being provided for heating up said drying air and cooling down said refrigerant;
- said refrigerant circuit further comprising a refrigerant-to-refrigerant heat exchanger having a high-pressure side arranged between said first heat exchanger and said expansion device and a low-pressure side arranged between said second heat exchanger and an inlet of said compressor, said refrigerant-to-refrigerant heat exchanger being provided for transferring heat from said high-pressure side to said low-pressure side;

the method comprising a step of activating said heat pump system;
wherein the method further comprises a step of transferring heat from said refrigerant leaving said refrigerant-to-refrigerant heat exchanger to said condensed water generated at said second heat exchanger.

[0037] In a first preferred embodiment of the invention, the step of transferring heat from the refrigerant leaving the refrigerant-to-refrigerant heat exchanger to the condensed water generated at the second heat exchanger and the step of activating the heat pump system take place simultaneously.

[0038] In another preferred embodiment of the invention, the step of transferring heat from the refrigerant leaving the refrigerant-to-refrigerant heat exchanger to the condensed water generated at the second heat exchanger takes place after a pre-determined period of time with respect to the step of activating the heat pump system.

[0039] Preferably, the step of transferring heat from the refrigerant leaving the refrigerant-to-refrigerant heat exchanger to the condensed water generated at the second heat exchanger takes place in a portion of the refrigerant circuit connecting the low-pressure side of the refrigerant-to-refrigerant heat exchanger to the compressor inlet.

[0040] Preferably, the portion is a portion of pipe of the refrigerant circuit connecting the low-pressure side of the refrigerant-to-refrigerant heat exchanger to the compressor inlet.

[0041] In a preferred embodiment of the invention, the step of transferring heat from the refrigerant leaving the refrigerant-to-refrigerant heat exchanger to the condensed water generated at the second heat exchanger takes place in the portion of pipe which is arranged below the second heat exchanger where the condensed water drips from the second heat exchanger.

[0042] In a more preferred embodiment of the invention, the step of transferring heat from the refrigerant leaving the refrigerant-to-refrigerant heat exchanger to the condensed water generated at the second heat exchanger takes place in the portion of pipe which is arranged at least partially inside a main container receiving said condensed water.

[0043] Preferably, the method further comprises a step of draining condensed water from the main container to a collection tank or to the outside.

[0044] In a preferred embodiment of the invention, the step of draining condensed water from the main container takes place when the temperature of the condensed water in the main container increases above a pre-determined level.

[0045] In a further preferred embodiment of the invention, the step of draining condensed water from the main container takes place when the water level of the condensed water at the main container increases above a pre-determined level. More preferably, the step of draining condensed water from the main container takes place when the main container is full.

[0046] In a further preferred embodiment of the invention, the step of transferring heat from the refrigerant leaving the refrigerant-to-refrigerant heat exchanger to the condensed water generated at the second heat exchanger takes place in the portion of pipe which is arranged at least partially inside an additional container connected to, and receiving the condensed water from, a main container receiving said condensed water.

[0047] Preferably, the method further comprises a step of draining condensed water from the additional container to a collection tank or to the outside.

[0048] In a preferred embodiment of the invention, the step of draining condensed water from the additional container takes place when the temperature of the condensed water in the additional container increases above a pre-determined level.

[0049] In a further preferred embodiment of the invention, the step of draining condensed water from the additional container takes place when the water level of the condensed water in the additional container increases above a pre-determined level.

[0050] More preferably, the step of draining condensed water from the additional container takes place when the additional container is full.

[0051] Preferably, the method further comprises a step of draining condensed water from the main container to the additional container.

[0052] More preferably, the step of draining condensed water from the main container to the additional container takes place when the water level of the condensed water in the main container increases above a pre-determined level In a further preferred embodiment of the invention, the step of transferring heat from the refrigerant leaving the refrigerant-to-refrigerant heat exchanger to the condensed water generated at the second heat exchanger takes place in an additional heat exchanger having one side arranged in a portion of the refrigerant circuit connecting the refrigerant-to-refrigerant heat exchanger to the compressor inlet and the other side arranged in a condensed water flow flowing out of a main container receiving the condensed water.

[0053] Preferably, the method further comprises a step of continuously draining condensed water from the main container in order to create said condensed water flow.

[0054] In a further preferred embodiment of the invention, the step of transferring heat from the refrigerant leaving the refrigerant-to-refrigerant heat exchanger to the condensed water generated at the second heat exchanger takes place in an additional heat exchanger having one side arranged in a portion of the refrigerant circuit connecting the refrigerant-to-refrigerant heat exchanger to the compressor inlet and the other side arranged in a condensed water flow flowing out of the second heat exchanger.

[0055] Preferably, the method further comprises a step of continuously draining condensed water from the second heat exchanger in order to create said condensed water flow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0056] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate possible embodiments of the invention and together with the description serve to explain the principles of the invention. In the drawings, corresponding characteristics and/or components are identified by the same reference numbers. In particular:

- Figure 1 illustrates a schematic diagram of a laundry dryer according to a first embodiment of the present invention;
- Figures from 2 to 6 illustrate schematic diagrams of laundry dryers according to further embodiments of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0057] The present invention has proved to be particularly successful when applied to a front-loading drying machine with a rotatable laundry container; however it is clear that the present invention can be applied as well to a top-loading drying machine and also to laundry drying machines of cabinet type, i.e. laundry drying machines where the laundry container does not rotate. Furthermore, the present invention can be usefully applied to all the machines requiring a drying phase for wetted clothes, as for example a combined laundry washing and drying machine. Figure 1 illustrates a schematic diagram of a laundry drying machine 1, or laundry dryer, with a heat pump system 20 according to a first embodiment of the present invention.

[0058] The laundry dryer 1 preferably comprises, though not necessarily, a substantially parallelepiped-shaped outer boxlike casing, not illustrated, which is preferably structured for resting on the floor and a preferably, though not necessarily, substantially cylindrical rotatable drum 9 which is structured for housing the laundry to be dried.

[0059] The laundry dryer 1 is provided with an air stream circuit 10 which is structured to circulate inside the drum 9 a stream of hot air having a low moisture content. The hot air circulates over and through the laundry located inside the drum 9 to dry the laundry.

[0060] The air stream circuit 10 is also structured for drawing moist air from the drum 9, cooling down the moist air leaving the drum 9 so to extract and retain the surplus moisture. The dehumidified air is then heated up to a predetermined temperature preferably higher than that of the moist air arriving from the drum 9. Finally the heated, dehumidified air is conveyed again into the drum 9, where it flows over and through the laundry stored inside the rotatable drum 9 to rapidly dry the laundry, as said above.

[0061] The air stream circuit 10 forms therefore a closed-loop for the air A, as schematically illustrated with dashed line in Figure 1.

[0062] A fan 12 is preferably arranged along the circuit 10 for generating the air stream, more preferably upstream of the drum 9. The fan 12 is adapted and designed for circulating the air within the air stream circuit 10.

[0063] Preferably, and more particularly, the air stream circuit 10 comprises a dehumidifying unit 23 arranged downstream of the drum 9 and a heater unit 21 arranged downstream of the dehumidifying unit 23 and upstream of the drum 9. It is underlined that in the present application the terms "upstream" and "downstream" are referred to the flowing direction of the air, heated air and/or moist air, during the standard functioning of the laundry dryer; for example saying that the fan is arranged upstream of the drum means that in the standard functioning of the laundry dryer the air firstly passes through the fan and then flows into the drum; saying that the dehumidifying unit is arranged downstream of the drum means that in the standard functioning of the laundry dryer the air firstly circulates inside the drum and then passes through the dehumidifying unit. In the dehumidifying unit 23 the moist air condenses and the water generated therein is preferably collected in a main container 25 arranged below the dehumidifying unit 23.

[0064] In the preferred embodiment here described, the dehumidifying unit 23 is the evaporator of the heat pump system 20 and the heating unit 21 is the condenser of said heat pump system 20.

[0065] Therefore, the evaporator 23 dehumidifies the moist air coming from the drum 9 and then the condenser 21 heats up the dehumidified air coming from the evaporator 23. The heated air is then conveyed again into the drum 9.

[0066] The heat pump system 20 with its evaporator 23 and condenser 21, therefore, interacts with the air stream circuit 10. In fact, the air stream circuit 10 and the heat pump system 20 are thermally coupled by the condenser 21 and the evaporator 23.

[0067] In particular, the heat pump system 20 advantageously comprises a refrigerant circuit 30 forming a closed-loop circuit where a refrigerant flows.

[0068] The refrigerant circuit 30 comprises a compressor 24, a first heat exchanger 21, i.e. the condenser 21 in the preferred embodiment here described, an expansion device 22 and a second heat exchanger 23, i.e. the evaporator 23 in the preferred embodiment here described. The compressor 24, the condenser 21, the expansion device 22 and the evaporator 23 are connected in series to form said closed-loop circuit.

[0069] The refrigerant flows in the refrigerant circuit 30 wherein is compressed by the compressor 24, condensed in the condenser 21, expanded in the expansion device 22 and then vaporized in the evaporator 23.

[0070] In different embodiments, the first heat exchanger may comprises a gas cooler (instead of the condenser) and the second heat exchanger may comprises a gas heater (instead of the evaporator). In this case the refrigerant is advantageously a gas, such as CO_2, which maintains its gaseous state along all the closed-loop circuit, and in particular in the gas cooler and in the gas heater. In this type of heat pump system the gas temperature changes while passing through the gas cooler and the gas heater.

[0071] The portion of the refrigerant circuit 30 comprised between the compressor outlet 24b and the expansion device inlet 22a defines a high-pressure side wherein the refrigerant is compressed at a high pressure (for example 20-30 bars when the refrigerant used is R407c).

[0072] On the other hand, the portion of the refrigerant circuit 30 comprised between the expansion device outlet 22b and the compressor inlet 24a defines a low-pressure side wherein the refrigerant is expanded at a low pressure (for example 8-10 bars when the refrigerant used is R407c).

[0073] The heat pump system 20 further comprises a refrigerant-to-refrigerant heat exchanger 40 arranged between the high-pressure side of the refrigerant circuit 30 and the low-pressure side of the refrigerant circuit 30.

[0074] More particularly, one side of the refrigerant-to-refrigerant heat exchanger 40, or high-pressure side, is arranged between the condenser outlet 21b and the expansion device inlet 22a and the other side of the refrigerant-to-refrigerant heat exchanger 40, or low-pressure side, is arranged between the evaporator outlet 23b and the compressor inlet 24a.

[0075] The refrigerant-to-refrigerant heat exchanger 40 exchanges heat from its high-pressure side to its low-pressure side. In other words, the refrigerant-to-refrigerant heat exchanger 40 exchanges heat from the refrigerant compressed by the compressor 24 and discharged from the condenser 21 to the refrigerant discharged by the evaporator 23.

[0076] The refrigerant-to-refrigerant heat exchanger 40 therefore cools down the refrigerant leaving the condenser 21 before it reaches the evaporator 23 and heats up the vapour leaving the evaporator 23 before it reaches the compressor 24. This allows the refrigerant to enter in the evaporator 23 in a more favourable conditions therefore increasing the cooling and the dehumidifying capacity of the evaporator 23.

[0077] Furthermore, the heat transferred to the refrigerant leaving the evaporator 23 assures the absence of liquid in the refrigerant before it reaches the compressor 24.

[0078] Further, the laundry dryer 1 preferably comprises a collection tank 50 for the condensed water, more preferably a removable collection tank.

[0079] The collection tank 50 is preferably arranged on the top of the laundry dryer 1 so that it can be easily emptied by the user when necessary.

[0080] The condensed water collected in the main container 25 arranged below the dehumidifying unit 23 is preferably conveyed to the collection tank 50 by means of a draining pump 51.

[0081] According to the invention, between the low-pressure side of the refrigerant-to-refrigerant heat exchanger 40 and the compressor inlet 24a, the laundry dryer 1 comprises an auxiliary heat exchanging system 60 suitable for exchanging heat between the refrigerant in the refrigerant circuit 30 and the condensed water collected in the main container 25.

[0082] In the preferred embodiment shown in Figure 1, the auxiliary heat exchanging system 60 is preferably realized by placing the pipe 31 of the refrigerant circuit 30 that connects the refrigerant-to-refrigerant heat exchanger 40 to the compressor inlet 24a below the evaporator 23, where the condensed water drips from the evaporator 23. The pipe 31 is preferably at least partially arranged inside the main container 25 so that the external surface of the pipe 31 may contact the condensed water which is collected in the main container 25. The heat of the refrigerant flowing in the refrigerant circuit 30 leaving the refrigerant-to-refrigerant heat exchanger 40 may therefore be transferred by heat conduction to the condensed water collected in the main container 25.

[0083] In a further preferred embodiment, not illustrated, the pipe 31 of the refrigerant circuit 30 that connects the refrigerant-to-refrigerant heat exchanger 40 to the compressor inlet 24a is placed below the evaporator 23 but outside the main container 25. The external surface of the pipe 31 may be contacted by the condensed water which drips from the evaporator 23. The heat of the refrigerant flowing in the refrigerant circuit 30 leaving the refrigerant-to-refrigerant heat exchanger 40 may therefore be transferred by heat conduction to the condensed water falling down from the evaporator 23 and successively collected in the main container 25.

[0084] The effects of said heat transferring are better described below with reference to the operation of the laundry dryer 1.

[0085] The operation cycle of the heat pump system is subdivided into a transitory phase, or warm-up phase, and a successive steady state phase.

[0086] During the transitory phase the temperatures of the drying air stream A and of the heat pump system 20, which are usually at the ambient temperature when the laundry dryer 1 starts to operate, increase up to desired levels. During the steady state phase, the temperatures of the drying air stream A remain substantially constant and also the temperatures of the heat pump system are kept quiet constant. This is obtained, for example, by means of a compressor cooling fan or an auxiliary condenser that extracts heat from the compressor 24. If heat is not extracted from the compressor 24, the temperature would dangerously increase. Advantageously, and according to the invention, the auxiliary heat exchanging system 60 transfers heat from the refrigerant to the condensed water before the refrigerant reaches the compressor 24. The auxiliary heat exchanging system 60, therefore, cools down the refrigerant before it reaches the compressor 24. More advantageously the compressor 24 of the heat pump system 20 may work in safety conditions thus lowering the failure rate with respect to the laundry dryer of known type.

[0087] Still advantageously, transferring heat from the refrigerant to the condensed water before it reaches the compressor 24 may reduce, or eliminate, the use of a compressor cooling fan or the use of an auxiliary condenser.

[0088] Therefore the energy efficiency increases with respect to the laundry drying machines of known type.

[0089] In a preferred embodiment of the invention the draining pump 51 is preferably activated when the temperature of the condensed water inside the main container 25 increases above a pre-determined level and is no longer able to cool down the refrigerant and/or when the space in the main container 25 is not sufficient to collect more water, for example when the main container 25 is full.

[0090] It should to be noted that during the transitory phase the refrigerant temperature is not so high and the compressor 24 can therefore work under safety condition. On the other hand, during the transitory phase, it would be better not to extract heat from the refrigerant in order to speed-up the transitory phase.

[0091] Nevertheless in the transitory phase, i.e. at the beginning of the cycle, the amount of condensed water inside the water collecting container 25 is low and unable to cool down the refrigerant. Therefore the auxiliary heat exchanging system 60 substantially does not affect the good functioning of the heat pump system in the transitory phase.

[0092] In a further preferred embodiment of the invention, as illustrated in Figure 2, the heat pump system may be provided with a controlled switching device 70 which allows to by-pass the auxiliary heat exchanging system 60. The controlled switching device 70 may comprise, for example, a three-way valve which is interconnected between the refrigerant-to-refrigerant heat exchanger 40, the auxiliary heat exchanging system 60 and the compressor inlet 24a.

[0093] Through the controlled switching device 70, the auxiliary heat exchanging system 60 may be advantageously excluded during the transitory phase while it may be advantageously activated during the steady state.

[0094] This advantageously improve the energy efficiency during the steady state, as explained above, while the auxiliary heat exchanging system 60 advantageously does not intervene in the transitory phase.

[0095] Figure 3 shows a schematic diagram of a laundry dryer 100 according to another embodiment of the present invention.

[0096] The laundry dryer 100 of this embodiment comprises the same components as the laundry dryer described with reference to Figure 1, except for the realization of the the auxiliary heat exchanging system 160.

[0097] The laundry dryer 100 comprises an additional container 125 connected to the main container 25, which is preferably placed below the evaporator 23.

[0098] The additional container 125 is preferably arranged at a lower level with respect to the main container 25 so that the condensed water flows from the main container 25 to the additional container 125 by gravity.

[0099] The condensed water collected in the additional container 125 is conveyed to the collection tank 50 by means of the draining pump 51.

[0100] The auxiliary heat exchanging system 160 is realized by arranging the pipe 31 of the refrigerant circuit 30 that connects the refrigerant-to-refrigerant heat exchanger 40 to the compressor inlet 24a at least partially inside the additional container 125. Therefore the external surface of the pipe 31 may contact the condensed water which is collected in the additional container 125. Analogously to the first embodiment previously described, the heat of the refrigerant leaving the auxiliary heat exchanging system 160 and flowing in the refrigerant circuit 30 may therefore be transferred by heat conduction to the condensed water, this time collected in the additional container 125.

[0101] Effects and advantages of said heat transferring are the same above described with reference to the first embodiment.

[0102] In the preferred embodiment here described, the draining pump 51 is preferably activated when the temperature of the condensed water in the additional container 125 increases above a pre-determined level and is no longer able to cool down the refrigerant or when the space in the additional container 125 is not sufficient to collect more water.

[0103] Figure 4 shows a schematic diagram of a laundry dryer 200 according to another embodiment of the present invention.

[0104] The laundry dryer 200 shown in Figure 4 differs from the laundry dryer 100 described with reference to Figure 3 for the fact that the draining pump 151 is arranged between the main container 25 and the additional container 125 instead of downstream of the additional container 125.

[0105] Here, the draining pump 151 is first preferably activated to fill the additional container 125 with condensed water withdraws from the main container 25. The draining pump 151 is then activated again when the space in the main container 25 is not sufficient to collect more water or when the temperature of the condensed water in the additional container 125 increases above a pre-determined level and is no longer able to cool down the refrigerant.

[0106] With the draining pump 151 activated, condensed water is withdrawn from the main container 25 and conveyed to the additional container 125 while the hot condensed water inside the additional container 125 if forced towards the collection tank 50.

[0107] In different embodiments, a further draining pump may be arranged between the additional container 125 and the collection tank 50. The step of conveying water from the main container 25 to the additional container 125 and the step of conveying water from the additional container 125 to the collection tank may be advantageously independently controlled.

[0108] Figure 5 shows a schematic diagram of a laundry dryer 300 according to a further embodiment of the present invention.

[0109] The laundry dryer 300 of this embodiment comprises the same components as the laundry dryer described with reference to Figure 1, except for the realization of the auxiliary heat exchanging system 360.

[0110] The laundry dryer 300 comprises, in fact, an additional heat exchanger 325 suitable for exchanging heat between the refrigerant in the refrigerant circuit 30 and the condensed water collected in the main container 25.

[0111] Effects and advantages of said heat transferring are the same above described with reference to the first embodiment.

[0112] More particularly, one side of the additional heat exchanger 325 is arranged between the low-pressure side of the refrigerant-to-refrigerant heat exchanger 40 and the compressor inlet 24a and the other side of the additional heat exchanger 325 is arranged along the path o a water flow flowing from the main container 25 to the collection tank 50.

[0113] The additional heat exchanger 325, therefore, transfers heat from the refrigerant in the refrigerant circuit 30 to the condensed water flow flowing out of the main container 25. The additional heat exchanger 325 may preferably comprise a tube-in-tube heat exchanger.

[0114] The draining pump 51 is preferably arranged between the additional heat exchanger 325 and the collection tank 50.

[0115] Here, the draining pump 51 is preferably activated continuously to convey the condensed water from the main container 25 to the additional heat exchanger 325 and from there to the collection tank 50.

[0116] In different embodiments, the draining pump 51 may be activated when necessary, for example only when the main water receiving container 25 is full and/or only when the refrigerant temperature increase to a predetermined level. In a different embodiment, the draining pump 51 may be arranged between the main water receiving container 25 and the additional heat exchanger 325 or an additional draining pump may be arranged between the main container 25 and the additional heat exchanger 325.

[0117] In the embodiments above described, the water generated in the dehumidifying unit 23 is collected in a main container 25 which is preferably arranged below the dehumidifying unit 23 itself.

[0118] Nevertheless, it should to be noted that in different embodiments the main container 25 may not be positioned below the dehumidifying unit 23. The main container may be positioned, for example, in a more suitable position inside the casing. In this case, the condensed water is preferably collected by a collector placed below the dehumidifying unit which conveys the condensed water to said main container.

[0119] In further embodiments, furthermore, the main container could be even absent. This is illustrated, for example, with reference to Figure 6 which shows a schematic diagram of a laundry dryer 400 according to a further embodiment of the present invention.

[0120] The laundry dryer 400 of this embodiment comprises the same components as the laundry dryer described with reference to Figure 5, except for the fact that the condensed water is conveyed to the additional heat exchanger 325, and then to the collection tank 50, directly form a collector 25a placed below the evaporator 23.

[0121] The additional heat exchanger 325, therefore, transfers heat from the refrigerant in the refrigerant circuit 30 to the condensed water flow flowing out of the evaporator 23, more particularly the condensed water flow flowing out of the collector 25a.

[0122] Here, the draining pump 51 is preferably activated continuously to convey the condensed water from the main collector 25a to the additional heat exchanger 325 and from there to the collection tank 50.

[0123] In a different embodiment, the draining pump 51 may be arranged between the collector 25a and the additional heat exchanger 325 or an additional draining pump may be arranged between the collector 25a and the additional heat exchanger 325.

[0124] It should to be noted that any of the alternative embodiments described in Figures from 3 to 6 may be provided with a controlled switching device of the type described in Figure 2, which allows to by-pass the auxiliary heat exchanging system during the transitory phase.

[0125] According to the description, therefore, the auxiliary heat exchanging system may be defined as a heat exchanging exchanger suitable for transferring heat from the refrigerant to the condensed water generated at the second heat exchanger.

[0126] The heat exchanging exchanger may advantageously comprise a heat exchanger as such, for example the additional heat exchanger 325 above described with reference to the last embodiments of Figures 5 or 6. Nevertheless, a heat exchanging exchanger encompasses any arrangement suitable for transferring heat from the refrigerant to the condensed water generated at the second heat exchanger, as illustrated and described with reference to the other embodiments. In further embodiments, for example, the heat exchanging exchanger may comprise any arrangement wherein the condensed water from the container, or the collector, is sprayed against a portion the refrigerant circuit arranged between the low-pressure side of the refrigerant-to-refrigerant heat exchanger and the compressor inlet. More preferably the condensed water is sprayed against a portion of pipe of the refrigerant circuit arranged between the low-pressure side of the refrigerant-to-refrigerant heat exchanger and the compressor inlet. More preferably, the condensed water is sprayed against the pipe by means of a pump system.

[0127] It has thus been shown that the present invention allows all the set objects to be achieved. In particular, it makes it possible to obtain a laundry dryer which may work in safe condition.

[0128] Clearly, changes may be made to the laundry dryer as described herein without, however, departing from the scope of the present invention.

[0129] For example, the laundry dryer may be configured to drain condensed water from the main container or from the additional container directly to the outside. In this case the collection tank may be advantageously absent.

[0130] Although illustrative embodiments of the present invention have been described herein with reference to the accompany drawings, it is to be understood that the present invention is not limited to those precise embodiments, and that various other changes and modifications may be affected therein by one skilled in the art without departing from the scope or spirit of the invention. All such changes and modifications are intended to be included within the scope of the invention as defined by the appended claims.

Claims

1. A laundry drying machine (1; 100; 200; 300; 400) comprising:

- a laundry chamber (9) suitable for receiving the laundry to be dried;
- an air stream circuit (10) for circulating drying air through said laundry chamber (9);
- a heat pump system (20) comprising a closed refrigerant circuit (30) for a refrigerant, wherein said refrigerant circuit (30) comprises a compressor (24), a first heat exchanger (21), an expansion device (22) and a second heat exchanger (23) connected in series to form a closed-loop circuit; and wherein:
- said air stream circuit (10) comprises said first heat exchanger (21), said laundry chamber (9), said second heat exchanger (23) and at least one blowing device (12) for said air;
- said refrigerant circuit (30) and said air stream circuit (10) are thermally coupled by said first heat exchanger (21) and said second heat exchanger (23), said second heat exchanger (23) being provided for cooling down and dehumidifying said drying air leaving said laundry chamber (9) and for heating up said refrigerant, wherein said drying air at least partially condens-

es at said second heat exchanger (23) generating condensed water;

- said first heat exchanger (21) being provided for heating up said drying air and cooling down said refrigerant;
- said refrigerant circuit (30) further comprising a refrigerant-to-refrigerant heat exchanger (40) having a high-pressure side arranged between said first heat exchanger (21) and said expansion device (22) and a low-pressure side arranged between said second heat exchanger (23) and an inlet (24a) of said compressor (24), said refrigerant-to-refrigerant heat exchanger (40) being provided for transferring heat from said high-pressure side to said low-pressure side; **characterized in that** said machine further comprises an auxiliary heat exchanging system (60; 160; 360) arranged between said low-pressure side of said refrigerant-to-refrigerant heat exchanger (40) and said compressor inlet (24a), said auxiliary heat exchanging system (60; 160; 360) being suitable for transferring heat from said refrigerant to said condensed water generated at said second heat exchanger (23).

2. A machine (1) according to claim 1, **characterized in that** said auxiliary heat exchanging system (60) comprises a portion (31) of said refrigerant circuit (30) connecting said low-pressure side of said refrigerant-to-refrigerant heat exchanger (40) to said compressor inlet (24a).

3. A machine (1) according to claim 2, **characterized in that** said portion is a portion of pipe (31) of said refrigerant circuit (30) connecting said low-pressure side of said refrigerant-to-refrigerant heat exchanger (40) to said compressor inlet (24a).

4. A machine (1; 100; 200; 300) according to claim 3, **characterized in that** said portion of pipe (31) is arranged below said second heat exchanger (23) where said condensed water drips from said second heat exchanger (23).

5. A machine (1; 100; 200; 300) according to claim 3, **characterized in that** it further comprises a main container (25) suitable for receiving said condensed water generated at said second heat exchanger (23).

6. A machine (1) according to claim 5, **characterized in that** said portion of pipe (31) of said refrigerant circuit (30) connecting said refrigerant-to-refrigerant heat exchanger (40) to said compressor inlet (24a) is arranged at least partially inside said main container (25).

7. A machine (1; 100; 200; 300) according to claim 5 or 6, **characterized in that** said auxiliary heat exchanging system (60; 160; 360) further comprises a draining pump (51; 151) suitable for draining water from said main container (25) to a collection tank (50) or to the outside.

8. A machine (100; 200) according to claim 5, **characterized in that** said portion of pipe (31) of said refrigerant circuit (30) is arranged at least partially inside an additional container (125) connected to, and receiving said condensed water from, said main container (25).

9. A machine (100; 200) according to claim 8, **characterized in that** said auxiliary heat exchanging system (160) further comprises a draining pump (51; 151) suitable for draining water from said additional container (125) to a collection tank (50) or to the outside.

10. A machine (300) according to claim 5, **characterized in that** said auxiliary heat exchanging system (360) comprises an additional heat exchanger (325) having one side arranged in a portion of said refrigerant circuit (30) connecting said refrigerant-to-refrigerant heat exchanger (40) to said compressor inlet (24a) and the other side arranged in a condensed water flow flowing out of said main container (25).

11. A machine (300) according to claim 10, **characterized in that** said auxiliary heat exchanging system (360) further comprises a draining pump (51) suitable for draining water from said main container (25) in order to create said condensed water flow and for successively draining said water to a collection tank (50) or to the outside.

12. A machine (400) according to claim 1, **characterized in that** said auxiliary heat exchanging system (360) comprises an additional heat exchanger (325) having one side arranged in a portion of said refrigerant circuit (30) connecting said refrigerant-to-refrigerant heat exchanger (40) to said compressor inlet (24a) and the other side arranged in a condensed water flow flowing out of a collector (25a) arranged below said second heat exchanger (23).

13. A machine (400) according to claim 12, **characterized in that** said auxiliary heat exchanging system (360) further comprises a draining pump (51) suitable for draining water from said collector (25a) in order to create said condensed water flow and for successively draining said water to a collection tank (50) or to the outside.

14. A machine (100) according to any one of the preceding claims, **characterized in that** it further comprises a switching device (70) suitable for selectively connecting said auxiliary heat exchanging system (60) to said refrigerant circuit (30), so that said refrigerant can flow either through said auxiliary heat exchanging system (60) or from said refrigerant-to-refrigerant heat exchanger (40) to said compressor inlet (24a) directly by-passing said auxiliary heat exchanging system (60).

15. A method for operating a laundry drying machine (1; 100; 200; 300; 400) of the type comprising:

- a laundry chamber (9) suitable for receiving the laundry to be dried;
- an air stream circuit (10) for circulating drying air through said laundry chamber (9);
- a heat pump system (20) comprising a closed refrigerant circuit (30) for a refrigerant, wherein said refrigerant circuit (30) comprises a compressor (24), a first heat exchanger (21), an expansion device (22) and a second heat exchanger (23) connected in series to form a closed-loop circuit; and wherein:
- said air stream circuit (10) comprises said first heat exchanger (21), said laundry chamber (9), said second heat exchanger (23) and at least one blowing device (12) for said air;
- said refrigerant circuit (30) and said air stream circuit (10) are thermally coupled by said first heat exchanger (21) and said second heat exchanger (23), said second heat exchanger (23) being provided for cooling down and dehumidifying said drying air leaving said laundry chamber (9) and for heating up said refrigerant, wherein said drying air at least partially condenses at said second heat exchanger (23) generating condensed water;
- said first heat exchanger (21) being provided for heating up said drying air and cooling down said refrigerant;
- said refrigerant circuit (30) further comprising a refrigerant-to-refrigerant heat exchanger (40) having a high-pressure side arranged between said first heat exchanger (21) and said expansion device (22) and a low-pressure side arranged between said second heat exchanger (23) and an inlet (24a) of said compressor (24), said refrigerant-to-refrigerant heat exchanger (40) being provided for transferring heat from said high-pressure side to said low-pressure side;

the method comprising a step of activating said heat pump system (20); **characterized in that** the method further comprises a step of transferring heat from said refrigerant leaving said refrigerant-to-refrigerant heat exchanger (40) to said condensed water generated at said second heat exchanger (23).

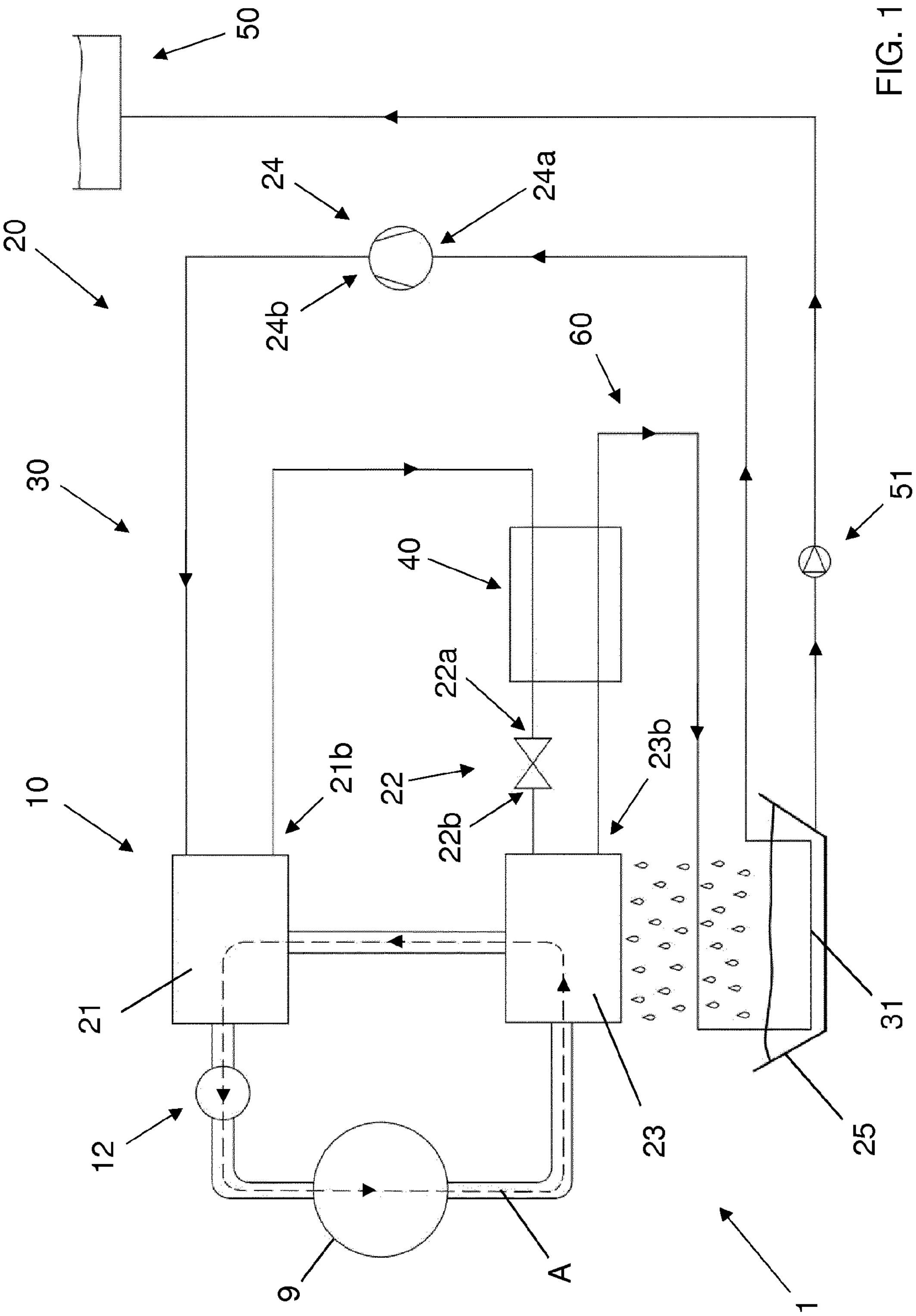
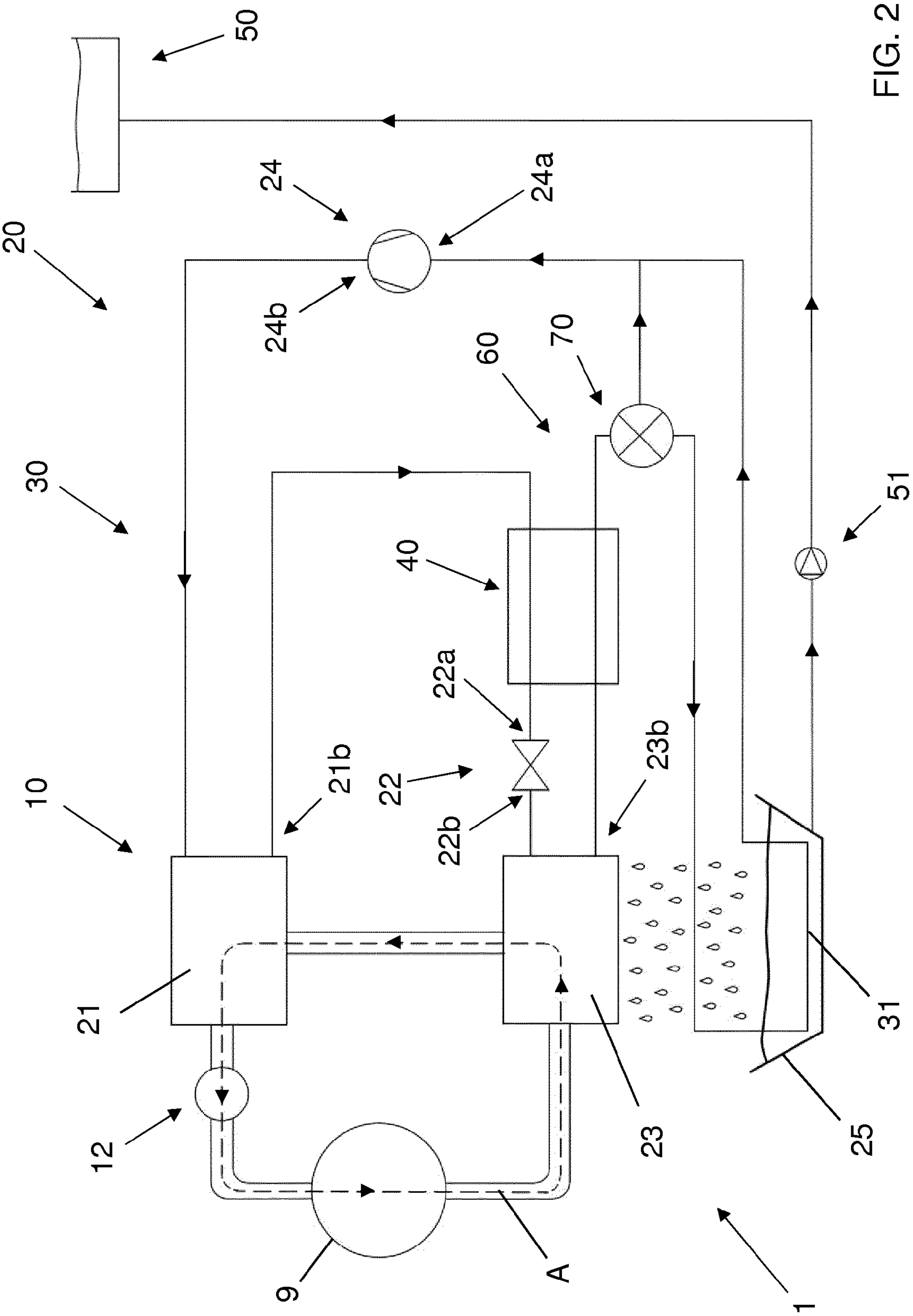


FIG. 1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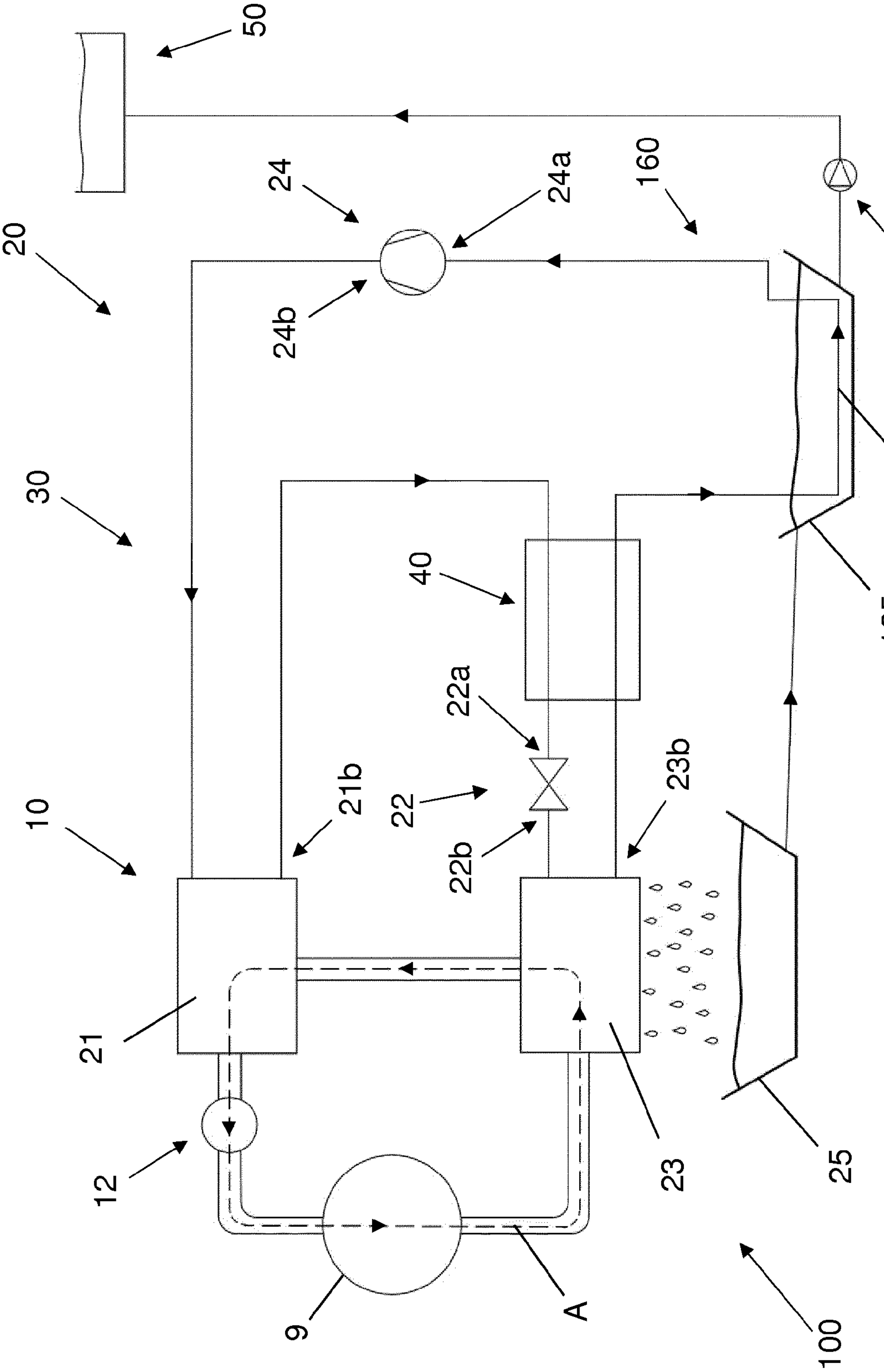
1

FIG. 2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A
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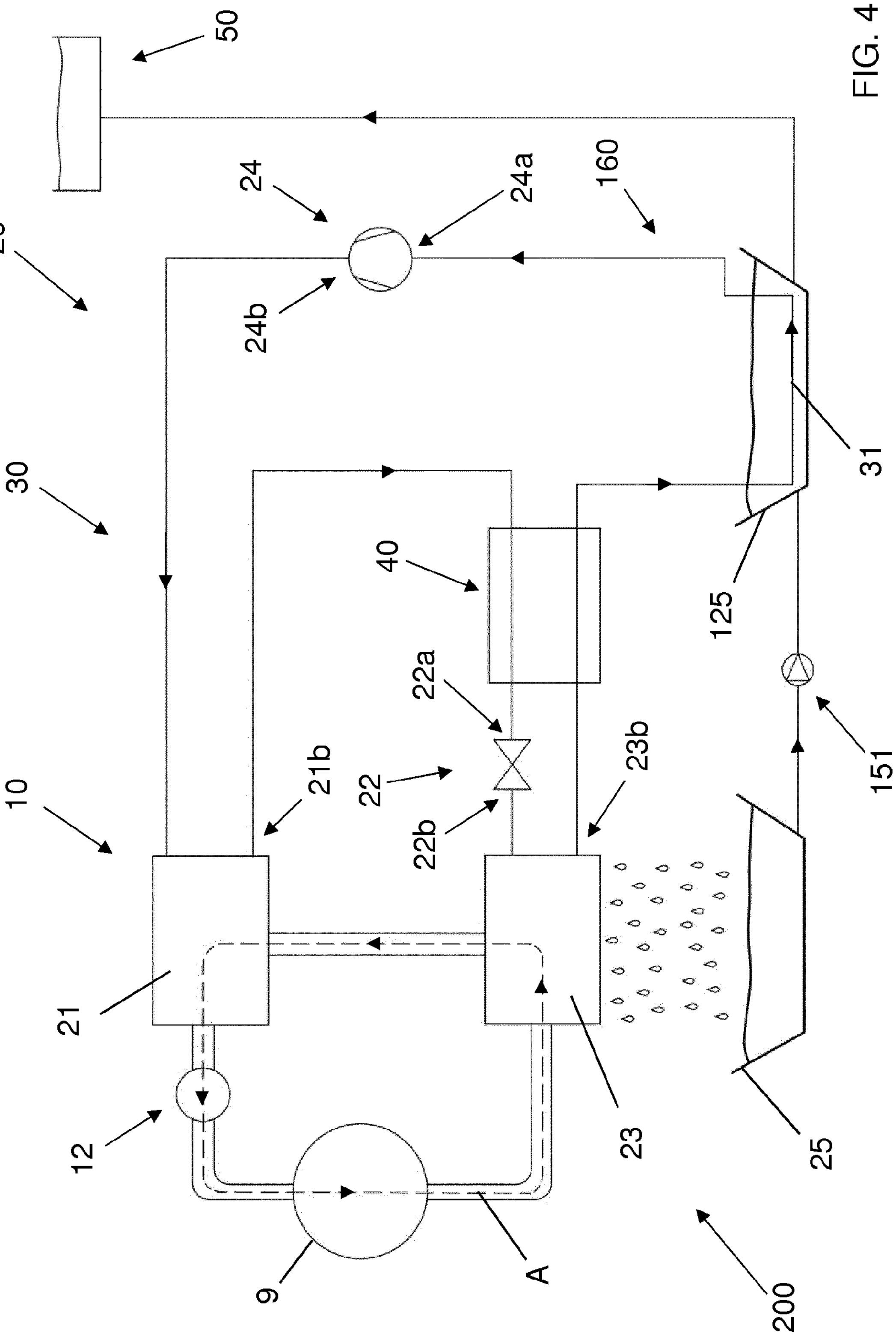
25
100

FIG. 3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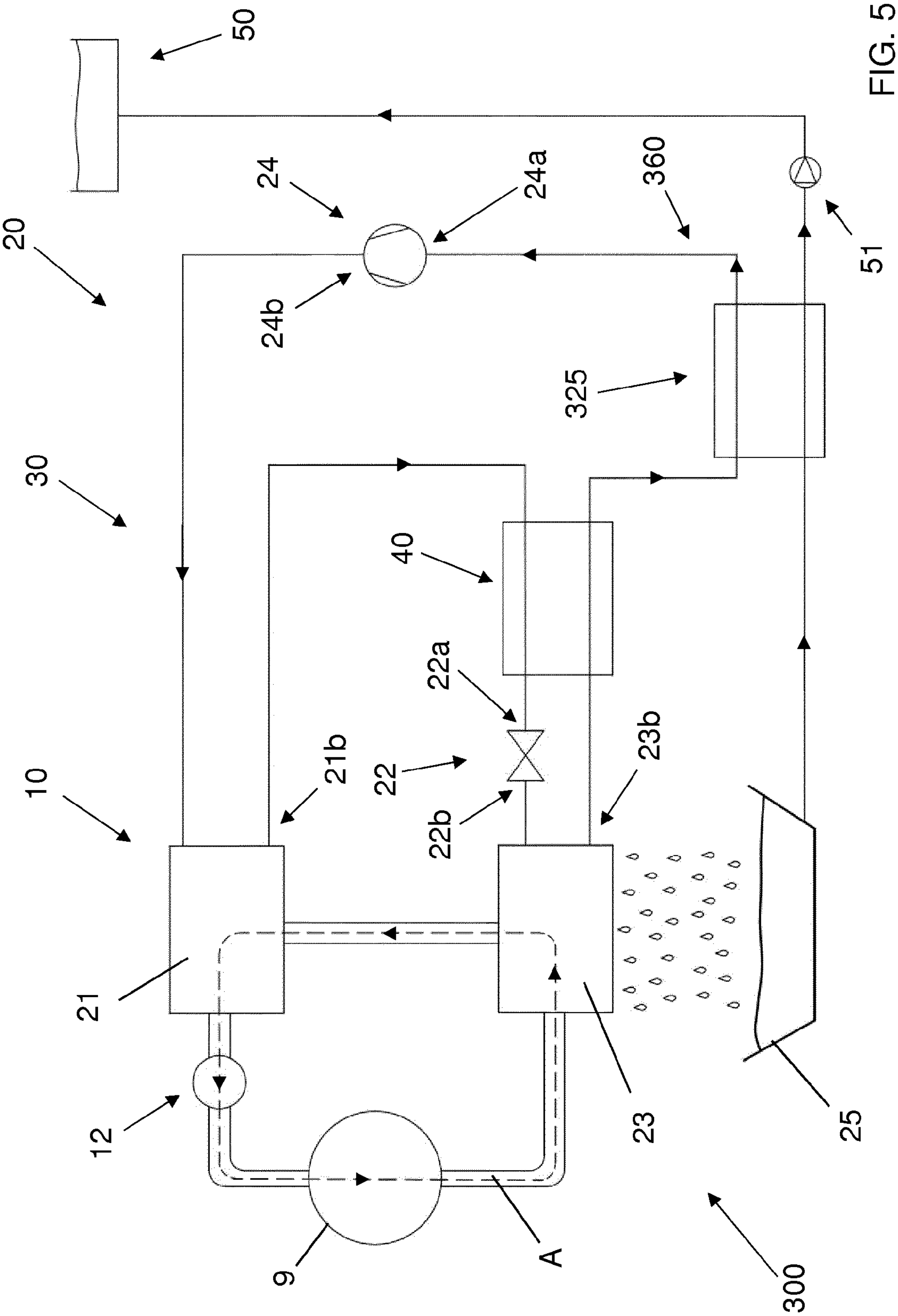
200

FIG. 4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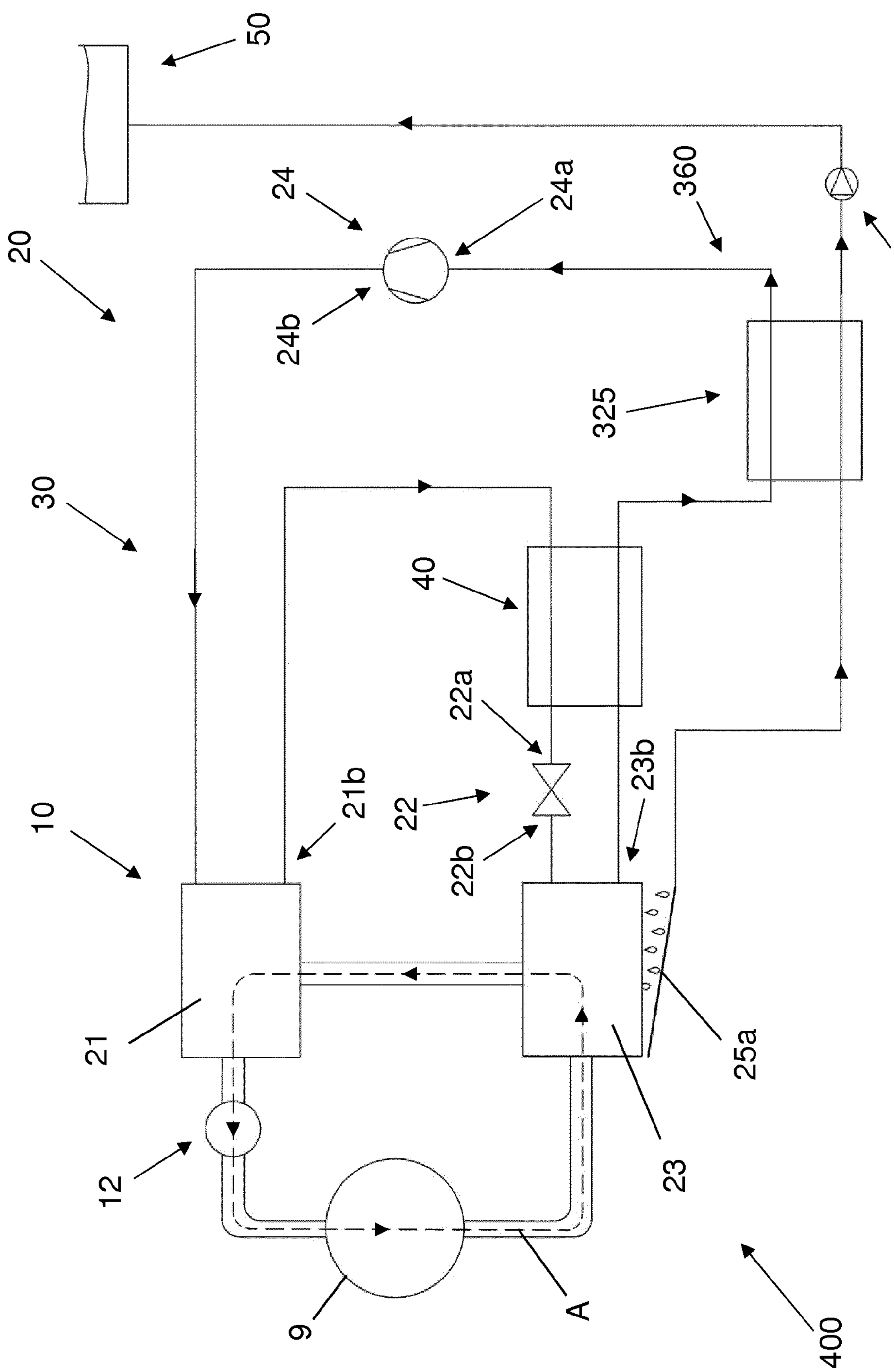
A
25
300

FIG. 5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23b
22b
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23
9
A
400

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 12 18 7443

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D06F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	13 February 2013	Spitzer, Bettina

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