(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 594 687 A1

(12) # EUROPEAN PATENT APPLICATION

(43) Date of publication:
22.05.2013 Bulletin 2013/21

(51) Int Cl.:
D06F 58/20 *(2006.01)*

(21) Application number: **11189866.4**

(22) Date of filing: **21.11.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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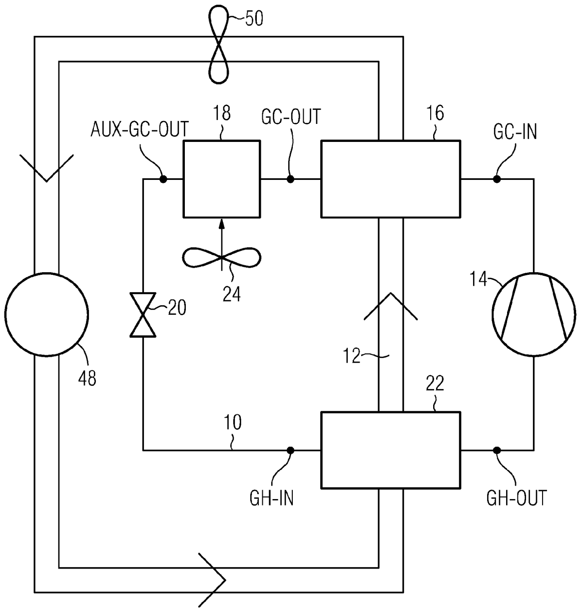
(54) **A laundry dryer with a heat pump system**

(57) A laundry dryer with a heat pump system comprising a refrigerant circuit (10) for a refrigerant and a drying air circuit (12) for a drying air, wherein the refrigerant circuit (10) includes a high pressure portion extending from the outlet of a compressor (14) via a first heat exchanger (16) to the inlet of lamination means (20) and a low pressure portion extending from the outlet of the lamination means (20) via a second heat exchanger (22) to the inlet of the compressor (14), the refrigerant operates at least at critical pressure in the high pressure portion of the refrigerant circuit (10), wherein the refrigerant circuit (10) includes at least one auxiliary heat exchanger (18) interconnected between the first heat exchanger (16) and the lamination means (20), the auxiliary heat exchanger (18) is a heat exchanger between the refrigerant and ambient air or water, at least one auxiliary fan (24) for driving the ambient air or at least a water delivery device for supplying water corresponds with the auxiliary heat exchanger (18), and the auxiliary fan (24) or the water delivery device is controlled or controllable in dependence of at least a parameter associated to the drying air and/or to the refrigerant.

FIG 1



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Description

[0001] The present invention relates to a laundry dryer with a heat pump system according to the preamble of claim 1.

[0002] The heat pump technology is at present the most efficient way to dry clothes in view of energy consumption. In a typical heat pump laundry dryer an air stream flows in a closed air stream circuit. Usually, the air stream is moved by a fan, passes through a laundry chamber, which is preferably formed as a rotatable laundry drum. Therein the air stream removes water from wet clothes, is then cooled down and dehumidified in an evaporator or gas heater, heated up in a condenser or gas cooler and at last re-inserted into the laundry drum again. The refrigerant is compressed by a compressor, condensed in the condenser or gas cooler, laminated in an expansion device and then vaporized in the evaporator or gas heater. The temperatures of the air stream and the refrigerant are strictly connected to each other.

[0003] The evaporator or gas heater and the condenser or gas cooler are heat exchangers between the air stream circuit and the refrigerant circuit. If the refrigerant changes its phase, then the heat exchangers act as evaporator and condenser, respectively. If the refrigerant remains in the gas phase, then the heat exchangers act as gas heater and gas cooler, respectively.

[0004] The cycle of the heat pump laundry dryer is characterized by two phases: a transitory phase and a steady state phase. During the transitory phase, the temperatures of the air stream and the refrigerant, which are usually at an ambient temperature when the system begins to operate, increase up to a desired level. During the steady state phase, the temperatures of the air stream and the refrigerant are kept almost constant. A cooling fan cools down the compressor, which removes excess heat from the heat pump system, in order to keep the temperatures of the air stream and the refrigerant constant until the laundry is dried.

[0005] There are some differences between heat pump systems, which use as refrigerant carbon dioxide (CO_2) on the one hand, and those heat pump systems using traditional fluids, like R134a and R407C, on the other hand, since carbon dioxide has peculiar properties. The critical temperature of carbon dioxide is about 31° C and relative low. The air stream needs to be heated up at 60°C to 65°C for an effective drying of the laundry. Thus, the heat pump works in a trans-critical cycle. In a high pressure portion of the heat pump circuit the refrigerant is kept always in a gaseous phase.

[0006] The traditional condenser, in which the refrigerant is coming from the outlet of the compressor condensates while the air stream is heated up, is substituted by a gas cooler, in which the carbon dioxide is cooled down while the air stream is heated up. At the outlet of the gas cooler there is no refrigerant in liquid state, but a gas with an increased density. After an expansion, the carbon dioxide is partially liquid and evaporates in the evaporator like the traditional refrigerants.

[0007] Further, the heat pump system can be forced working in a totally-supercritical cycle. In this case, the refrigerant is kept always in a gaseous phase, also in a low pressure portion of the heat pump circuit. When the totally-supercritical cycle occurs, the evaporator acts as a gas heater, since the carbon dioxide is heated up without change of phase. Thus, the terms evaporator and gas heater are hereinafter used as synonymous. Before achieving the totally-supercritical cycle, the heat pump system passes through a trans-critical cycle.

[0008] FIG 2 shows a temperature-entropy diagram of carbon dioxide in the trans-critical cycle. In a similar way, FIG 4 shows the temperature-entropy diagram of carbon dioxide in the totally-supercritical cycle. The temperature-entropy diagrams comprise a high pressure isobaric line 30, a low pressure isobaric line 32, a saturation curve 34 of carbon dioxide, a compression phase 36 and a lamination phase 38. Further, a state GH-OUT of the refrigerant at the outlet of the gas heater, a state GC-IN of the refrigerant at the inlet of the gas cooler, a state GC-OUT of the refrigerant at the outlet of the gas cooler and a state GH-IN of the refrigerant at the inlet of the gas heater are indicated in the temperature-entropy diagrams. Additionally, a state EV-OUT of the refrigerant at the outlet of the evaporator and a state EV-IN of the refrigerant at the inlet of the evaporator are also indicated in the temperature-entropy diagrams.

[0009] A gas cooling phase occurs from the state GC-IN to the state GC-OUT along the high pressure isobaric line 30. A gas lamination phase occurs from the state GC-OUT to the state GH-IN or EV-IN, respectively, along the lamination phase 38. A gas heating phase occurs from the state GH-IN to the state GH-OUT along the low pressure isobaric line 32. An evaporation and superheating phase occurs from the state EV-IN to the state EV-OUT along the low pressure isobaric line 32. A gas compression phase occurs from the state GH-OUT or EV-OUT to the state GC-IN along the compression phase 36.

[0010] If the pressure of the low pressure isobaric line 32 is higher than about 71 bar (refrigerant critical pressure in case of carbon dioxide refrigerant), then the whole cycle is always in the gas phase zone, i.e. the portion of the chart is outside the saturation curve 34. Thus, the refrigerant is heated up without phase change in the gas heater from the state GH-IN to the state GH-OUT. The evaporation phase, in which the pressure and the temperature remain constant, is avoided. The temperature difference between the refrigerant and the air stream, which has to be cooled down for dehumidifying the moisture air stream, is reduced. Thus, the performance of the gas heater is improved.

[0011] There are some advantages in increasing the value of the pressure in the low pressure portion of the refrigerant circuit, also in the trans-critical cycle. If the pressure in the low pressure portion increases, then the density of the refrigerant at the inlet of the compressor increases as well and the flow rate of the refrigerant becomes higher. Thus, the heating and cooling capacity increase. Further, the difference between the pressures in the low pressure portion and the high pressure portion decreases, so that the power required by the compressor also decreases.

[0012] Summarised, the increase of the pressure level in the low pressure portion of the refrigerant circuit has the advantages of the higher refrigerant flow rate and the lower difference between the pressures assuming that the pressure in the high pressure portion remains constant. The higher refrigerant flow rate results in an increased cooling and heating capacity of the heat pump system. The lower difference between the pressures allows a reduced power required by the compressor. Additionally, if the pressure in the low pressure portion becomes higher than the critical level, i.e. the totally-supercritical cycle, then a better matching between the refrigerant and the air stream through the gas heater is achieved.

[0013] However, the temperature of the refrigerant at the evaporator or gas heater increases with the pressure in the low pressure portion. The relative high temperature of the refrigerant at the evaporator or gas heater can reduce the ability of dehumidifying the air steam, which means a disadvantage for the performance of the heat pump system.

[0014] It is an object of the present invention to provide a laundry dryer with a heat pump system, which overcomes the disadvantages of the high temperature of the refrigerant caused by the increased pressure in the low pressure portion.

[0015] The object of the present invention is achieved by the laundry dryer according to claim 1.

[0016] According to the present invention

- the refrigerant circuit includes at least one auxiliary gas cooler interconnected between the gas cooler and the lamination means,
- the auxiliary gas cooler is a heat exchanger between the refrigerant and ambient air or water,
- at least one auxiliary fan for driving the ambient air or a water delivery device for supplying water corresponds with the auxiliary gas cooler, and
- the auxiliary fan or the water delivery device is controlled or controllable in dependence of at least one parameter so as to drive ambient air or supply water towards/over/through the auxiliary gas cooler.

the present invention provides an additional auxiliary gas cooler with the auxiliary fan or the water delivery device, wherein the auxiliary fan and the water delivery device are controlled or controllable.

[0017] The present invention allows that the refrigerant works in the low pressure portion of the refrigerant circuit at a pressure lower than the critical pressure and that the temperature of the refrigerant at the inlet of the evaporator is lower than the evaporation temperature.

[0018] The present invention allows that the refrigerant works in the low pressure portion of the refrigerant circuit at a pressure equal to or higher than the critical pressure and that the temperature of the refrigerant at the inlet of the gas heater is lower than the critical temperature of the refrigerant.

[0019] The auxiliary gas cooler is arranged outside the drying air circuit so that no heat exchange occurs between the auxiliary gas cooler and the drying air.

[0020] Further, the auxiliary fan or the water delivery device is controlled or controllable in dependence of the temperature of the refrigerant and/or the drying air.

[0021] For example, the auxiliary fan is activated, if the temperature of the drying air at the inlet of the laundry drum exceeds a predetermined set-point temperature.

[0022] According to another example, the auxiliary fan is activated, if the temperature of the refrigerant at the inlet of the gas cooler exceeds a predetermined set-point temperature.

[0023] Further, the auxiliary fan may be activated, if the temperature of the refrigerant at the inlet of the evaporator or at the inlet of the gas heater exceeds a predetermined set-point temperature.

[0024] Additionally or alternatively, the auxiliary fan or the water delivery device is controlled or controllable in dependence of the pressure of the refrigerant.

[0025] Preferably, the auxiliary fan works in an on-off mode.

[0026] In particular, the refrigerant is carbon dioxide.

[0027] Preferably, the auxiliary gas cooler is a heat exchanger between the refrigerant and condensate water of the heat pump system.

[0028] Preferably, the laundry dryer comprises an auxiliary fan controller or a water delivery device controller adapted to activate or deactivate the auxiliary fan and the water delivery device in response to the temperature and/or pressure of the refrigerant and/or in response to the temperature of the drying air.

[0029] Preferably, the laundry dryer comprises at least one sensor for detecting the temperature of the drying air and/or the temperature refrigerant and/or the pressure of the refrigerant.

[0030] Preferably, the auxiliary fan or the water delivery device is activated, if the temperature of the drying air at the inlet of the laundry treatment chamber exceeds a predetermined set-point temperature, wherein the predetermined set-point temperature is preferably in a range between 50°C and 75°C, preferably in a range between 55°C and 70°C, preferably in a range between 57°C and 65°C.

[0031] Preferably, the auxiliary fan or the water delivery device is deactivated, if the temperature of the drying air at the inlet of the laundry treatment chamber becomes lower than said predetermined set-point temperature minus preferably 0°C to 5°C, minus preferably 1°C to 4°C, minus preferably 2°C to 3°C.

[0032] Preferably, the auxiliary fan or the water delivery device is activated, if the temperature of the refrigerant at the outlet of the first heat exchanger exceeds a predetermined set-point temperature, wherein the predetermined set-point temperature is preferably in a range between 35°C and 60°C, preferably, in a range between 40°C and 55°C.

[0033] Preferably, the auxiliary fan or the water delivery device is deactivated, if the temperature of the refrigerant at the outlet of the first heat exchanger becomes lower than said predetermined set-point temperature minus preferably 0°C to 5°C, minus preferably 1°C to 4°C, minus preferably 2°C to 3°C.

[0034] Preferably, the auxiliary fan or the water delivery device is activated, if the temperature of the refrigerant at the inlet of the second heat exchanger exceeds a predetermined set-point temperature, wherein the predetermined set-point temperature is in a range preferably between 20°C and 31°C, preferably in a range between 25°C and 31°C, preferably in a range between 28°C and 31°C, and the refrigerant operates below the critical pressure in the low pressure portion of the refrigerant circuit.

[0035] Preferably, The auxiliary fan or the water delivery device is deactivated, if the temperature of the refrigerant at the inlet of the second heat exchanger becomes lower than said predetermined set-point temperature minus 0°C to 5°C, preferably minus 1°C to 4°C, preferably minus 2°C to 3°C.

[0036] Preferably, the auxiliary fan or the water delivery device is activated, if the temperature of the refrigerant at the inlet of the second heat exchanger exceeds a predetermined set-point temperature, wherein the predetermined set-point temperature is in a range preferably between 31°C and 40°C, preferably between 33°C and 36°C, and the refrigerant operates at least at critical pressure in the low pressure portion of the refrigerant circuit.

[0037] Preferably, the auxiliary fan or the water delivery device of the auxiliary heat exchanger is deactivated, if the temperature of the refrigerant at the inlet of the second heat exchanger becomes lower than said predetermined set-point temperature minus preferably 0°C to 5°C, minus preferably 1°C to 4°C, minus preferably 2°C to 3°C.

[0038] Preferably, the auxiliary fan or the water delivery device is activated, if a first condition is met and a second condition is met, wherein the first condition is met when the temperature of the refrigerant at the inlet of the second heat exchanger reaches or exceeds a predetermined temperature value and the second condition includes at least one of the following:

the temperature of the refrigerant at the inlet of the second heat exchanger reaches or exceeds a further predetermined temperature value,

the temperature of the refrigerant at the outlet of the first heat exchanger reaches or exceeds a predetermined temperature,

temperature of the drying air at the inlet of laundry treatment chamber reaches or exceeds a predetermined temperature.

[0039] Preferably, the second condition includes a set-point temperature range having an upper limit and a lower limit, the auxiliary fan or the water delivery device is activated when temperature of the refrigerant at the inlet of the second heat exchanger reaches or exceeds the upper limit and deactivated when the temperature of the refrigerant at the inlet of the second heat exchanger reaches or goes below the lower limit, wherein both the upper limit and a lower limit of the second condition are lower than said predetermined temperature value of the first condition and at least the lower limit of the set-point temperature range is lower than the evaporation temperature of the refrigerant and the refrigerant operates below the critical pressure in the low pressure portion of the refrigerant circuit.

[0040] Preferably, the second condition includes a set-point temperature range having an upper limit and a lower limit, the auxiliary fan or the water delivery device is activated when temperature of the refrigerant at the inlet of the second heat exchanger reaches or exceeds the upper limit and deactivated when the temperature of the refrigerant at the inlet of the second heat exchanger reaches or goes below the lower limit, wherein the lower limit of the second condition is lower than said predetermined temperature value and lower than the critical temperature of the refrigerant and the refrigerant operates at least at critical pressure in the low pressure portion of the refrigerant circuit.

[0041] Preferably, the auxiliary fan or the water delivery device is controlled or controllable so that either

- the temperature of the refrigerant at the inlet of the second heat exchanger is lower than the evaporation temperature of the refrigerant and the refrigerant operates below the critical pressure in the low pressure portion of the refrigerant circuit, or
- the temperature of the refrigerant at the inlet of the second heat exchanger is lower than the critical temperature of the refrigerant and the refrigerant operates at least at critical pressure in the low pressure portion of the refrigerant circuit.

[0042] The novel and inventive features believed to be the characteristic of the present invention are set forth in the appended claims.

[0043] The invention will be described in further detail with reference to the drawings, in which

FIG 1 shows a schematic diagram of a heat pump system for a laundry dryer according to a preferred embodiment of the present invention,

FIG 2 shows a temperature-entropy diagram of a trans-critical cycle in the heat pump system for a laundry dryer according to the prior art,

FIG 3 shows a detailed temperature-entropy diagram of the trans-critical cycle in the heat pump system for the laundry dryer according to the preferred embodiment of the present invention,

FIG 4 shows a temperature-entropy diagram of a totally-supercritical cycle in the heat pump system for the laundry dryer according to the prior art,

FIG 5 shows a detailed temperature-entropy diagram of a totally-supercritical cycle in the heat pump system for the laundry dryer according to the preferred embodiment of the present invention,

FIG 6 shows a schematic flow chart diagram of a method for controlling an auxiliary fan of the heat pump system for the laundry dryer according to a first embodiment of the present invention,

FIG 7 shows a schematic flow chart diagram of the method for controlling the auxiliary fan of the heat pump system for the laundry dryer according to a second embodiment of the present invention, and

FIG 8 shows a schematic flow chart diagram of the method for controlling the auxiliary fan of the heat pump system for the laundry dryer according to a third embodiment of the present invention.

[0044] FIG 1 illustrates a schematic diagram of a heat pump system for a laundry dryer according to a preferred embodiment of the present invention. The heat pump system includes a closed refrigerant circuit 10 and a drying air circuit 12.

[0045] The refrigerant circuit 10 includes a compressor 14, a gas cooler 16, an auxiliary gas cooler 18, lamination means 20 and an evaporator 22 or gas heater 22. The compressor 14, the gas cooler 16, the auxiliary gas cooler 18, the lamination means 20 and the evaporator 22 or gas heater 22 are switched in series and form a closed loop. The drying air circuit 12 includes the gas heater 22 or evaporator 22, the gas cooler 16, a laundry treatment chamber 48, preferably a rotatable drum, and a drying air fan 50.

[0046] The evaporator 22 or gas heater 22 is one single physical device, which acts as evaporator 22, if the refrigerant changes its phase, and acts as gas heater 22, if the refrigerant remains in the gas phase. Thus, the use of the denotation "evaporator" or "gas heater" depends on the aggregate states of the refrigerant.

[0047] The gas cooler 16 and the evaporator 22 or gas heater 22 are heat exchangers and form the thermal interconnections between the refrigerant circuit 10 and the drying air circuit 12. The auxiliary gas cooler 18 is also a heat exchanger and forms the thermal interconnection between the refrigerant circuit 10 and ambient air or water. The auxiliary gas cooler 18 corresponds with an auxiliary fan 24 for driving the ambient air towards/over/through the auxiliary gas cooler 18 or with a water delivery device, such as sprinkling head or spray nozzle or a water conveyor, for supplying water to the auxiliary gas cooler. Preferably, the water is condensate water collected at the evaporator or gas heater 22 during the dehumidification of the drying air.

[0048] The evaporator 22 or gas heater 22 cools down and dehumidify the drying air, after said drying air has passed the laundry drum 48. Then the gas cooler 16 heats up the drying air, before the drying air is re-inserted into the laundry drum 48. The drying air is driven by the drying air fan 50. The drying air circuit 12 is preferably a closed loop in which the process air is continuously circulated through the laundry storing chamber. However it may also be provided that a (preferably smaller) portion of the process air is exhausted from the process air loop and fresh air (e.g. ambient air) is taken into the process air loop to replace the exhausted process air. And/or the process air loop is temporally opened (preferably only a short section of the total processing time) to have an open loop discharge.

[0049] The refrigerant circuit 10 is subdivided into a high pressure portion and a low pressure portion. The high pressure portion extends from the outlet of the compressor 14 via the gas cooler 16 and the auxiliary gas cooler 18 to the inlet of the lamination means 20. The low pressure portion extends from the outlet of the lamination means 20 via the evaporator 22 or gas heater 22 to the inlet of the compressor 14.

[0050] The refrigerant is compressed and heated up by the compressor 14. The gas cooler 16 cools down the refrigerant and heats up the drying air. Then, the refrigerant is further cooled down in the auxiliary gas cooler 18 by ambient air or by water. The ambient air is driven by the auxiliary fan 24, the water is supplied by the water delivery device. The refrigerant is expanded in the lamination means 20. Therein the pressure of the refrigerant is decreased down to the pressure of the low pressure portion of the refrigerant circuit. Then, the refrigerant enters the evaporator 22 or gas heater 22. In the evaporator 22 or gas heater 22 the refrigerant is vaporised and superheated or heated up, respectively. At last, the refrigerant is sucked by the inlet of the compressor 14.

[0051] The auxiliary gas cooler 18 increases the cooling capacity of the evaporator 22 or gas heater 22. Thus, the performance of the heat pump system and the laundry dryer is improved. The heat removed from the refrigerant circuit 10 by the auxiliary gas cooler 18 allows a balance between the refrigerant and the drying air, so that a steady state phase can be kept. In particular, the heat pump system may use carbon dioxide as refrigerant. Since no condensation of carbon dioxide occurs, the auxiliary gas cooler 18 acts as gas cooler.

[0052] The use of an auxiliary gas cooler 18 allows that the temperature at the inlet of the evaporator 22 can be lower than the evaporation temperature, when the refrigerant works in the trans-critical cycle. Further, the use of an auxiliary gas cooler 18 allows that the temperature at the inlet of the gas heater 22 can be lower than the critical temperature of the refrigerant, when the refrigerant works in the totally-supercritical cycle. In this way, the heat pump system can work at a higher pressure level in the low pressure portion of the refrigerant circuit 10 and keep an average temperature of the evaporator 22 or gas heater 22 lower.

[0053] FIG 2 shows a temperature-entropy diagram of a trans-critical cycle in the heat pump system for a laundry dryer according to the invention. Said temperature-entropy diagram relates to the heat pump system in FIG 1, wherein the auxiliary gas cooler 18 and the auxiliary fan 24 or the water delivery device are switched off, i.e. no heat exchange occurs between the auxiliary heat exchanger and the ambient air or the water. The temperature-entropy diagrams comprise a high pressure isobaric line 30, a low pressure isobaric line 32, a saturation curve 34 of carbon dioxide, a compression phase 36 and a lamination phase 38. Further, a state EV-OUT of the refrigerant at the outlet of the evaporator 22, a state GC-IN of the refrigerant at the inlet of the gas cooler 16, a state GC-OUT of the refrigerant at the outlet of the gas cooler 16 and a state EV-IN of the refrigerant at the inlet of the evaporator 22 are indicated in the temperature-entropy diagrams. The state EV-IN is inside the saturation curve 34 of carbon dioxide, so that the state EV-IN belongs to a two-phase zone.

[0054] FIG 3 shows a detailed temperature-entropy diagram of the trans-critical cycle in the heat pump system for the laundry dryer according to the present invention. FIG 3 clarifies the effect of the auxiliary gas cooler 18 and the auxiliary fan 24 or the water delivery device.

[0055] When the auxiliary fan 24 of the auxiliary gas cooler 18 or the water delivery device is switched on, then the refrigerant coming from the gas cooler 16 is additionally cooled down. The auxiliary gas cooler 18 and the auxiliary fan 24 cause the transfer in the diagram from the state GC-OUT to a state AUX-GC-OUT representing the state of the refrigerant at the outlet of the auxiliary gas cooler 18. The three states AUX-GC-OUT', AUX-GC-OUT" and AUX-GC-OUT'" at the outlet of the auxiliary gas cooler 18 correspond with the states EV-IN', EV-IN" and EV-IN"', respectively, at the inlet of the evaporator 22. If the cooling effect of the auxiliary gas cooler 18 is low, then the state EV-IN' still belongs to the two-phase zone. When the cooling effect of the auxiliary gas cooler 18 increases, then the temperature at the outlet of the auxiliary gas cooler 18 becomes lower, as in the states AUX-GC-OUT" and AUX-GC-OUT'", so that the states EV-IN" and EV-IN'" start belonging to the liquid zone.

[0056] The applicant has found that when the temperature of the refrigerant at the inlet of the evaporator 22 goes below the evaporation temperature, the cooling and dehumidifying capacity of the evaporator 22 increases.

[0057] FIG 4 shows a temperature-entropy diagram of a totally-supercritical cycle in the heat pump system for the laundry dryer according to present invention. Said temperature-entropy diagram relates to the heat pump system in FIG 1, wherein the auxiliary gas cooler 18 and the auxiliary fan 24 or the water delivery device are switched off, i.e. no heat exchange occurs between the auxiliary heat exchanger and the ambient air or the water. The temperature-entropy diagrams comprise the high pressure isobaric line 30, the low pressure isobaric line 32, the saturation curve 34 of carbon dioxide, the compression phase 36 and the lamination phase 38. Further, the state GH-OUT of the refrigerant at the outlet of the gas heater 22, the state GC-IN of the refrigerant at the inlet of the gas cooler 16, the state GC-OUT of the refrigerant at the outlet of the gas cooler 16 and the state GH-IN of the refrigerant at the inlet of the gas heater 22 are indicated in the temperature-entropy diagrams. All the states of the refrigerant are outside the saturation curve 34 of carbon dioxide, so that the refrigerant belongs to the gas phase zone during the whole cycle.

[0058] FIG 5 shows a detailed temperature-entropy diagram of the totally-supercritical cycle in the heat pump system for the laundry dryer according to the preferred embodiment of the present invention. FIG 5 clarifies the effect of the auxiliary gas cooler 18 and the auxiliary fan 24 or the water delivery device.

[0059] When the auxiliary fan 24 of the auxiliary gas cooler 18 is switched on, then the refrigerant coming from the gas cooler 16 is additionally cooled down. The auxiliary gas cooler 18 and the auxiliary fan 24 cause the transfer in the diagram from the state GC-OUT to the states AUX-GC-OUT', AUX-GC-OUT" or AUX-GC-OUT'". FIG 5 clarifies that the lower the temperature at the outlet of the auxiliary gas cooler 18, the lower is the temperature at the inlet of the gas heater 22. The states AUX-GC-OUT', AUX-GC-OUT" and AUX-GC-OUT'" at the outlet of the auxiliary gas cooler 18 correspond with the states GH-IN', GH-IN" and GH-IN"', respectively, at the inlet of the gas heater 22.

[0060] The applicant has found that when the temperature of the refrigerant at the inlet of the gas heater 22 goes below the critical temperature, the cooling and dehumidifying capacity of the evaporator 22 increases.

[0061] Preferably, that the auxiliary fan 24 of the auxiliary gas cooler 18 is switched off in the beginning of the cycle, so that the temperatures of the refrigerant and the drying air increase up to desired levels. The end of the transitory phase can be determined by detecting the temperature of the drying air in the laundry drum 48, preferably at the drum inlet, the temperature and/or pressure of the refrigerant at the outlet of the gas cooler 16 or the temperature and/or pressure of the refrigerant at the inlet of the evaporator/gas heater 22.

[0062] When the auxiliary gas cooler 18 and the auxiliary fan 24 start working, then the temperatures of the drying air and the refrigerant are kept constant. However, if the cooling capacity of the auxiliary gas cooler 18 is higher than necessary in order to balance the heat pump system, then the temperatures of the drying air and the refrigerant start decreasing. If the temperatures of the drying air and the refrigerant remain constant, then the auxiliary gas cooler 18 and the auxiliary fan 24 can work continuously. If the temperatures of the drying air and the refrigerant decrease, then the auxiliary gas cooler 18 and the auxiliary fan 24 work in an on-off mode.

[0063] According to a first example, the auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 is switched on, if the temperature of the drying air at the inlet of the laundry drum 48 becomes higher than a predetermined set-point temperature. Said predetermined set-point temperature is in a range between 50°C and 75°C. Preferably, said predetermined set-point temperature is in a range between 55°C and 70°C. In particular, said predetermined set-point temperature is in a range between 57°C and 65°C. The auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 is switched off, if the temperature of the drying air at the inlet of the laundry drum 48 becomes lower than said predetermined set-point temperature minus 0°C to 5°C, preferably minus 1°C to 4°C, preferably minus 2°C to 3°C.

[0064] According to a second example, the auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 is switched on, if the temperature of the refrigerant at the outlet of the gas cooler 16 becomes higher than a further predetermined set-point temperature. Said predetermined set-point temperature is in a range between 35°C and 60°C. Preferably, said predetermined set-point temperature is in a range between 40°C and 55°C. The auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 is switched off, if the temperature of the refrigerant at the outlet of the gas cooler 16 becomes lower than said predetermined set-point temperature minus preferably 0°C to 5°C, preferably minus 1°C to 4°C, preferably minus 2°C to 3°C.

[0065] According to a third example, the auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 is switched on, if the temperature of the refrigerant at the inlet of the evaporator 22 becomes higher than a further predetermined set-point temperature. Said predetermined set-point temperature is in a range between 20°C and 31°C. Preferably, said predetermined set-point temperature is in a range between 25°C and 31°C. In particular, said predetermined set-point temperature is in a range between 28°C and 31°C. The auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 is switched off, if the temperature of the refrigerant at the inlet of the evaporator 22 becomes lower than said predetermined set-point temperature minus preferably 0°C to 5°C, preferably minus 1°C to 4°C, preferably minus 2°C to 3°C.

[0066] Alternatively, the auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 is switched on, if the temperature of the refrigerant at the inlet of the gas heater 22 becomes higher than a predetermined set-point temperature, which is in a range between 31°C and 40°C, in particular between 33°C and 36°C. The auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 is switched off, if the temperature of the refrigerant at the inlet of the gas heater 22 becomes lower than said predetermined set-point temperature minus preferably 0°C to 5°C, preferably minus 1°C to 4°C, preferably minus 2°C to 3°C.

[0067] FIG 6 shows a schematic flow chart diagram of a method for controlling the auxiliary fan 24 of the heat pump system for the laundry dryer according to a first embodiment of the present invention. Said first embodiment relates to the above three examples.

[0068] After the start of the cycle, the auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 remains switched off. Then, a switch on-off condition 40 is checked in order to switch on and to switch off the auxiliary fan 24 or the water delivery device when predetermined conditions are met. In particular the auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 are activated or deactivated in response to the detection of predetermined values of quantities associated to the drying air or to the refrigerant. The switch on-off condition 40 may depend on the temperature of the drying air at the inlet of the laundry drum 48 according to the first example. Further, the switch on-off condition 40 may depend on the temperature of the refrigerant at the outlet of the gas cooler 16 according to the second example. Moreover, the switch on-off condition 40 may depend on the temperature of the refrigerant at the inlet of the evaporator 22 or gas heater 22 according to the third example. When a cycle end condition 42 is satisfied, then the cycle is stopped.

[0069] An auxiliary fan controller or a water delivery device controller is provided to drive the auxiliary fan 24 or the water delivery device in response to the detected temperature values of the drying air or in response to the detected temperature values of the refrigerant.

[0070] FIG 7 shows a schematic flow chart diagram of the method for controlling the auxiliary fan 24 or the water delivery device of the heat pump system for the laundry dryer according to a second embodiment of the present invention wherein the refrigerant operates below the critical temperatures in the low pressure side of the refrigerant circuit 10.

[0071] After the start of the cycle, the auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 remains switched off. Then, a first condition 44 is checked whether it is met. The first condition 44 relates to the temperature of the refrigerant at the inlet of the evaporator 22.

[0072] The auxiliary fan 24 or the water delivery device is kept OFF until the temperature at the evaporator inlet reaches or exceeds a value corresponding to a desired relatively high pressure level at the low pressure portion of the refrigerant circuit 10 and then the auxiliary fan 24 or the water delivery device starts working. In this way the heat pump works in trans-critical conditions with a relatively high pressure level at the low pressure portion of the refrigerant circuit 10.

[0073] Preferably, the auxiliary fan 24 or the water delivery device is kept OFF until the temperature at the evaporator inlet reaches a value comprises in a range between 20°C and 31°C or, preferably, between 25°C and 31°C or, preferably, between 28°C and 31°C.

[0074] For example, according to the first condition 44 a predetermined set-point temperature of the refrigerant at the inlet of the evaporator 22 is set at 28°C. If the first condition 44 is met, i.e. when the temperature reaches at least 28°C, then a second condition 46 is checked whether satisfied or not.

[0075] The second condition 46, preferably, relates to a predetermined set-point temperature range of the refrigerant at the inlet of the evaporator 22.

[0076] Said predetermined set-point temperature comprises and an upper limit (for example 25°C) for switching on the auxiliary fan 24 or the water delivery device and a lower limit (for example 22°C) for switching off the auxiliary fan 24 or the water delivery device. In other words when the temperature of refrigerant detected at the inlet of the evaporator 22 is equal to or higher than the upper limit, the auxiliary fan 24 or the water delivery device is activated, while when the temperature of refrigerant detected at the inlet of the evaporator 22 is equal to or lower than the upper limit, the auxiliary fan 24 or the water delivery device is deactivated.

[0077] The upper limit (for example 25°C) and the lower limit (for example 22°C) of the set-point temperature range are both lower than the temperature value of the first condition (for example 28°C) and preferably at least the lower limit of the set-point temperature range is lower than the evaporation temperature of the refrigerant.

[0078] In practise, if the temperature of the refrigerant at the inlet of the evaporator 22 meets both the first condition and the set-point temperature range upper limit of second condition 46, the auxiliary fan 24 or the water delivery are activated (switched on, energized), while if the temperature of the refrigerant at the inlet of the evaporator 22 first meets the first condition and then the set-point temperature range lower limit of second condition 46, the auxiliary fan 24 or the water delivery are deactivated (switched off, de-energized).

[0079] Alternatively, the second condition 46 relates to the predetermined set-point temperature of the during air at the inlet of the laundry drum 48 or of the refrigerant at the outlet of the gas cooler 16.

[0080] Particularly, the auxiliary fan 24 or the water delivery are activated when the temperature of the refrigerant at the outlet of the gas cooler 16 reaches or exceeds a predetermined temperature, or when temperature of the drying air at the inlet of laundry treatment chamber 48 reaches or exceeds a predetermined temperature. When a cycle end condition 42 is satisfied, then the cycle is stopped.

[0081] An auxiliary fan controller or a water delivery device controller are provided to drive the auxiliary fan 24 or the water delivery device according to the first and second condition 44, 46.

[0082] FIG 8 shows a schematic flow chart diagram of the method for controlling the auxiliary fan 24 of the heat pump system for the laundry dryer according to a third embodiment of the present invention wherein the refrigerant operates at least at the critical temperatures in the low pressure side of the refrigerant circuit 10.

[0083] After the start of the cycle, the auxiliary fan 24 or the water delivery device of the auxiliary gas cooler 18 remains switched off. Then, a first condition 44 is checked whether it is met. The first condition 44 relates to the temperature of the refrigerant at the inlet of the gas heater 22.

[0084] The auxiliary fan 24 or the water delivery device is kept OFF until the temperature at the gas heater inlet reaches or exceeds a value (at least equal to the refrigerant critical temperature) corresponding to a desired relatively high pressure level at the low pressure portion of the refrigerant circuit 10 and then the auxiliary fan 24 or the water delivery device starts working. In this way the heat pump works in totally-supercritical conditions with a relatively high pressure level at the low pressure portion. Preferably, the auxiliary fan 24 or the water delivery device is kept OFF until the temperature at the gas cooler inlet reaches a value comprises in a range between 31°C and 40°C or, preferably, between 33°C and 36°C.

[0085] For example, according to the first condition 44 the predetermined set-point temperature of the refrigerant at the inlet of the gas heater 22 is set at 35°C.

[0086] If the first condition 44 is met, i.e. when the temperature reaches at least 35°C, then a second condition 46 is checked whether satisfied or not.

[0087] The second condition 46, preferably, relates to a predetermined set-point temperature range of the refrigerant at the inlet of the gas heater 22.

[0088] Said predetermined set-point temperature comprises an upper limit (for example 30°C) for switching on the auxiliary fan 24 or the water delivery device and a lower limit (for example 26°C) for switching off the auxiliary fan 24 or the water delivery device. In other words when the temperature of refrigerant detected at the inlet of the gas heater 22 is equal to or higher than the upper limit, the auxiliary fan 24 or the water delivery device is activated, while when the temperature of refrigerant detected at the inlet of the evaporator 22 is equal to or lower than the upper limit, the auxiliary fan 24 or the water delivery device is deactivated.

[0089] The lower limit (for example 26°C) of the set-point temperature range is lower than the temperature value of the first condition (for example 35°C) and preferably the lower limit of the set-point temperature range is lower than the critical temperature of the refrigerant (31°C in case of carbon dioxide).

[0090] The upper limit (for example 30°C) is preferably lower than the temperature value of the first condition (for example 35°C) but it can also be higher (for example 38°C) and preferably the upper limit (for example 30°C) of the set-point temperature range is lower than the critical temperature of the refrigerant.

[0091] In practise, if the temperature of the refrigerant at the inlet of the gas heater 22 meets both the first condition and the set-point temperature range upper limit of second condition 46, the auxiliary fan 24 or the water delivery are activated (switched on, energized), while if the temperature of the refrigerant at the inlet of the gas heater 22 first meets the first condition and then the set-point temperature range lower limit of second condition 46, the auxiliary fan 24 or the water delivery are deactivated (switched off, de-energized).

[0092] Alternatively, the second condition 46 relates to the predetermined set-point temperature of the drying air at the inlet of the laundry drum 48 or of the refrigerant at the outlet of the gas cooler 16.

[0093] Particularly, the auxiliary fan 24 or the water delivery are activated when the temperature of the refrigerant at the outlet of the gas cooler 16 reaches or exceeds a predetermined temperature, or when temperature of the drying air at the inlet of laundry treatment chamber (48) reaches or exceeds a predetermined temperature.

[0094] When a cycle end condition 42 is satisfied, then the cycle is stopped.

[0095] An auxiliary fan controller or a water delivery device controller are provided to drive the auxiliary fan 24 or the water delivery device according to the first and second condition 44, 46.

[0096] Although illustrative embodiments of the present invention have been described herein with reference to the accompanying 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.

List of reference numerals

[0097]

10	refrigerant circuit
12	drying air circuit
14	compressor
16	gas cooler
18	auxiliary gas cooler
20	lamination means
22	evaporator, gas heater
24	auxiliary fan
30	high pressure isobaric line
32	low pressure isobaric line
34	saturation curve of carbon dioxide
36	compression phase
38	lamination phase
40	switch on-off condition
42	cycle end condition
44	first condition
46	second condition
48	laundry drum
50	drying air fan
GH-OUT	state of the refrigerant at the gas heater outlet
GC-IN	state of the refrigerant at the gas cooler inlet
GC-OUT	state of the refrigerant at the gas cooler outlet
GH-IN	state of the refrigerant at the gas heater inlet
EV-OUT	state of the refrigerant at the evaporator outlet
EV-IN	state of the refrigerant at the evaporator inlet

Claims

1. A laundry dryer with a heat pump system comprising a refrigerant circuit (10) for a refrigerant and a drying air circuit (12) for a drying air, wherein

- the refrigerant circuit (10) forms a closed loop and includes a compressor (14), a first heat exchanger (16), lamination means (20) and a second heat exchanger (22),
- the drying air circuit (12) includes the first heat exchanger (16), the second heat exchanger (22), a laundry treatment chamber (48) and at least one drying air fan (50) forming a loop,
- the refrigerant circuit (10) and the drying air circuit (12) are thermally coupled by the first heat exchanger (16) and the second heat exchanger (22),
- the first heat exchanger (16) is provided for heating up the drying air and cooling down the refrigerant, and
- the second heat exchanger (22) is provided for cooling down the drying air and heating up the refrigerant,

wherein the refrigerant circuit (10) includes a high pressure portion extending from the outlet of the compressor (14) via the first heat exchanger (16) to the inlet of the lamination means (20) and a low pressure portion extending from the outlet of the lamination means (20) via the second heat exchanger (22) to the inlet of the compressor (14),
- the refrigerant operates at least at critical pressure in the high pressure portion of the refrigerant circuit (10),
characterized in, that
- the refrigerant circuit (10) includes at least one auxiliary heat exchanger(18) interconnected between the first heat exchanger (16) and the lamination means (20),
- the auxiliary heat exchanger (18) is a heat exchanger between the refrigerant and ambient air or water,
- at least one auxiliary fan (24) for driving the ambient air or at least a water delivery device for supplying water corresponds with the auxiliary heat exchanger (18), and
- the auxiliary fan (24) or the water delivery device is controlled or controllable in dependence of at least a parameter associated to the drying air and/or to the refrigerant.

2. The laundry dryer according to claim 1, **characterized in, that**
the laundry dryer comprises at least one sensor for detecting the temperature of the drying air and/or the temperature refrigerant and/or the pressure of the refrigerant.

3. The laundry dryer according to claim 1 or 2, **characterized in, that**
the auxiliary fan (24) or the water delivery device is controlled or controllable in dependence of the temperature of the refrigerant and/or the temperature of the drying air.

4. The laundry dryer according to any one of the preceding claims,
characterized in, that
the auxiliary fan (24) or the water delivery device is activated, if the temperature of the drying air at the inlet of the laundry treatment chamber (48) exceeds a predetermined set-point temperature, wherein the predetermined set-point temperature is preferably in a range between 50°C and 75°C, preferably in a range between 55°C and 70°C, preferably in a range between 57°C and 65°C.

5. The laundry dryer according to claim 4,
characterized in, that
the auxiliary fan (24) or the water delivery device is deactivated, if the temperature of the drying air at the inlet of the laundry treatment chamber (48) becomes lower than said predetermined set-point temperature minus preferably 0°C to 5°C, minus preferably 1°C to 4°C, minus preferably 2°C to 3°C.

6. The laundry dryer according to any one of the preceding claims 1 to 3,
characterized in, that
the auxiliary fan (24) or the water delivery device is activated, if the temperature of the refrigerant at the outlet of the first heat exchanger (16) exceeds a predetermined set-point temperature, wherein the predetermined set-point temperature is preferably in a range between 35°C and 60°C, preferably, in a range between 40°C and 55°C.

7. The laundry dryer according to claim 6,
characterized in, that
the auxiliary fan (24) or the water delivery device is deactivated, if the temperature of the refrigerant at the outlet of the first heat exchanger (16) becomes lower than said predetermined set-point temperature minus preferably 0°C to 5°C, minus preferably 1°C to 4°C, minus preferably 2°C to 3°C.

8. The laundry dryer according to any one of the claims 1 to 3,
characterized in, that
the auxiliary fan (24) or the water delivery device is activated, if the temperature of the refrigerant at the inlet of the second heat exchanger (22) exceeds a predetermined set-point temperature, wherein the predetermined set-point temperature is in a range preferably between 20°C and 31°C, preferably in a range between 25°C and 31°C, preferably in a range between 28°C and 31°C, and the refrigerant operates below the critical pressure in the low pressure portion of the refrigerant circuit (10).

9. The laundry dryer according to claim 8,
characterized in, that
The auxiliary fan (24) or the water delivery device is deactivated, if the temperature of the refrigerant at the inlet of the second heat exchanger (22) becomes lower than said predetermined set-point temperature minus 0°C to 5°C, preferably minus 1°C to 4°C, preferably minus 2°C to 3°C.

10. The laundry dryer according to any one of the claims 1 to 3,
characterized in, that
the auxiliary fan (24) or the water delivery device is activated, if the temperature of the refrigerant at the inlet of the second heat exchanger (22) exceeds a predetermined set-point temperature, wherein the predetermined set-point temperature is in a range preferably between 31°C and 40°C, preferably between 33°C and 36°C, and the refrigerant operates

at least at critical pressure in the low pressure portion of the refrigerant circuit (10).

11. The laundry dryer according to claim 10,
characterized in, that
the auxiliary fan (24) or the water delivery device of the auxiliary heat exchanger (18) is deactivated, if the temperature of the refrigerant at the inlet of the second heat exchanger (22) becomes lower than said predetermined set-point temperature minus preferably 0°C to 5°C, minus preferably 1°C to 4°C, minus preferably 2°C to 3°C.

12. The laundry dryer according to any one of the claims 1 to 3,
characterized in, that
the auxiliary fan (24) or the water delivery device is activated, if a first condition is met and a second condition is met, wherein the first condition is met when the temperature of the refrigerant at the inlet of the second heat exchanger (22) reaches or exceeds a predetermined temperature value and the second condition includes at least one of the following:

the temperature of the refrigerant at the inlet of the second heat exchanger (22) reaches or exceeds a further predetermined temperature value,
the temperature of the refrigerant at the outlet of the first heat exchanger (16) reaches or exceeds a predetermined temperature,
temperature of the drying air at the inlet of laundry treatment chamber (48) reaches or exceeds a predetermined temperature.

13. The laundry dryer according to claim 12,
characterized in, that
the second condition includes a set-point temperature range having an upper limit and a lower limit, the auxiliary fan (24) or the water delivery device is activated when temperature of the refrigerant at the inlet of the second heat exchanger (22) reaches or exceeds the upper limit and deactivated when the temperature of the refrigerant at the inlet of the second heat exchanger (22) reaches or goes below the lower limit, wherein both the upper limit and a lower limit of the second condition are lower than said predetermined temperature value of the first condition and at least the lower limit of the set-point temperature range is lower than the evaporation temperature of the refrigerant and the refrigerant operates below the critical pressure in the low pressure portion of the refrigerant circuit (10).

14. The laundry dryer according to claim 12,
characterized in, that
the second condition includes a set-point temperature range having an upper limit and a lower limit, the auxiliary fan (24) or the water delivery device is activated when temperature of the refrigerant at the inlet of the second heat exchanger (22) reaches or exceeds the upper limit and deactivated when the temperature of the refrigerant at the inlet of the second heat exchanger (22) reaches or goes below the lower limit, wherein the lower limit of the second condition is lower than said predetermined temperature value of the first condition and lower than the critical temperature of the refrigerant and the refrigerant operates at least at critical pressure in the low pressure portion of the refrigerant circuit (10).

15. The laundry dryer according to any one of the preceding claims,
characterized in, that
the auxiliary fan (24) or the water delivery device is controlled or controllable so that either

- the temperature of the refrigerant at the inlet of the second heat exchanger (22) is lower than the evaporation temperature of the refrigerant and the refrigerant operates below the critical pressure in the low pressure portion of the refrigerant circuit (10), or
- the temperature of the refrigerant at the inlet of the second heat exchanger (22) is lower than the critical temperature of the refrigerant and the refrigerant operates at least at critical pressure in the low pressure portion of the refrigerant circuit (10).

FIG 1

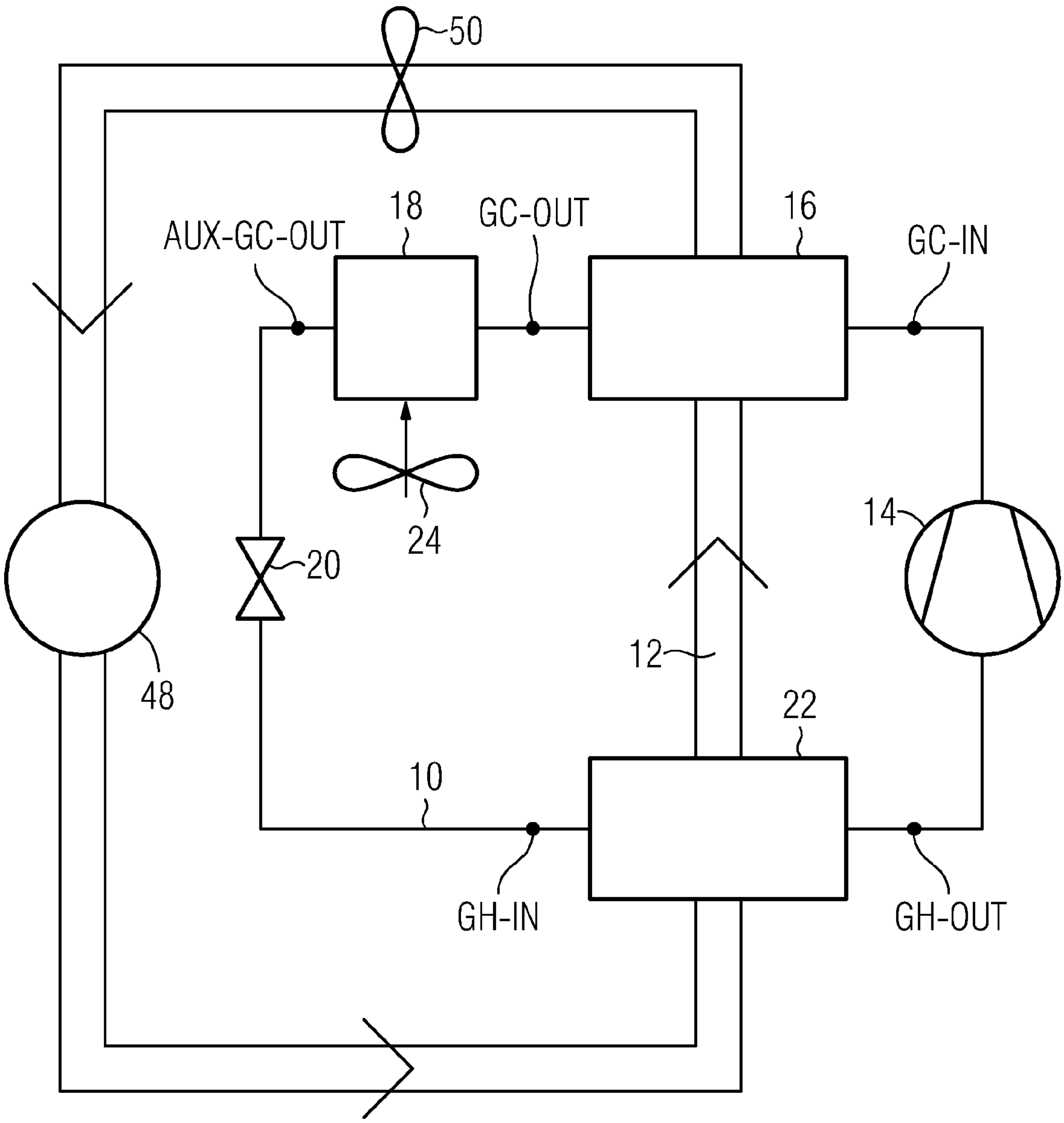


FIG 2

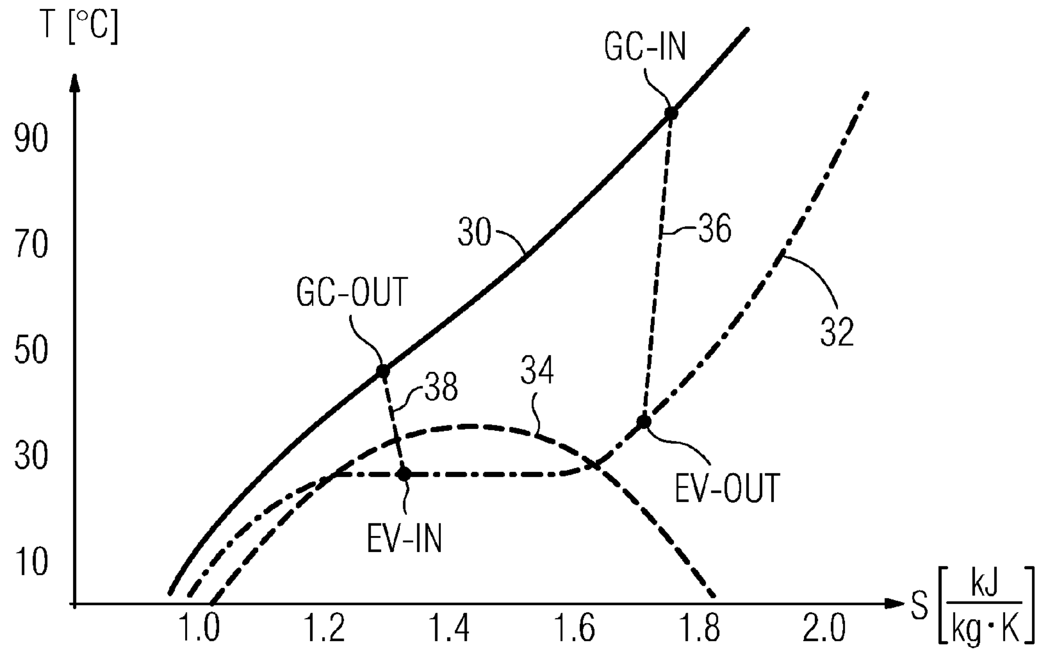

T [°C]
90
70
50
30
10
GC-IN
30
36
GC-OUT
38
34
32
EV-OUT
EV-IN
1.0
1.2
1.4
1.6
1.8
2.0
S [kJ/kg·K]

FIG 3

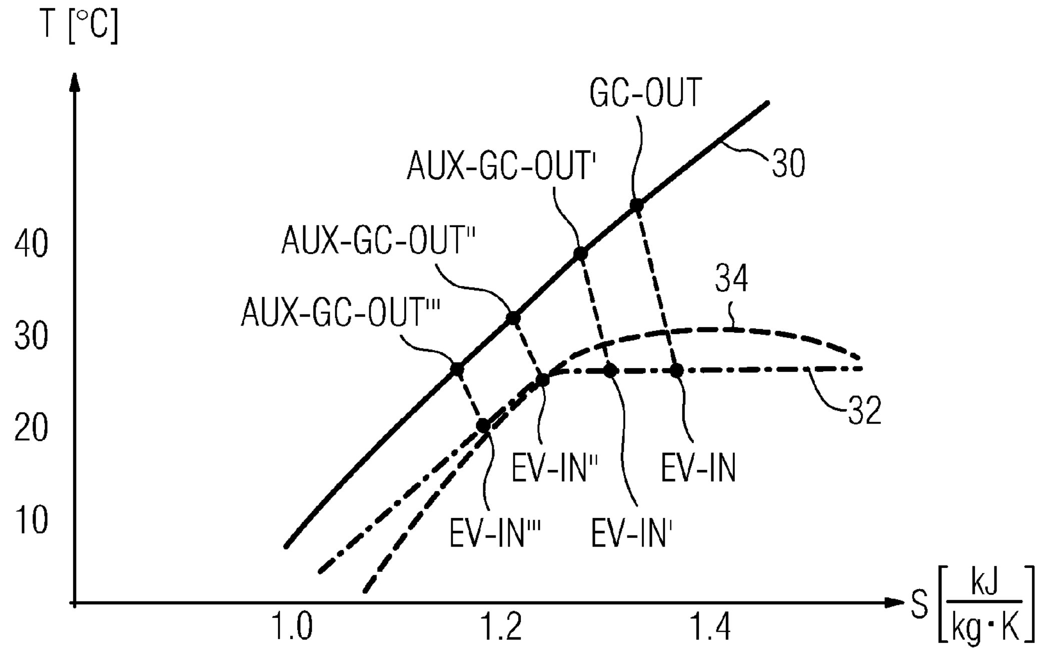

T [°C]
40
30
20
10
GC-OUT
30
AUX-GC-OUT'
AUX-GC-OUT''
34
AUX-GC-OUT'''
32
EV-IN''
EV-IN
EV-IN'''
EV-IN'
1.0
1.2
1.4
S [kJ/kg·K]

FIG 4

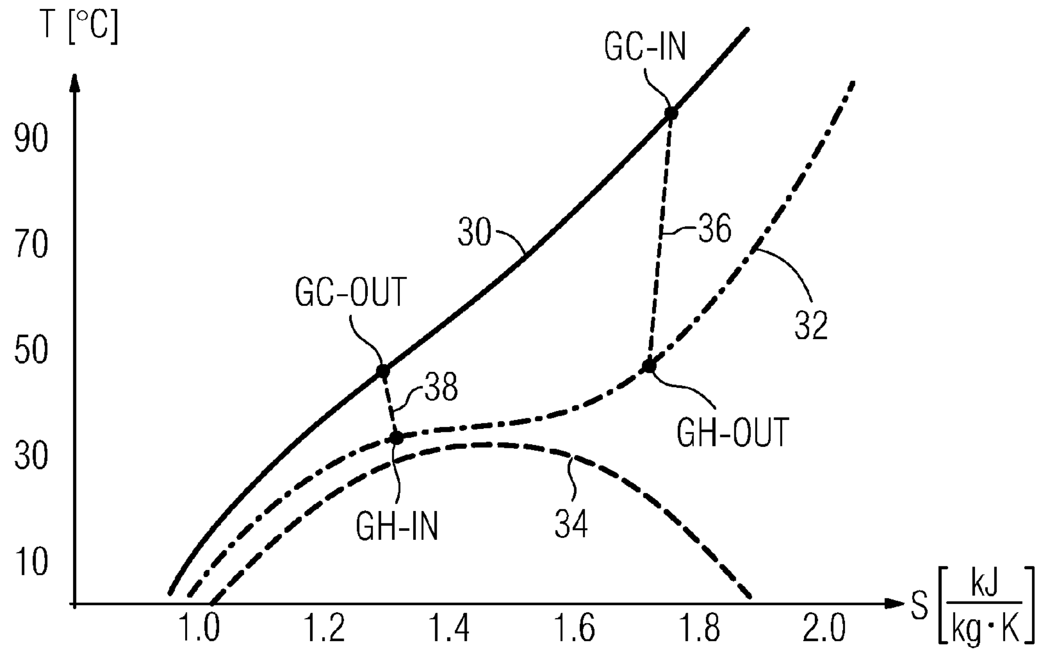

T [°C]
90
70
50
30
10
GC-IN
30
36
GC-OUT
38
32
GH-OUT
GH-IN
34
1.0
1.2
1.4
1.6
1.8
2.0
S [kJ/kg·K]

FIG 5

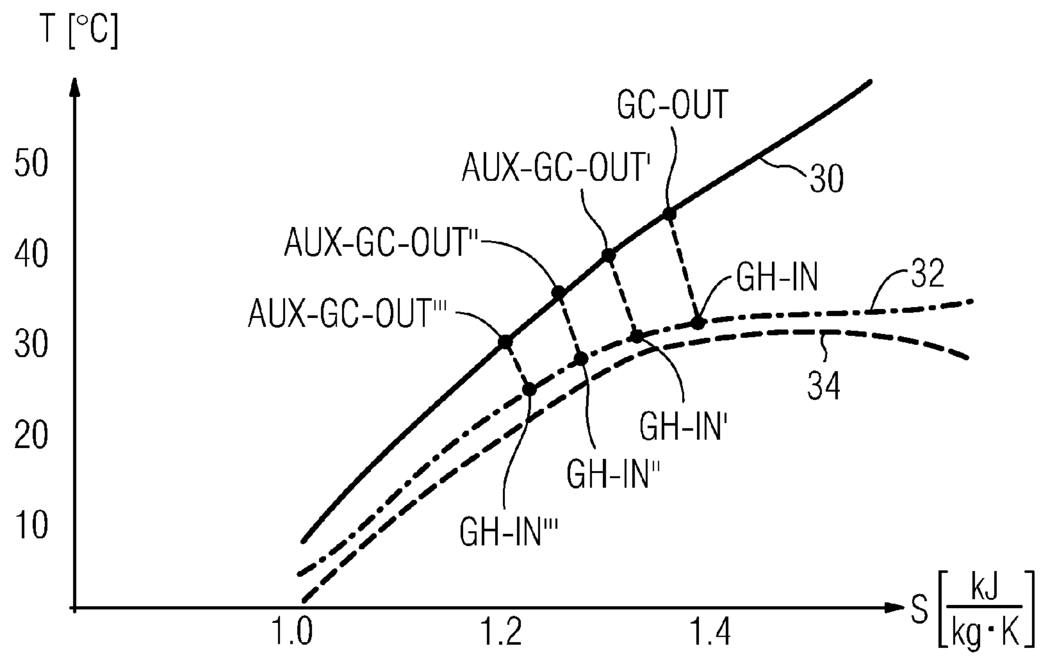

T [°C]
50
40
30
20
10
GC-OUT
AUX-GC-OUT'
30
AUX-GC-OUT''
GH-IN
32
AUX-GC-OUT'''
34
GH-IN'
GH-IN''
GH-IN'''
1.0
1.2
1.4
S [kJ/kg·K]

FIG 6

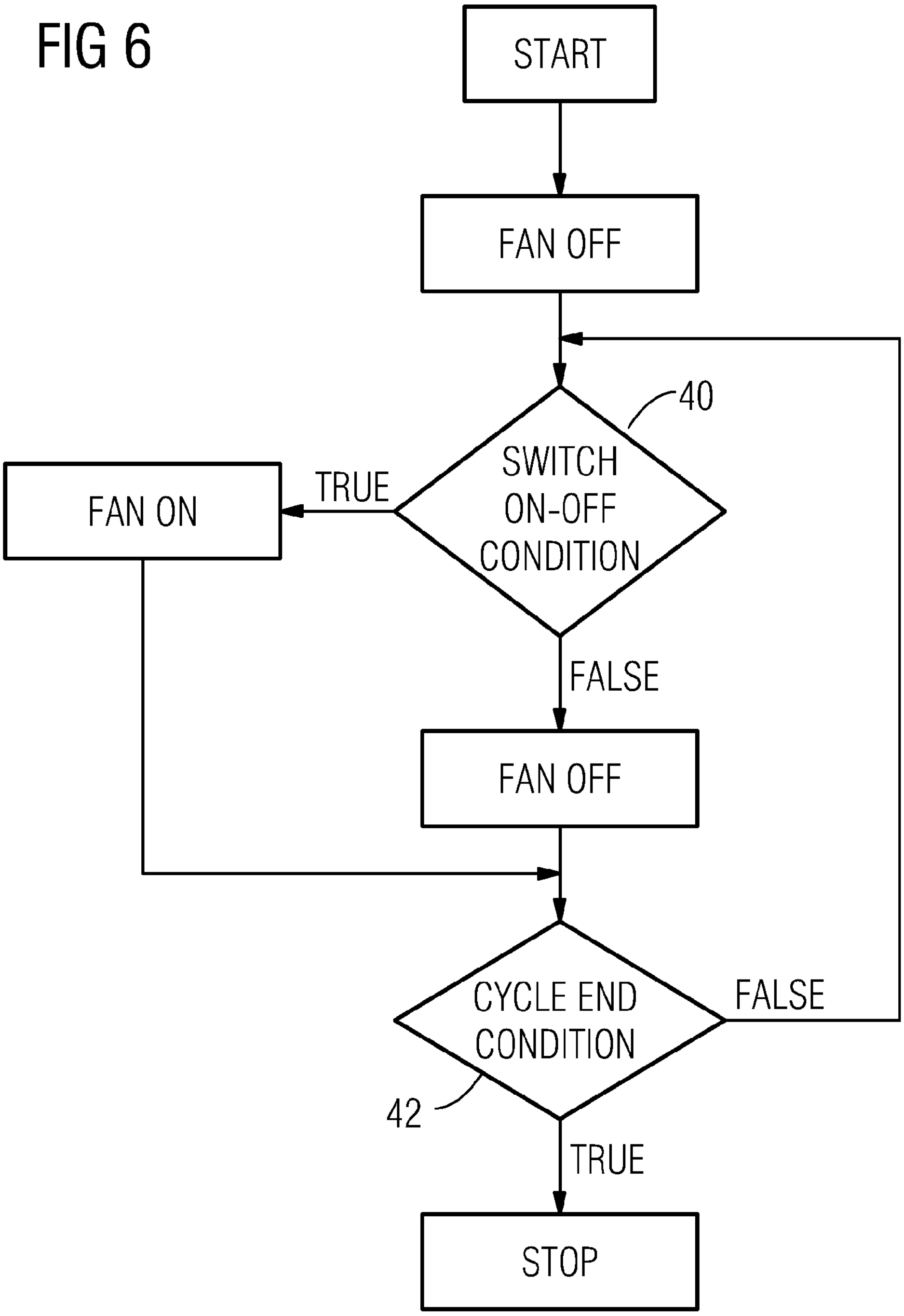

START
FAN OFF
40
SWITCH ON-OFF CONDITION
TRUE
FAN ON
FALSE
FAN OFF
CYCLE END CONDITION
FALSE
42
TRUE
STOP

FIG 7

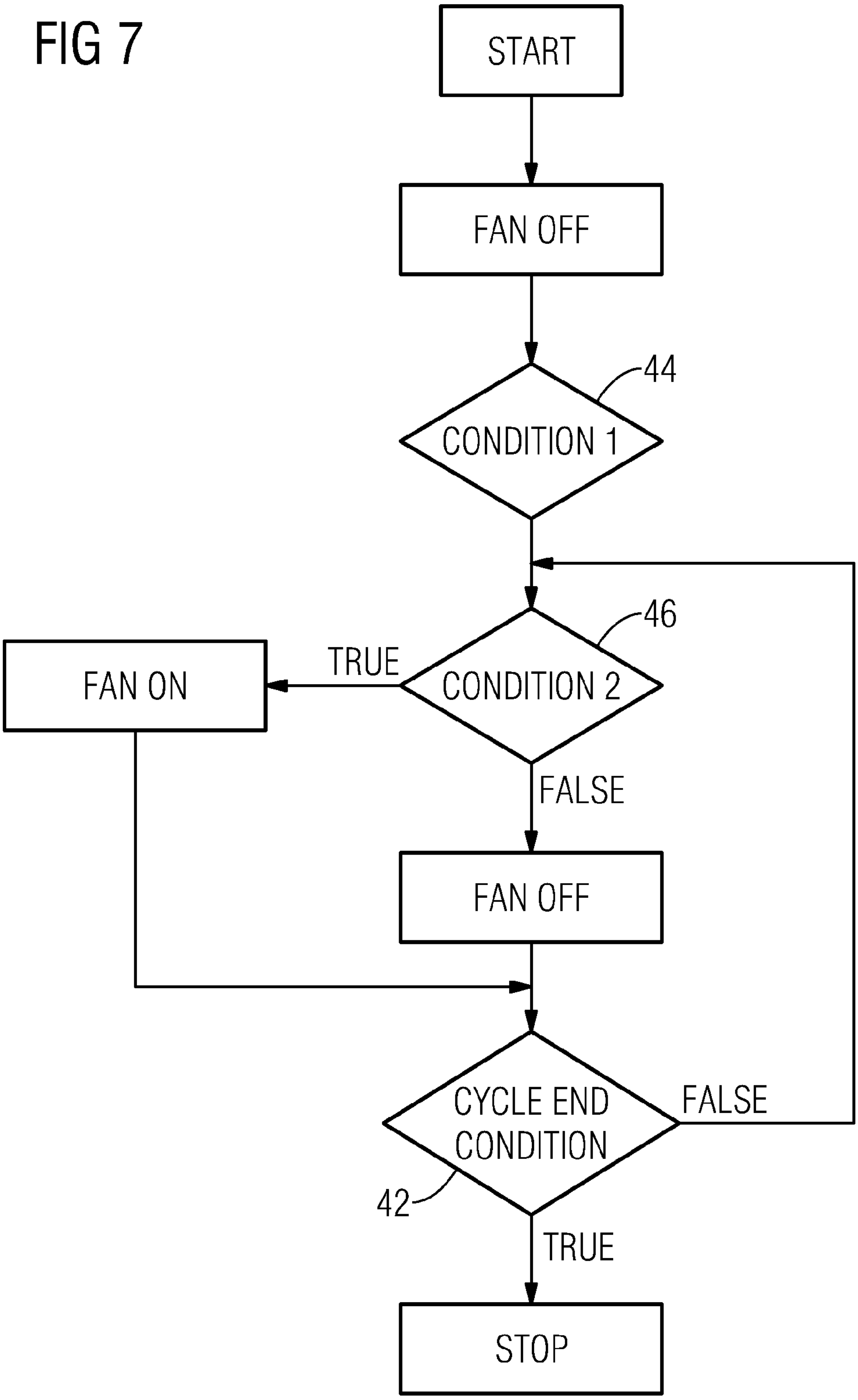
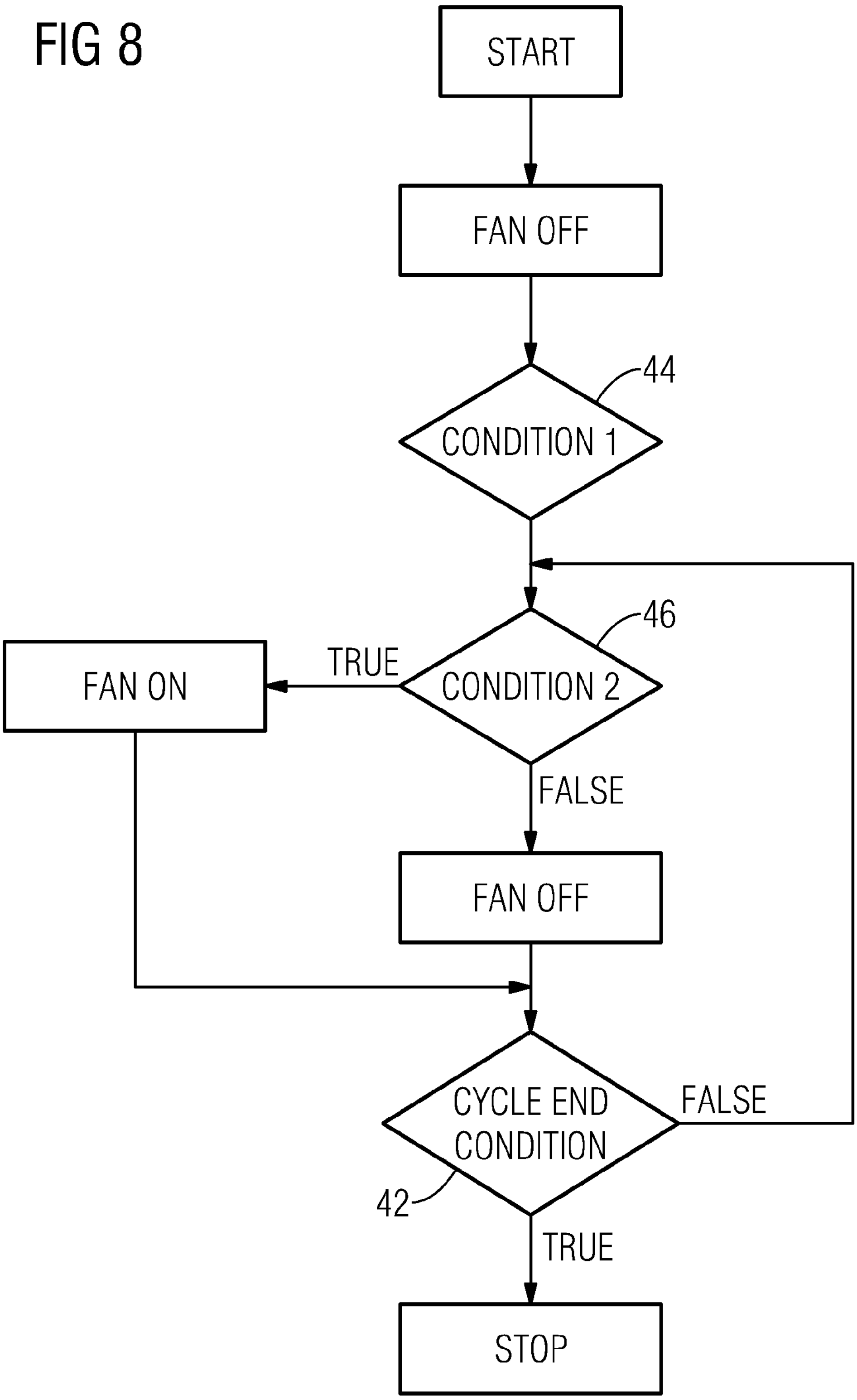

START
FAN OFF
44
CONDITION 1
46
TRUE
FAN ON
CONDITION 2
FALSE
FAN OFF
CYCLE END
CONDITION
FALSE
42
TRUE
STOP

FIG 8


START
FAN OFF
44
CONDITION 1
46
TRUE
FAN ON
CONDITION 2
FALSE
FAN OFF
CYCLE END
CONDITION
FALSE
42
TRUE
STOP

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EUROPEAN SEARCH REPORT

Application Number
EP 11 18 9866

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 1 884 586 A2 (V ZUG AG [CH]) 6 February 2008 (2008-02-06) * paragraphs [0017] - [0031], [0037], [0038], [0039] - [0047]; figures 1,3 *	1-3	INV. D06F58/20
A	WO 2008/086933 A1 (BSH BOSCH SIEMENS HAUSGERAETE [DE]; STEFFENS GUENTER [DE]; GRUNERT KLA) 24 July 2008 (2008-07-24) * abstract; figure 1 *	1	

TECHNICAL FIELDS SEARCHED (IPC)
D06F

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	25 May 2012	Kising, Axel

CATEGORY OF CITED DOCUMENTS

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25-05-2012

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		WO 2008086933 A1	24-07-2008

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