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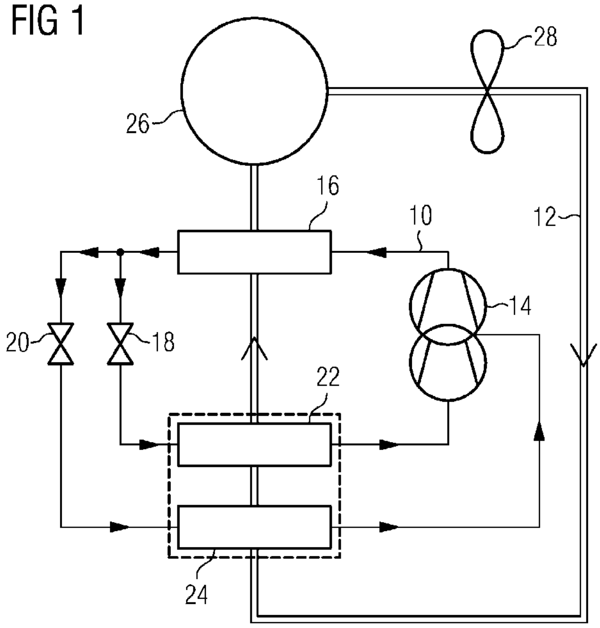
(54) **A heat pump system for a laundry dryer**

(57) The present invention relates to a heat pump system for a laundry dryer, said heat pump system comprises a refrigerant circuit (10) for a refrigerant and an air stream circuit (12) for an air stream. The refrigerant circuit (10) includes a compressor (14), a first heat exchanger (16), lamination means (18) and a second heat exchanger (22) connected in series and forming a loop. The air stream circuit (12) includes the first heat exchanger (16), a laundry drum (26), at least one air stream fan (26) and the second heat exchanger (22) connected in series and forming a closed loop. The refrigerant circuit (10) and the air stream circuit (12) are thermally coupled by the first heat exchanger (16) and the second heat exchanger (22). The compressor (14) is formed as a multi-stage compressor or as a plurality of serial compressors. The refrigerant circuit (10) includes at least one series of further lamination means (20) and a third heat exchanger (24). The compressor (14) includes an intermediate connection arranged between the stages of the multi-stage compressor or between the serial compressors, respectively. The inlet of the further lamination means (20) is connected to the outlet of the first heat exchanger (16). The outlet of the third heat exchanger (24) is connected to the intermediate connection of the compressor (14).

FIG 1



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Description

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

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

[0003] The cycle of the heat pump laundry dryer is characterized by two phases: a transitory phase or warm-up 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. For example, a cooling fan cools down the compressor or an auxiliary condenser, 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.

[0004] There are some differences between these heat pump laundry dryers, which use as refrigerant carbon dioxide (CO_2) on the one hand and those heat pump laundry dryers 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.

[0005] The traditional condenser, in which the refrigerant 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 gas cooler outlet there is no refrigerant in liquid state, but a gas with a lower temperature and an increased density. Depending on the amount of carbon dioxide in the heat pump circuit and design of the heat pump circuit as such, there could be a very short transient phase, i.e. a few seconds or a few minutes, after the switching on the compressor in which the refrigerant is in the liquid phase in the high pressure portion of the heat pump circuit.

[0006] 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 is called 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.

[0007] FIG 3 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 40, a low pressure isobaric line 42, a saturation curve 44 of carbon dioxide, a compression phase 46 and a lamination phase 48. Further, a state a of the refrigerant at the gas heater outlet, a state b of the refrigerant at the gas cooler inlet, a state c of the refrigerant at the gas cooler outlet and a state d of the refrigerant at the gas heater inlet are indicated in the temperature-entropy diagrams.

[0008] During the compression phase 46, the temperature and pressure of carbon dioxide increase. During a cooling phase the carbon dioxide follows the high pressure isobaric line 40. During the lamination phase 48, the temperature and pressure of carbon dioxide decrease. During a heating phase the carbon dioxide follows the low pressure isobaric line 42.

[0009] Assuming the pressure of the high pressure isobaric line 40 and the temperature in the state a are constant, it is possible to see what happens to the cycle when the pressure of the low pressure isobaric line 42 increases. The main difference is that, when the pressure of the low pressure isobaric line 42 is higher than about 71 bar, then the cycle is in the one-phase zone, i.e. the portion of the chart is outside the saturation curve 44. Thus, the refrigerant is heated up without phase change in the gas heater, and the heat pump system works in the totally-supercritical cycle.

[0010] The evaporation phase following the low pressure isobaric line 42 from the state d, wherein the pressure and temperature stay constant, is avoided. Therefore 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 performances of the gas heater are improved.

[0011] Further, if the pressure of the low pressure isobaric line 42 increases, then the density of the refrigerant at the inlet of the compressor increases as well. Thus, the refrigerant flow rate becomes higher. In this way the cooling and the heating capacity increase, even if the delta enthalpy at the gas cooler and the gas heater decrease. In this case, the phases following the high pressure isobaric line 40 and the low pressure isobaric line 42, respectively, are "shorter" in FIG 4.

[0012] Thus, there are some advantages in operating the heat pump system in totally-supercritical conditions rather than in trans-critical conditions. However, in passing from the trans-critical to the totally-supercritical cycle, there are some disadvantages that penalize the drying air thermal conditions. The main one is connected to the fact that the temperature of the refrigerant at the inlet of the gas heater is greater than the temperature of the refrigerant at the inlet of the gas heater during the trans-critical cycle. This reduces the capacity of the refrigerant for dehumidifying the air stream.

[0013] Usually, the compressors for carbon dioxide and further refrigerants are double stage compressors. FIG 5 shows a refrigerant circuit according to the prior art. The refrigerant circuit includes a compressor 14 form as double stage compressor. Further, the refrigerant circuit includes a gas cooler 16, lamination means 18 and an evaporator 22. The double stage compressor 14 is characterized by having two inlets and two outlets, namely a low pressure suction, an intermediate pressure discharge, an intermediate pressure suction and a high pressure discharge. For usual heat pump applications, the intermediate pressure discharge and the intermediate pressure suction are welded together, so that the compressor behaves as one single stage compressor.

[0014] The heat pump system of the laundry dryer using carbon dioxide as refrigerant can work in a trans-critical or total-supercritical cycle. Both cycle processes present some advantages and disadvantages due to the heat pump performances and the interaction between the refrigerant and the air stream.

[0015] It is an object of the present invention to provide a heat pump system for a laundry dryer, which overcomes the disadvantages of the trans-critical cycle as well as of the totally-supercritical cycle.

[0016] The object of the present invention is achieved by the heat pump system according to claim 1.

[0017] According to the present invention

- the refrigerant circuit includes at least one series of further lamination means and a third heat exchanger,
- the compressor includes an intermediate connection arranged between the stages of the multi-stage compressor or between the serial compressors, respectively,
- the inlet of the further lamination means is connected to the outlet of the first heat exchanger, and
- the outlet of the third heat exchanger is connected to the intermediate connection of the compressor.

[0018] The present invention provides a heat pump system, wherein the structure of the refrigerant circuit results in three portions of said refrigerant circuit with different pressure levels. The structure of the refrigerant circuit allows that the heat pump system can works in the totally-supercritical cycle and the trans-critical cycle at the same time, so that the advantages of said totally-supercritical cycle and trans-critical cycle are connected. Preferably, the refrigerant in the refrigerant circuit is carbon dioxide.

[0019] Further, the refrigerant circuit and the air stream circuit may be thermally coupled by the third heat exchanger.

[0020] In particular, the third heat exchanger is provided for cooling down the air stream and heating up the refrigerant.

[0021] According to a special embodiment of the present invention the second heat exchanger and the third heat exchanger form a common heat exchanger with at least two different circuits for the refrigerant, wherein at least one circuit is provided for the second heat exchanger and at least one further circuit is provided for the third heat exchanger.

[0022] Preferably, the heat pump system is provided for working in a trans-critical cycle and a totally-supercritical cycle at the same time.

[0023] Further, the heat pump system may be provided for splitting the flow rate of the refrigerant at the outlet of the first heat exchanger.

[0024] In particular, the first heat exchanger forms a gas cooler. The gas cooler is arranged within a high pressure portion of the refrigerant circuit.

[0025] In a similar way, the second heat exchanger forms an evaporator. The evaporator is arranged within a low pressure portion of the refrigerant circuit.

[0026] Moreover, the third heat exchanger forms a gas heater. The gas heater is arranged within an intermediate pressure portion of the refrigerant circuit.

[0027] Preferably, the heat pump system is provided for working in a totally-supercritical cycle through the first, second, third heat exchanger.

[0028] For example, at least one of the lamination means is formed as a capillary tube.

[0029] Alternatively or additionally, at least one of the lamination means is formed as an electronic expansion valves.

[0030] Preferably, the refrigerant circuit includes at least one on-off valve arranged between the outlet of the third heat exchanger and the inlet of the compressor.

[0031] In a similar way, the refrigerant circuit includes at least one on-off valve arranged between the outlet of the third heat exchanger and the intermediate connection of the compressor.

[0032] At last, the present invention relates to a laundry dryer with at least one heat pump system, wherein the laundry dryer comprises at least one heat pump system mentioned above.

[0033] The novel and inventive features believed to be the characteristic of the present invention are set forth in the appended claims.

[0034] 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 first embodiment of the present invention, FIG 2 shows a schematic diagram of the heat pump system for the laundry dryer according to a second embodiment of the present invention,

FIG 3 shows a temperature-entropy diagram of a transcritical cycle in the heat pump system for the laundry dryer,

FIG 4 shows a temperature-entropy diagram of a totallysupercritical cycle in the heat pump system for the laundry dryer, and

FIG 5 shows a schematic diagram of the heat pump system for the laundry dryer according to the prior art.

[0035] FIG 1 illustrates a schematic diagram of a heat pump system for a laundry dryer according to a first embodiment of the present invention. The heat pump system includes a closed refrigerant circuit 10 and a drying air circuit 12.

[0036] The refrigerant circuit 10 includes a compressor 14, a gas cooler 16, first lamination means 18, second lamination means 20, an evaporator 22 and a gas heater 24. The compressor 14 is formed as a multi-stage compressor and in a preferred embodiment the compressor is a double (two) stage compressor. As evident, multi-stage compressor includes a compressor having at least two stages of compression wherein the refrigerant compressed in a compression chamber passes into a further compression chamber for further compression. The following description will refer to a double stage compressor only for convenience.

[0037] The double stage compressor 14 includes two single compressor stages connected in series. The inlet of the compressor 14 corresponds with the inlet of a first compressor stage. An intermediate connection of the compressor 14 corresponds with the outlet of the first compressor stage and the inlet of a second compressor stage. The outlet of the compressor 14 corresponds with the outlet of the second compressor stage.

[0038] The compressor 14, the gas cooler 16, the first lamination means 18 and the evaporator 22 are switched in series and form a first loop of the refrigerant circuit 10. The second stage of the compressor 14, the gas cooler 16, the second lamination means 20 and the gas heater 24 are switched in series and form a second loop of the refrigerant circuit 10. Thus, the series of the second lamination means 20 and the gas heater 24 is arranged in parallel to the series of the first lamination means 18, the evaporator 22 and the first stage of the compressor 14. In other words, the outlet of the evaporator 22 is connected to the inlet of the compressor 14, and the outlet of the gas heater 24 is connected to the intermediate connection of the compressor 14.

[0039] The drying air circuit 12 includes the gas heater 24, the evaporator 22, the gas cooler 16, a laundry treatment chamber 26, preferably a rotatable drum, and an air stream fan 28. The gas cooler 16, the evaporator 22 and the gas heater 24 are heat exchangers and form the thermal interconnections between the refrigerant circuit 10 and the drying air circuit 12. The evaporator 22 and the gas heater 24 cool down and dehumidify the drying air, after said drying air has passed the laundry drum 26. Then the gas cooler 16 heats up the drying air, before the drying air is re-inserted into the laundry drum 26. The drying air is driven by the air stream fan 28.

[0040] The drying air is preferably circulated in a closed loop in which the drying air is preferably continuously flown through the laundry treatment chamber. However it may also be provided that a (preferably smaller) portion of the air stream 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 small fraction of the total processing time) to have an open loop discharge

[0041] In any case, at least a part of the drying air after having passed through the evaporator 22 and gas heater 24 passes through the gas cooler 16.

[0042] The refrigerant circuit 10 is subdivided into a high pressure portion, a low pressure portion and an intermediate pressure portion. The high pressure portion extends from the outlet of the compressor 14 via the gas cooler 16 to the inlets of the first lamination means 18 and the second lamination means 20. The low pressure portion extends from the outlet of the first lamination means 18 via the evaporator 22 to the inlet of the compressor 14. The intermediate pressure portion extends from the outlet of the second lamination means 20 via the gas heater 24 to the intermediate connection of the compressor 14.

[0043] The refrigerant is compressed and heated up by the compressor 14. Then, the gas cooler 16 cools down the refrigerant and heats up the air stream. At the outlet of the gas cooler 16 the flow rate of the refrigerant is divided into a first flow rate and a second flow rate.

[0044] The first flow rate of the refrigerant flows through the first lamination means 18. In the first lamination means 18 the pressure of the refrigerant is decreased down to the pressure of the low pressure portion of the refrigerant circuit, i.e. the same pressure value as at the inlet of the compressor 14. Then, the refrigerant enters into the evaporator 22. In the evaporator 22 the refrigerant is vaporised and superheated. Then, the refrigerant is sucked by the inlet of the compressor 14 and compressed in the first stage of the compressor.

[0045] The second flow rate of the refrigerant flows through the second lamination means 20. In the second lamination means 20 the pressure of the refrigerant is decreased down to the pressure of the intermediate pressure portion, i.e. the same pressure value as at the intermediate connector of the compressor 14. Then, the refrigerant enters the gas heater 24. In the gas heater 24 the refrigerant is heated up.

[0046] The first flow rate and the second flow rate of the refrigerant are mixed at the intermediate connection of the compressor 14. Then, the whole refrigerant is compressed in the second stage of the compressor 14 and cooled down in the gas cooler 16.

[0047] In this way the refrigerant works at three different pressure levels in the high pressure portion, the low pressure portion and the intermediate pressure portion, respectively. The high pressure level occurs between the outlet of the compressor 14 and the inlets of the lamination means 18 and 20. The intermediate pressure level occurs between the outlet of the second lamination means 20 and the intermediate connection of the compressor 14. The low pressure level occurs between the first lamination means 18 and the inlet of the compressor 14.

[0048] According to an alternative embodiment of the present invention a plurality of separate compressors arranged in series may be used instead the multi-stage stage compressor 14. The separate compressors (two in a preferred embodiment) work at different pressure levels, wherein the outlet of the compressor running at the lower pressure is connected to the inlet of the compressor running at the higher pressure.

[0049] According to another aspect of the present invention at least an evaporator 22 and at least a gas heater 24 are connected between the gas cooler 16 and compressor means and working in parallel. The evaporator 22 is connected to a first compression stage of the two-stage compressor, which provides a first level of refrigerant compression. The gas heater 24 is connected to a second compression stage of the two-stage compressor and providing a second level of refrigerant compression. Of course, gas cooler means that the refrigerant operates at least at critical pressure in the high pressure side of the heat pump circuit.

[0050] The first flow rate of the refrigerant flows in two phases, namely as liquid and as vapour, and evaporates in the evaporator 22. The first flow rate of the refrigerant operates at least at the critical pressure in the high pressure portion of the refrigerant circuit 10. The first flow rate of the refrigerant operates below the critical pressure in the low pressure portion side of the refrigerant circuit 10.

[0051] The second flow rate of the refrigerant, which flows in the gas cooler 16, in the gas heater 24 and in the second stage of the compressor 14, can be in gaseous state. Thus, the second flow rate of the refrigerant can operate at least at critical pressure in the low pressure portion as well as in the high pressure portion of the refrigerant circuit 10.

[0052] At the beginning of the drying cycle the gas heater 24 can work as an evaporator, until the intermediate pressure reaches the CO_2 critical pressure level.

[0053] The amounts of the first flow rate and second flow rate of the refrigerant are determined by the design of the first lamination means 18 and the second lamination means 20. The more is the amount of the second flow rate of the refrigerant, the more is the efficiency of the heat pump system. In fact, the difference between the pressures of the second flow rate, i.e. between the intermediate pressure portion to the high pressure portion is lower than the difference between the pressures of the first flow rate from the low pressure portion to the high pressure portion. The compression power is reduced when the amount of the second flow rate increases.

[0054] However, the temperature level of the refrigerant flowing in the gas heater 24 is higher than the temperature level of the refrigerant flowing in the evaporator 22. If the second flow rate of the refrigerant is too high, then the drying capacity of the heat pump system can be penalized, and the efficiency of the drying process and of the laundry dryer decrease as well.

[0055] The ratio of the first and second flow rate of the refrigerant can be chosen in order to maximize the efficiency of the drying process according to the considerations above, by properly designing the lamination means 18 and 20.

[0056] The evaporator 22 and the gas heater 24 can be two different heat exchangers. Alternatively, the evaporator 22 and the gas heater 24 can be formed by the same finned coil with two different circuits for the refrigerant, wherein one circuit is provided for the evaporator 22 and one circuit is provided for the gas heater 24.

[0057] Since the lamination means 18 and 20 are capillary tubes or similar passive lamination means, it is difficult to modulate the ratio of the first and second flow rate of the refrigerant during the cycle. Further, by using electronic expansion valves it is possible to change the ratio of the flow rates according to the variable thermodynamic conditions of the refrigerant in order to maximize the efficiency of the heat pump system. The second flow rate of the refrigerant can be reduced during the drying cycle when the temperature of the refrigerant at the inlet or at the outlet of the gas heater 24 becomes too high.

[0058] During some phases of the drying cycle, the refrigerant could work only in the trans-critical cycle. It means that the whole refrigerant should flow in the evaporator 22 via the first lamination valve 18. In this case, in addition to the electronic expansion valves, a more quiet complex circuit is provided. In fact the evaporator 22 cannot vaporize the whole refrigerant, if it is designed for only a percentage of it. Thus, also the gas heater 24 can work as an additional evaporator.

[0059] For example, it could be convenient that in the first part of the drying cycle the refrigerant operates in trans-critical conditions only, since the temperature at the gas cooler 16 and the evaporator 22 is below the critical temperature, which is about 31° C for carbon dioxide. In practise, the temperature of the air stream at the beginning of the drying cycle is still not enough high to promote the totally-supercritical cycle.

[0060] Additionally or alternatively, at the end of the drying cycle, wherein few moisture is contained in the clothes, it could be convenient to have a trans-critical cycle only so that the lower temperature of the refrigerant at the evaporator 22 and the gas heater 24, now working as an additional evaporator, with respect to the temperature of the refrigerant at the gas cooler 16 is more suitable to remove the residual humidity from the clothes.

[0061] An easier solution is described below. When the refrigerant circuit is to be turned only in the trans-critical cycle, then the electronic expansion valves, e.g. the lamination means 18 and 20, give the same pressure drops to the refrigerant decreasing its pressure down to the low pressure level. In this case, the first flow rate and the second flow rate have same pressure level. Both flow rates occur in two phase status, i.e. as liquid and as vapour, so that the evaporator 22 and the gas heater 24 act as a unique evaporator with two circuits for the refrigerant. The both flow rates of the refrigerant mix together and are sucked by the low pressure suction of the compressor 14 in this case. To obtain it, the refrigerant circuit of the heat pump system is modified as shown in the following scheme.

[0062] FIG 2 shows a schematic diagram of the heat pump system for the laundry dryer according to a second embodiment of the present invention. The heat pump system for the laundry dryer according to the second embodiment has the same components as the first embodiment in FIG 1. Additionally, the heat pump system of the second embodiment comprises a first on-off valve 30 and a second on-off valve 32.

[0063] The first on-off valve 30 is interconnected between the outlets if the evaporator 22 and the gas heater 24. The second on-off valve 32 is interconnected between the outlet if the gas heater 24 and the intermediate connection of the compressor 14. When the heat pump system is working in the trans-critical cycle and totally-supercritical cycle at the same time (or generally when the heat pump is working with the evaporator 22 and at the gas heater 24 at two different pressure levels), then the first on-off valve 30 is closed, while the second on-off valve 32 is open. When the heat pump system is working only in trans-critical cycle (or generally when the heat pump is working with the evaporator 22 and at the gas heater 24 at the same pressure levels), then the first on-off valve 30 is open, while the second on-off valve 32 is closed, so that the whole flow rate of the refrigerant is sucked by the low pressure suction of the compressor 14, i.e. the inlet of the compressor 14. In this case the lamination means 18 and 20 give the same pressure drop to the two refrigerant flow rates down to the low pressure level as explained above. Further, the first on-off valve 30 and the second on-off valve 32 may be actuated in response to the temperature and/or pressure of the refrigerant and the air stream. It is clear that a three-way valve can replace the first on-off valve 30 and the second on-off valve 32 in a further embodiment.

[0064] FIG 3 shows a temperature-entropy diagram of a trans-critical cycle in the heat pump system for the laundry dryer. The temperature-entropy diagrams comprise a high pressure isobaric line 40, a low pressure isobaric line 42, a saturation curve 44 of carbon dioxide, a compression phase 46 and a lamination phase 48. Further, a state a of the refrigerant at the outlet of the gas heater, a state b of the refrigerant at the inlet of the gas cooler, a state c of the refrigerant at the outlet of the gas cooler and a state d of the refrigerant at the inlet of the gas heater are indicated in the temperature-entropy diagrams.

[0065] FIG 4 shows a temperature-entropy diagram of a totally-supercritical cycle in the heat pump system for the laundry dryer. The temperature-entropy diagrams comprise the high pressure isobaric line 40, the low pressure isobaric line 42, the saturation curve 44 of carbon dioxide, the compression phase 46 and the lamination phase 48. Further, the state a of the refrigerant at the outlet of the gas heater, the state b of the refrigerant at the inlet of the gas cooler, the state c of the refrigerant at the outlet of the gas cooler and the state d of the refrigerant at the inlet of the gas heater are indicated in the temperature-entropy diagrams.

[0066] During the compression phase 46, the temperature and pressure of carbon dioxide increase. During a cooling phase the carbon dioxide follows the high pressure isobaric line 40. During the lamination phase 48, the temperature and pressure of carbon dioxide decrease. During a heating phase the carbon dioxide follows the low pressure isobaric line 42.

[0067] Assuming the pressure of the high pressure isobaric line 40 and the temperature in the state a are constant, it can be seen what happens to the cycle when the pressure of the low pressure isobaric line 42 increases. The main difference is that, when the pressure of the low pressure isobaric line 42 is higher than about 71 bar, then the bar the cycle is in the one-phase zone, i.e. the portion of the chart is outside the saturation curve 44. Thus, the refrigerant is heated up without phase change in the gas heater, and the heat pump system works in the totally-supercritical cycle.

[0068] The evaporation phase following the low pressure isobaric line 42 from the state d, wherein the pressure and temperature stay constant, is avoided. Therefore 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 performances of the gas heater are improved.

[0069] Further, if the pressure of the low pressure isobaric line 42 increases, then the density of the refrigerant at the inlet of the compressor increases as well. Thus, the refrigerant flow rate becomes higher. In this way the cooling and the heating capacity increase, even if the delta enthalpy at the gas cooler and the gas heater decrease. In this case, the phases following the high pressure isobaric line 40 and the low pressure isobaric line 42, respectively, are "shorter" in FIG 4.

[0070] FIG 5 shows a schematic diagram of the heat pump system for the laundry dryer according to the prior art. The refrigerant circuit includes a compressor 14, a gas cooler 16, lamination means 18 and an evaporator 22.

[0071] The compressor 14 is formed as double stage compressor. The double stage compressor 14 is characterized by having two inlets and two outlets, namely a low pressure suction, an intermediate pressure discharge, an intermediate pressure suction and a high pressure discharge. For usual heat pump applications, the intermediate pressure discharge and the intermediate pressure suction are welded together, so that the compressor behaves as one single stage compressor.

[0072] 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

[0073]

10 refrigerant circuit

12 air stream circuit

14 compressor

16 gas cooler, first heat exchanger

18 first lamination means

20 second lamination means

22 evaporator, second heat exchanger

24 gas heater, third heat exchanger

26 laundry drum

28 air stream fan

30 first on-off valve

32 second on-off valve

40 high pressure isobaric line

42 low pressure isobaric line

44 saturation curve of carbon dioxide

46 compression phase

48 lamination phase

a state of the refrigerant at the gas heater outlet

b state of the refrigerant at the gas cooler inlet

c state of the refrigerant at the gas cooler outlet

d state of the refrigerant at the gas heater inlet

Claims

1. A heat pump system for a laundry dryer, said heat pump system comprises a refrigerant circuit (10) for a refrigerant and an air stream circuit (12) for an air stream, wherein

   - the refrigerant circuit (10) includes a compressor (14), a first heat exchanger (16), lamination means (18) and a second heat exchanger (22) connected in series and forming a loop,
   - the air stream circuit (12) includes the first heat exchanger (16), a laundry treatment chamber (26), at least one air stream fan (26) and the second heat exchanger (22),
   - the refrigerant circuit (10) and the air stream 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 air stream and cooling down the refrigerant,
   - the second heat exchanger (22) is provided for cooling down the air stream and heating up the refrigerant, and
   - the compressor (14) is formed as a multi-stage compressor or as a plurality of serial compressors,

   characterized in, that

   - the refrigerant circuit (10) includes at least one series of further lamination means (20) and a third heat exchanger (24),
   - the compressor (14) includes an intermediate connection arranged between the stages of the multi-stage stage compressor or between the serial compressors, respectively,
   - the inlet of the further lamination means (20) is connected to the outlet of the first heat exchanger (16), and
   - the outlet of the third heat exchanger (24) is connected to the intermediate connection of the compressor (14).

2. The heat pump system according to claim 1, **characterized in, that** the refrigerant in the refrigerant circuit (10) is carbon dioxide.

3. The heat pump system according to claim 1 or 2, **characterized in, that** the refrigerant circuit (10) and the air stream circuit

(12) are thermally coupled by the third heat exchanger (24) .

4. The heat pump system according to any one of the preceding claims,
characterized in, that
the third heat exchanger (24) is provided for cooling down the air stream and heating up the refrigerant.

5. The heat pump system according to any one of the preceding claims,
characterized in, that
the second heat exchanger (22) and the third heat exchanger (24) form a common heat exchanger with at least two different circuits for the refrigerant, wherein at least one circuit is provided for the second heat exchanger (22) and at least one further circuit is provided for the third heat exchanger (24).

6. The heat pump system according to any one of the preceding claims,
characterized in, that
the heat pump system is provided for working in a trans-critical cycle and a totally-supercritical cycle at the same time.

7. The heat pump system according to any one of the preceding claims,
characterized in, that
the heat pump system is provided for working with the second heat exchanger (22) and the third heat exchanger (24) at two different pressure levels, preferably the pressure level of the refrigerant at the second heat exchanger (22) is lower than the critical pressure, and the pressure level of the refrigerant at the third heat exchanger (24)is higher than the critical pressure so that the heat pump system works in a trans-critical cycle and a totally-supercritical cycle at the same time.

8. The heat pump system according to any one of the preceding claims,
characterized in, that
the first heat exchanger (16) forms a gas cooler.

9. The heat pump system according to any one of the preceding claims,
characterized in, that
the second heat exchanger (22) forms an evaporator.

10. The heat pump system according to any one of the preceding claims,
characterized in, that
the third heat exchanger (16) forms a gas heater.

11. The heat pump system according to any one of the preceding claims,
characterized in, that
at least one of the lamination means (18, 20) is formed as a capillary tube.

12. The heat pump system according to any one of the preceding claims,
characterized in, that
at least one of the lamination means (18, 20) is formed as an electronic expansion valve.

13. The heat pump system according to any one of the preceding claims,
characterized in, that
the refrigerant circuit (10) includes valve means (30, 32) arranged between the outlet of the third heat exchanger (24) and the inlet of the compressor (14) and arranged between the outlet of the third heat exchanger (24) and the intermediate connection of the compressor (14).

14. The heat pump system according to any one of the preceding claims,
characterized in, that
the heat pump system is provided for splitting the flow rate of the refrigerant at the outlet of the first heat exchanger (16).

15. A laundry dryer with at least one heat pump system,
characterized in, that
the laundry dryer comprises at least one heat pump system according to any one of the claims 1 to 14.

FIG 1

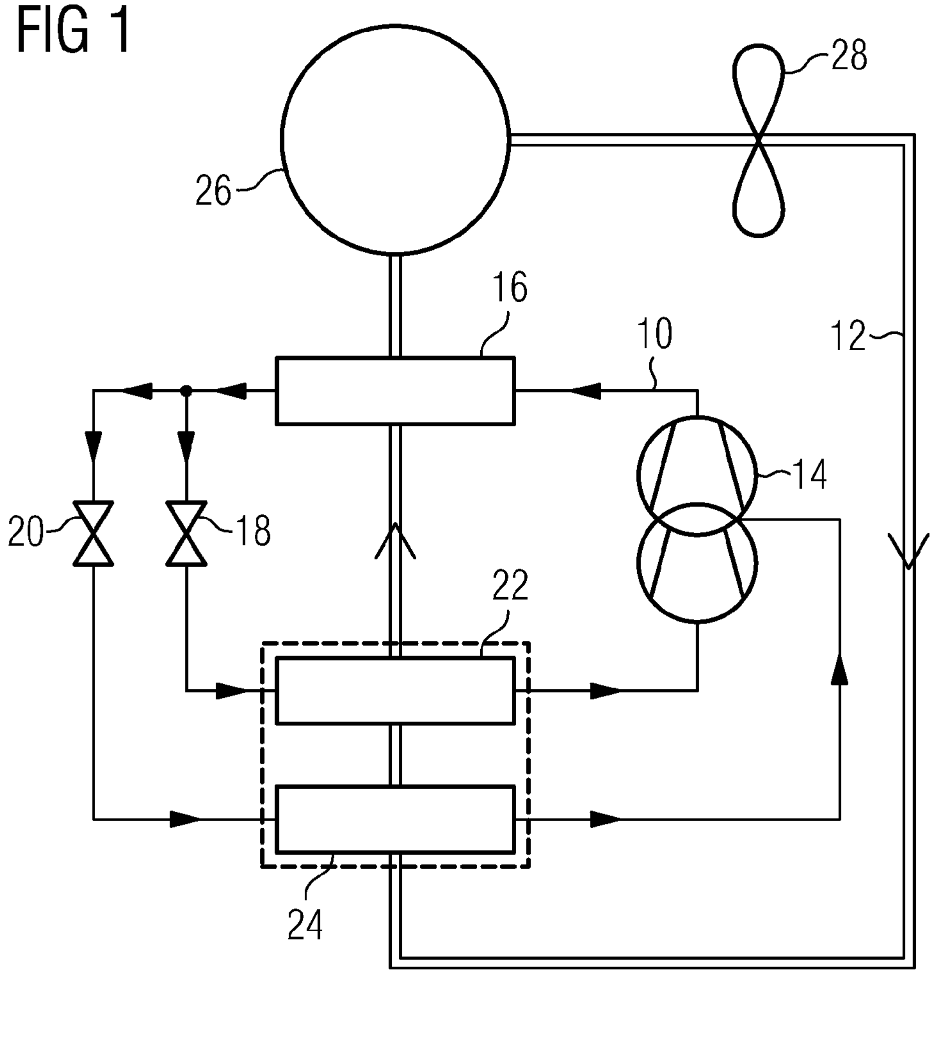


FIG 2

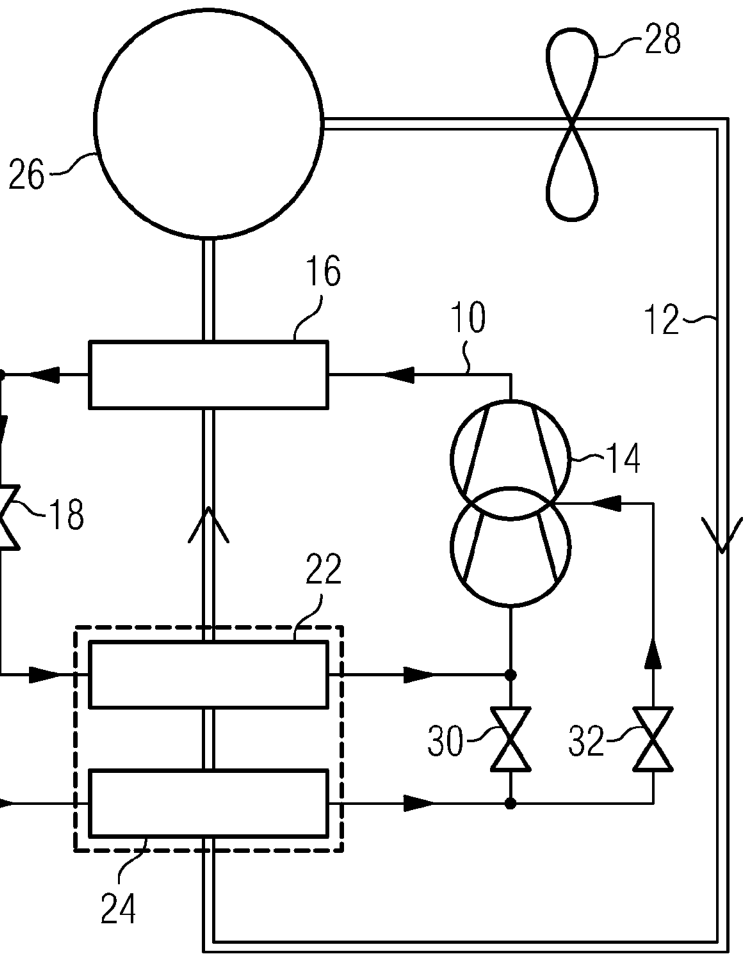


FIG 3

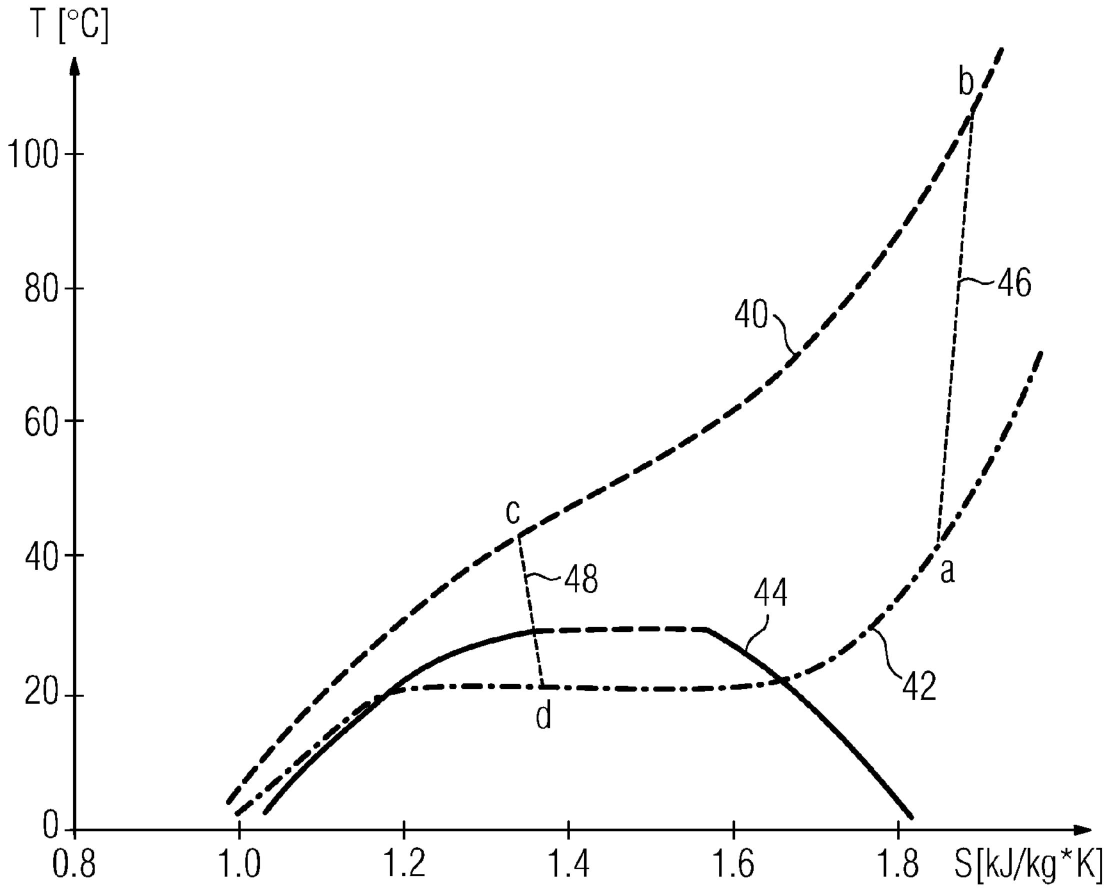


FIG 4

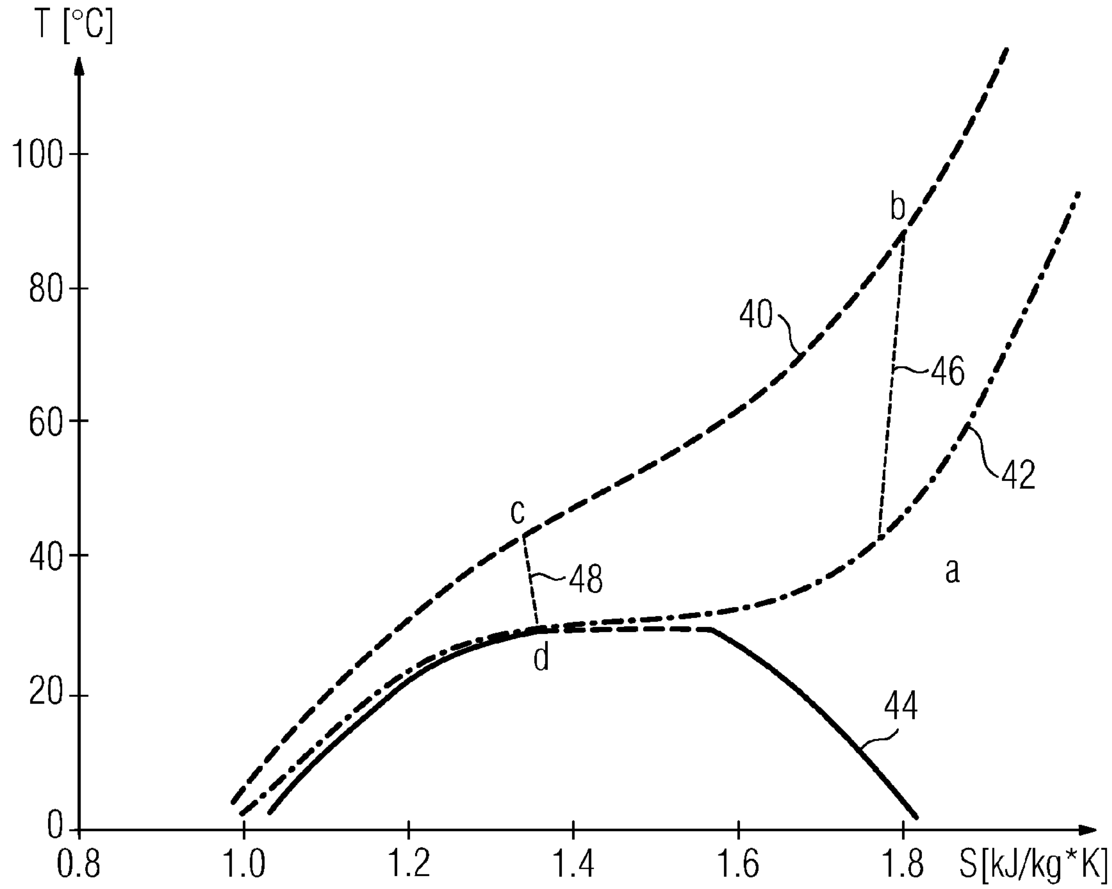
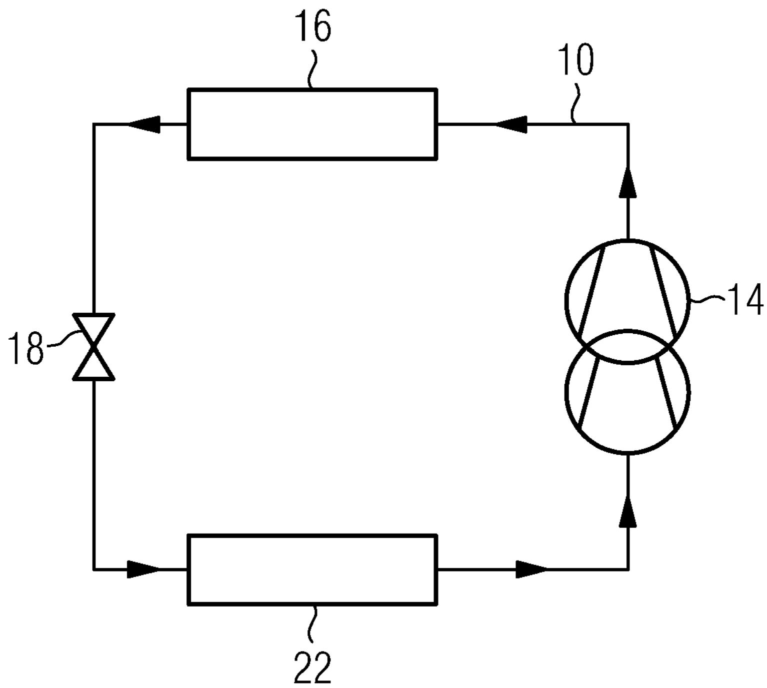


FIG 5



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EUROPEAN SEARCH REPORT

Application Number
EP 11 17 5681

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	10 January 2012	Spitzer, Bettina

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