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

(11) EP 2 594 688 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: **11189889.6**

(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

(71) Applicant: **Electrolux Home Products Corporation N.V.**
1130 Brussel (BE)

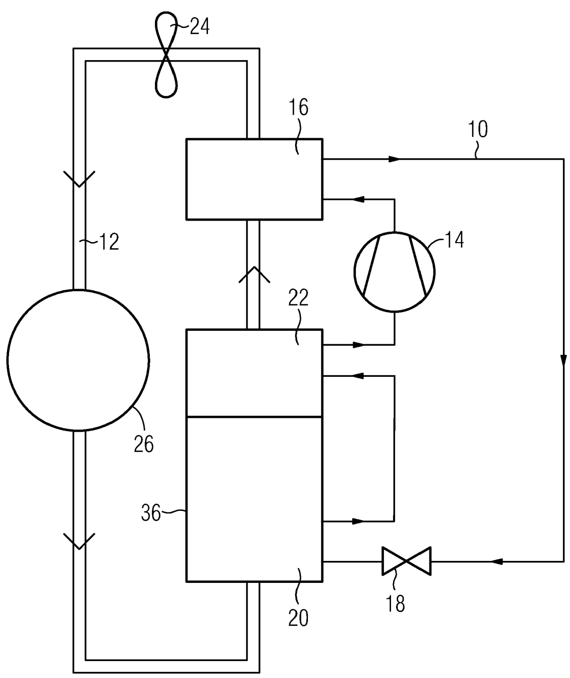
(72) Inventor: **Cavarretta, Francesco**
33080 Porcia (PN) (IT)

(74) Representative: **Nardoni, Andrea et al**
Electrolux Italia S.p.A.
Corso Lino Zanussi, 30
33080 Porcia (PN) (IT)

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

(57) The present invention relates to a laundry dryer with a heat pump system comprising 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), an expansion device (18), a second heat exchanger (20) and an additional heat exchanger (22) connected in series and forming a loop. The air stream circuit (12) includes at least one air stream fan (24), a laundry drum (26), the second heat exchanger (20), the additional heat exchanger (22) and the first heat exchanger (16) connected in series and forming a loop. The refrigerant circuit (10) and the air stream circuit (12) are thermally coupled by the first heat exchanger (16), the second heat exchanger (20) and the additional 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 (20) is provided for cooling down the air stream and heating up the refrigerant. The additional heat exchanger (22) is provided for pre-heating the air stream and cooling down the refrigerant. The additional heat exchanger (22) on the one hand and the first heat exchanger (16) or the second heat exchanger (20) on the other hand are formed as one heat exchanger assembly (36) including one air stream channel (34) and one or two refrigerant channels (42; 44, 46).

FIG 5



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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] At present the heat pump technology is in a laundry dryer the most efficient way to dry clothes by reduced energy consumption. In a conventional heat pump laundry dryer an air stream flows in a closed air stream circuit. The air stream is moved by a fan and passes through a laundry drum removing water from wet clothes. Then, the air stream is cooled down and dehumidified in an evaporator or gas heater and heated up in a condenser or gas cooler. At last, the air stream is re-inserted into the laundry drum again.

[0003] The refrigerant is compressed by a compressor. Then, the refrigerant is condensed in the condenser or cooled down in the gas cooler. Next, the refrigerant is laminated in an expansion device. At last, the refrigerant is vaporized in the evaporator or heated up in the gas heater. If the refrigerant operates at the critical pressure, then it is cooled down in the gas cooler and heated up in the gas heater, respectively. The temperatures of the air stream and the refrigerant are strictly connected to each other.

[0004] During a steady state phase of the conventional heat pump laundry dryer, the temperature of the air stream at an outlet of the evaporator is relative low, e.g. about 25°C. The temperature of the air stream at an inlet of the laundry drum should be relative high, e.g. about 65°C, so that the condenser has to heat up the refrigerant with a relative high temperature difference. The relationships between the temperatures of the air stream require heat exchangers with disadvantageous dimensions.

[0005] WO 2011/080045 A1 discloses a domestic appliance with a drying chamber and a heat pump circuit. The heat pump circuit includes a liquefier, an evaporator and two additional heat exchangers. The process air is heated by the liquefier and cooled by the evaporator. The one additional heat exchanger cools the refrigerant and heats the process air. The other additional heat exchanger undercools the condensate of the refrigerant and reduces the mass flow of the circulating refrigerant. However, the heat pump circuit comprises a high number of components and a complicated control system.

[0006] It is an object of the present invention to provide a laundry dryer with a heat pump system, which allows a reduced drying time and an improved performance of the heat pump system by low complexity.

[0007] The object of the present invention is achieved by the laundry dryer according to claim 1.

[0008] According to the present invention the additional heat exchanger on the one hand and the first heat exchanger or the second heat exchanger on the other hand are formed as one heat exchanger assembly including one air stream channel and at least one refrigerant channel.

[0009] The present invention provides the arrangement of the first or second heat exchanger and the additional heat exchanger within one physical heat exchanger assembly. Said heat exchanger assembly includes one channel or at least two separate channels for the refrigerant, which penetrates or penetrate a channel for the air stream. The channels for the refrigerant are connected to different parts of the refrigerant circuit, wherein the refrigerant has different thermal states. The heat exchanger assembly containing the first or second heat exchanger and the additional heat exchanger reduces the complexity of the heat pump system.

[0010] Preferably, the heat exchanger assembly comprises common fins and air stream channel between said fins and at least one refrigerant channel in thermal connection with the fins so as to define the first heat exchanger or the second heat exchanger and the additional heat exchanger side, the first heat exchanger or the second heat exchanger and the additional heat exchanger side share the common fins.

[0011] Preferably, thee refrigerant channel passes through the common fins.

[0012] Preferably, an inlet of the refrigerant channel is arranged at the second heat exchanger and an outlet of the refrigerant channel is arranged at the additional heat exchanger.

[0013] Preferably, the inlet of the refrigerant channel is connected to the outlet of the expansion device and an outlet of the refrigerant channel is connected to the inlet outlet of the compressor.

[0014] Preferably, at least a portion of the refrigerant channel, extending between the inlet and the outlet, crosses the heat exchanger assembly so as to pass from the second heat exchanger to the additional heat exchanger.

[0015] Preferably, the refrigerant circuit includes an internal heat exchanger, wherein a high pressure side of said internal heat exchanger is interconnected between the first heat exchanger and the expansion device and a low pressure side of said internal heat exchanger is interconnected between the second heat exchanger and the additional heat exchanger, so that the additional heat exchanger receives the refrigerant via said low pressure side of the internal heat exchanger.

[0016] Preferably, a first refrigerant channel corresponds with the second heat exchanger and a second refrigerant channel corresponds with the additional heat exchanger, and wherein an inlet of the first refrigerant channel is connected to the outlet of the expansion device and an outlet of the first refrigerant channel is connected to an inlet of the low pressure side of the internal heat exchanger and an inlet of the second refrigerant channel is connected to an outlet of the low pressure side (of the internal heat exchanger and an outlet of the second refrigerant channel is connected the inlet of the compressor.

[0017] Preferably, a first refrigerant channel corresponds with the additional heat exchanger and is part of the low pressure portion of the refrigerant circuit, whereas the second refrigerant channel corresponds with the first heat exchanger and is part of the high pressure portion of the refrigerant circuit.

[0018] Preferably, the inlet of the first refrigerant channel is connected to the refrigerant outlet of the evaporator and the outlet of the first refrigerant channel is connected to the inlet of the compressor and the inlet of the second refrigerant channel is connected to the outlet of the compressor and the outlet of the second refrigerant channel is connected the inlet of the expansion device.

[0019] Preferably, the inlet of the first refrigerant channel is connected to the outlet of the low pressure side of the internal heat exchanger and the outlet of the first refrigerant channel is connected to the inlet of the compressor and the inlet of the second refrigerant channel is connected to the outlet of the compressor and the outlet of the second refrigerant channel is connected the inlet of the high pressure side of the internal heat exchanger.

[0020] Preferably, the refrigerant circuit comprises a by-pass line so that the refrigerant can completely or partially by-pass said additional heat exchanger.

[0021] Preferably, the by-pass line includes at least one on-off valve for opening and closing said by-pass line or the by-pass line includes at least one control valve for a continuous opening of said by-pass line or the by-pass line includes at least one three-way valve for an alternating opening and closing of said by-pass line and a refrigerant side of the additional heat exchanger.

[0022] Preferably, the by-pass line is controlled or controllable by the temperature of the refrigerant in at least one position of the refrigerant circuit or the by-pass line is controlled or controllable by the temperature of the air stream in at least one position of the air stream circuit.

[0023] Preferably, the by-pass line is controlled or controllable by one of the following,

- the temperature of the refrigerant at the refrigerant outlet of the second heat exchanger,
- the temperature difference of the refrigerant at the refrigerant inlet and outlet of the second heat exchanger,
- the temperature difference of the refrigerant at the refrigerant outlet of the second heat exchanger and the temperature of the air stream at the air stream outlet of the second heat exchanger.

[0024] The first heat exchanger acts as a gas cooler, if the refrigerant remains in a gaseous state. In contrast, the first heat exchanger acts as a condenser, if the refrigerant at least partially transfers from the gaseous state to a liquid state.

[0025] The second heat exchanger acts as a gas heater, if the refrigerant remains in the gaseous state. Else, the second heat exchanger acts as an evaporator, if the refrigerant at least partially transfers from the liquid state to the gaseous state.

[0026] The novel and inventive features believed to be the characteristic of the present invention are set forth in the appended claims.

[0027] 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 schematic diagram of the heat pump system for the laundry dryer according to a third embodiment of the present invention,

FIG 4 shows a schematic diagram of the heat pump system for the laundry dryer according to a fourth embodiment of the present invention,

FIG 5 shows a schematic diagram of the heat pump system for the laundry dryer according to a fifth embodiment of the present invention,

FIG 6 shows a schematic diagram of a heat exchanger assembly for the heat pump system according to the fifth embodiment of the present invention,

FIG 7 shows a schematic diagram of the heat pump system for the laundry dryer according to a sixth embodiment of the present invention,

FIG 8 shows a schematic diagram of the heat exchanger assembly for the heat pump system according to the sixth embodiment of the present invention,

FIG 9 shows a schematic diagram of the heat pump system for the laundry dryer according to a seventh embodiment of the present invention,

FIG 10 shows a schematic diagram of the heat exchanger assembly for the heat pump system according to the seventh embodiment of the present invention,

FIG 11 shows a schematic diagram of the heat pump system for the laundry dryer according to an eighth embodiment of the present invention, and

FIG 12 shows a schematic diagram of the heat exchanger assembly for the heat pump system according to the eighth embodiment of the present invention.

[0028] 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 stream circuit 12.

[0029] The refrigerant circuit 10 includes a compressor 14, a condenser 16, an expansion device 18, an evaporator 20 and an additional heat exchanger 22. The compressor 14, the condenser 16, the expansion device 18, the evaporator 20 and the additional heat exchanger 22 are switched in series and form a closed loop. The air stream circuit 12 includes the evaporator 20, the additional heat exchanger 22, the condenser 16, an air stream fan 24 and a laundry treatment chamber 26, preferably a rotatable drum. The air stream circuit 12 forms also a loop.

[0030] The refrigerant is compressed by the compressor 14 and condensed by the condenser 16. The refrigerant is laminated in the expansion device 18 and vaporized in the evaporator 20. Then, the refrigerant is cooled down by the additional heat exchanger 22 and sucked by the compressor 14. The drying air stream is driven by the air stream fan 24 and passes through the laundry drum 26 removing water from wet laundry. Then, the drying air stream is cooled down and dehumidified by the evaporator 20 and pre-heated by the additional heat exchanger 22. At last, the drying air stream is heated up in the condenser 16 and re-inserted into the laundry drum 26 again.

[0031] The additional heat exchanger 22 is arranged inside the air stream circuit between the evaporator 20 and the condenser 16. The refrigerant and the drying air stream are thermally coupled by the additional heat exchanger 22, by the evaporator 20 and condenser 16. In the refrigerant circuit the additional heat exchanger 22 is arranged between a refrigerant outlet of the evaporator 20 and an inlet of the compressor 14. The refrigerant from the evaporator 20 is cooled down by the additional heat exchanger 22 before being sucked by the compressor 14, while the drying air stream is pre-heated by said additional heat exchanger 22.

[0032] In the evaporator 20 the drying air stream is cooled down in order to be dehumidified, while the refrigerant is vaporized and heated, preferably superheated, therein. During a steady state phase, the temperature of the air stream at an air stream outlet of the laundry drum 26 and at an air stream inlet of the evaporator 20, respectively, is about 40°C, for instance. The temperature of the air stream at an air stream outlet of the evaporator 20 is about 25°C, for example. In contrast, the refrigerant enters the evaporator at a temperature of about 20°C and is superheated by the evaporator up to about 35°C, for instance. Then, the air stream is pre-heated in the additional heat exchanger 22 by said superheated refrigerant. The temperature of the air stream at an air stream outlet of the condenser 16 and an air stream inlet of the laundry drum 26, respectively, is about 65°C, for instance. Thus, the additional heat exchanger 22 supports the condenser 16 in heating up the air stream.

[0033] The additional heat exchanger 22 has the advantage that a higher heating power is transferred to the air stream, so that a warming up phase of the heat pump system is shorten. Further, the air stream can reach a higher temperature during a steady state phase of the heat pump system. Moreover, the temperature of the refrigerant at the inlet of the compressor 14 is lower, so that the power required by the compressor 14 decreases, if the other parameters are assumed being constant.

[0034] FIG 2 illustrates 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 of the second embodiment comprises the same components as the heat pump system of the first embodiment. Additionally, the refrigerant circuit 10 of the second embodiment comprises a by-pass line 28.

[0035] The by-pass line 28 is arranged, preferably, in parallel to the additional heat exchanger 22. The by-pass line 28 allows that the refrigerant can completely or partially by-pass the additional heat exchanger 22. When the refrigerant flows through the by-pass line 28 and by-passes the additional heat exchanger 22, then a too low temperature of the refrigerant at the outlet of the compressor is avoided. Said too low temperature would provide, that the drying air stream cannot be heated up to desired levels.

[0036] The by-pass line 28 is switchable by one or more valves. The valves are not shown in FIG 2. For example, the pass line 28 comprises a pair of on-off valves arranged at the end portions of said by-pass line 28. Alternatively, the by-pass line 28 is switchable by only one on-off valve. According to another example, the pass line 28 comprises a pair of control valves arranged at the end portions of said by-pass line 28, wherein the control valves can be opened completely or partially. Alternatively, the by-pass line 28 is switchable by only one control valve. Further, the pass line 28 may comprise a three-away valve.

[0037] FIG 3 illustrates a schematic diagram of the heat pump system for the laundry dryer according to a third embodiment of the present invention. The heat pump system of the third embodiment comprises the same components as the heat pump system of the first embodiment. Additionally, the refrigerant circuit 10 of the third embodiment comprises an internal heat exchanger 30.

[0038] Unlike the condenser 16, the evaporator 20 and the additional heat exchanger 22, which couple thermally the refrigerant circuit 10 and the air stream circuit 12, the internal heat exchanger 30 acts only within the refrigerant circuit 10. The refrigerant circuit 10 couples thermally a high pressure portion and a low pressure portion of the refrigerant circuit 10. The high pressure portion extends from the outlet of the compressor 14 via the condenser 16 to the inlet of the expansion device 18. The low pressure portion extends from the outlet of the expansion device 18 via the evaporator 20 and the additional heat exchanger 22 to the inlet of the compressor 14.

[0039] The internal heat exchanger 30 comprises a high pressure side 32 and a low pressure side 34. The high pressure side 32 corresponds with the high pressure portion of the refrigerant circuit 10. The low pressure side 34 corresponds with the low pressure portion of the refrigerant circuit 10.

[0040] The refrigerant from the outlet of the evaporator 20 is heated up in the low pressure side 34 of the internal heat exchanger 30. Then, the refrigerant is cooled down in the additional heat exchanger 22. The internal heat exchanger 30 allows that the air stream in the additional heat exchanger 22 is heated up more as in the first and second embodiment without reaching the too low temperature level of the refrigerant at the inlet of the compressor 14.

[0041] FIG 4 illustrates a schematic diagram of the heat pump system for the laundry dryer according to a fourth embodiment of the present invention. The heat pump system of the fourth embodiment comprises the same components as the heat pump system of the third embodiment. Additionally, the refrigerant circuit 10 of the third embodiment comprises the by-pass line 28. In other words, the fourth embodiment is a combination of the second and third embodiment.

[0042] The by-pass line 28 is, preferably, arranged in parallel to the additional heat exchanger 22. The by-pass line 28 allows that the refrigerant can completely or partially pass by the additional heat exchanger 22. When the refrigerant flows through the by-pass line 28 and by-passes the additional heat exchanger 22, then the too low temperature of the refrigerant at the outlet of the compressor is avoided.

[0043] The by-pass line 28 is also switchable by one or more valves. The valves are not shown in FIG 4. For instance, the pass line 28 comprises a pair of on-off valves arranged at the end portions of said by-pass line 28. Alternatively, the by-pass line 28 is switchable by only one on-off valve. According to the other example, the pass line 28 comprises the pair of control valves arranged at the end portions of said by-pass line 28, wherein the control valves can be opened completely or partially. Alternatively, the by-pass line 28 is switchable by only one control valve. At last, the pass line 28 may comprise a three-away valve.

[0044] According to a further embodiment of the present invention the low pressure side 34 of the internal heat exchanger 30 is arranged downstream of the additional heat exchanger 22. After the refrigerant has been cooled down by the air stream in the additional heat exchanger 22, is heated up in the low pressure side 34 of the internal heat exchanger 30, so that the too low temperature levels at the inlet and outlet of the compressor 14 are avoided. This embodiment, preferably, does not require the by-pass line 28, since the position of the low pressure side 34 of the internal heat exchanger 30 ensures the appropriate temperature levels at the inlet and outlet of the compressor 14.

[0045] The valve or valves of the by-pass line 28 may be controlled in dependence of the temperature levels of the air stream and/or the refrigerant. At the beginning of a drying cycle the evaporator 20 may be flooded or the refrigerant may be superheated, i.e. the temperature of the refrigerant at the refrigerant outlet of the evaporator 20 could be lower than the temperature of the air stream. Thus, the refrigerant cannot heat up the air stream in the additional heat exchanger 22 and passes by said additional heat exchanger 22.

[0046] The by-pass line 28 is opened and the additional heat exchanger 22 does not work, if

- the temperature of the refrigerant at the refrigerant outlet of the evaporator 20 is lower than a predetermined value,
- the temperature difference of the refrigerant at the refrigerant inlet and outlet of the evaporator 20 is lower than a predetermined value, and/or
- the temperature of the refrigerant at the refrigerant outlet of the evaporator 20 is lower than the temperature of the air stream at the air stream outlet of the evaporator 20.

[0047] After the transitory phase or warm-up phase of the drying cycle, the additional heat exchanger 22 may be by-passed, if the air stream at the inlet of the laundry drum 26 cannot be kept at a higher level. This situation could occur at the beginning of the steady state phase. If the temperature of the refrigerant at the refrigerant inlet or outlet of the evaporator 20 or the refrigerant outlet of the condenser 16 is higher than a predetermined level corresponding to the beginning of the drying cycle and at the same time the temperature of the air stream at the inlet of the laundry drum 26 or the temperature of the refrigerant at the outlet of the compressor 14 is lower than another predetermined level, then the additional heat exchanger 22 may be passed by completely or partially. When the air stream reaches the desired value, then the additional heat exchanger 22 is activated again. Thus, the additional heat exchanger 22 works in an on-off mode.

[0048] FIG 5 shows a schematic diagram of the heat pump system for the laundry dryer according to a fifth embodiment of the present invention. The fifth embodiment differs from the first embodiment in that the evaporator 20 and the additional heat exchanger 22 are formed by a heat exchanger assembly 36.

[0049] Said heat exchanger assembly 36 comprises common fins 38 and one refrigerant channel 44 in thermal connection with the fins 38 so as to define an evaporator side 20 for cooling down the air stream and heating up the refrigerant and an additional heat exchanger side 22 for pre-heating the air stream and cooling down the refrigerant.

[0050] FIG 6 shows a schematic diagram of a heat exchanger assembly 36 for the heat pump system according to the fifth embodiment of the present invention. The heat exchanger assembly 36 comprises a plurality of fins 38. The heat exchanger assembly 36 comprises a common air stream channel 40 for the evaporator 20 and the additional heat exchanger 22, wherein the air stream channel 40 passes at first the evaporator 20 and then the additional heat exchanger 22. The refrigerant channel 42 penetrates the air stream channel 40 and is in thermal connection with the fins, preferably the refrigerant channel 42 passes through the common fins 38. The refrigerant channel 42 is, preferably, a serpentine. An inlet 48 of the refrigerant channel 42 is connected to the outlet of the expansion device 18. An outlet 50 of the refrigerant channel 42 is connected to the inlet outlet of the compressor 14.

[0051] The inlet 48 of the refrigerant channel 42 is arranged at the evaporator side of the heat exchanger assembly and the outlet 50 of the refrigerant channel 42 is arranged at the additional heat exchanger side the heat exchanger assembly.

[0052] At least a portion of the refrigerant channel 42 between the inlet 48 and outlet 50 crosses the heat exchanger assembly so as to pass from the evaporator side 20 to the additional exchanger side 22.

[0053] In the evaporator side 20 of the heat exchanger assembly 36 the air stream is cooled down and dehumidified. In the additional heat exchanger side 22 of the heat exchanger assembly 36 the air stream is pre-heated. In the evaporator side 20 of the heat exchanger assembly 36 the refrigerant is vaporized and superheated. In the additional heat exchanger side 22 of the heat exchanger assembly 36 the refrigerant is cooled down.

[0054] FIG 7 shows a schematic diagram of the heat pump system for the laundry dryer according to a sixth embodiment of the present invention. The sixth embodiment differs from the third embodiment in that the evaporator 20 and the additional heat exchanger 22 are formed by the heat exchanger assembly 36. Said heat exchanger assembly 36 comprises common fins 38 and two refrigerant channels 44,46 in thermal connection with the fins 38 so as to define an evaporator side 20 for cooling down the air stream and heating up the refrigerant and an additional heat exchanger side 22 for pre-heating the air stream and cooling down the refrigerant.

[0055] FIG 8 shows a schematic diagram of the heat exchanger assembly 36 for the heat pump system according to the sixth embodiment of the present invention. The heat exchanger assembly 36 comprises the plurality of fins 38 and the air stream channel 40 between said fins 38. The air stream channel 40 passes at first the evaporator 20 side and then the additional heat exchanger 22 side of the heat exchanger assembly 36. A first refrigerant channel 44 and a second refrigerant channel 46 penetrate the air stream channel 40. The first refrigerant channel 44 and the second refrigerant channel 46 are, preferably, serpentine.

[0056] The first refrigerant channel 44 in FIG 8 corresponds with the evaporator 20 side of the heat exchanger assembly 36. The second refrigerant channel 46 in FIG 8 corresponds with the additional heat exchanger 22 side of the of the heat exchanger assembly 36. An inlet 52 of the first refrigerant channel 44 is connected to the outlet of the expansion device 18. An outlet 54 of the first refrigerant channel 44 is connected to an inlet of the low pressure side 34 of the internal heat exchanger 30. An inlet 56 of the second refrigerant channel 46 is connected to an outlet of the low pressure side 34 of the internal heat exchanger 30. An outlet 58 of the second refrigerant channel 46 is connected the inlet of the compressor 14.

[0057] Between the first refrigerant channel 44 and the second refrigerant channel 46 the refrigerant passes the low pressure side 34 of the internal heat exchanger 30.

[0058] FIG 9 shows a schematic diagram of the heat pump system for the laundry dryer according to a seventh embodiment of the present invention. The seventh embodiment differs from the first embodiment in that the additional heat exchanger 22 and the condenser 16 are formed by the heat exchanger assembly 36. Said heat exchanger assembly 36 comprises common fins 38 and two refrigerant channels 44,46 in thermal connection with the fins 38 so as to define an additional heat exchanger side 22 for pre-heating the air stream and cooling down the refrigerant and a condenser side 16 for heating up the air stream and cooling down the refrigerant.

[0059] FIG 10 shows a schematic diagram of the heat exchanger assembly 36 for the heat pump system according to the seventh embodiment of the present invention. The heat exchanger assembly 36 comprises the plurality of fins 38. The heat exchanger assembly 36 comprises the common air stream channel 40 for the additional heat exchanger side 22 and the condenser side 16, wherein the air stream channel 40 passes at first the additional heat exchanger 22 and the condenser 16. The first refrigerant channel 44, preferably a serpentine, and the second refrigerant channel 46, preferably a serpentine, penetrate the air stream channel 40.

[0060] The first refrigerant channel 44 in FIG 10 corresponds with the additional heat exchanger side 22. The second refrigerant channel 46 in FIG 10 corresponds with the condenser side 16.

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 condenser 16 to the inlet of the expansion device 18. The low pressure portion extends from the outlet of the expansion device 18 via the evaporator 20 to the inlet of the compressor 14.

The first refrigerant channel 44 is part of the low pressure portion of the refrigerant circuit, whereas the second refrigerant channel 46 is part of the high pressure portion of the refrigerant circuit.

[0061] The inlet 52 of the first refrigerant channel 44 is connected to the refrigerant outlet of the evaporator 20. The outlet 54 of the first refrigerant channel 44 is connected to the inlet of the compressor 14. The inlet 56 of the second refrigerant channel 46 is connected to the outlet of the compressor 14. The outlet 58 of the second refrigerant channel 46 is connected the inlet of the expansion device 18.

[0062] In the additional heat exchanger side 22 of the heat exchanger assembly 36 the drying air stream is pre-heated, while the refrigerant is cooled down. In the condenser side 16 the refrigerant is cooled down, while the air stream is warmed up.

Additionally, the thermal conductivity of the fins 38 allows that the refrigerant flowing into the additional heat exchanger side 22 cools down the refrigerant flowing into the condenser side 16. Conversely, the refrigerant flowing into the condenser 16 heats up the refrigerant flowing into the additional heat exchanger 22, thus improving the efficiency of the heat pump system.

[0063] FIG 11 shows a schematic diagram of the heat pump system for the laundry dryer according to an eighth embodiment of the present invention. The eighth embodiment differs from the third embodiment in that the additional heat exchanger 22 and the condenser 16 are formed by the heat exchanger assembly 36.

Said heat exchanger assembly 36 comprises common fins 38 and two refrigerant channels 44,46 in thermal connection with the fins 38 so as to define the additional heat exchanger side 22 for pre-heating the air stream and cooling down the refrigerant and the condenser side 16 for heating up the air stream and cooling down the refrigerant.

[0064] FIG 12 shows a schematic diagram of the heat exchanger assembly for the heat pump system according to the eighth embodiment of the present invention. The heat exchanger assembly 36 comprises the common air stream channel 40 for the additional heat exchanger side 22 and the condenser side 16, wherein the air stream channel 40 passes at first the additional heat exchanger 22 and the condenser 16. The first refrigerant channel 44, preferably a serpentine, and the second refrigerant channel 46, preferably a serpentine, penetrate the air stream channel 40.

[0065] The first refrigerant channel 44 in FIG 12 corresponds with the additional heat exchanger side 22. The second refrigerant channel 46 in FIG 12 corresponds with the condenser side 16. The first refrigerant channel 44 is part of the low pressure portion of the refrigerant circuit, whereas the second refrigerant channel 46 is part of the high pressure portion of the refrigerant circuit.

[0066] The inlet 52 of the first refrigerant channel 44 is connected to the outlet of the low pressure side 34 of the internal heat exchanger 30. The outlet 54 of the first refrigerant channel 44 is connected to the inlet of the compressor 14. The inlet 56 of the second refrigerant channel 46 is connected to the outlet of the compressor 14. The outlet 58 of the second refrigerant channel 46 is connected the inlet of the high pressure side 32 of the internal heat exchanger 30.

[0067] In the additional heat exchanger 22 of the heat exchanger assembly 36 the air stream is pre-heated, while the refrigerant is cooled down. In the condenser 16 the refrigerant is cooled down, while the air stream is warmed up.

[0068] The heat exchanger assembly 36 is realized by one single component. Said single component is an air-to-liquid heat exchanger including one channel for the air stream and one, two or more channels for the refrigerant. The net result is favourable to an efficient heating up of the air stream.

[0069] If the refrigerant, e.g. carbon dioxide, operates at least at the critical pressure in the low pressure portion of the refrigerant circuit 10, then the refrigerant remains always in the gaseous state. In this case, no evaporation occurs and the evaporator 20 acts as a gas heater.

[0070] Preferably, the air stream circuit 12 is a closed loop, in which the air stream flows continuously through the laundry drum 26. However, a part of the air stream may be exhausted from the air stream circuit 12. The exhausted air may be replaced by fresh air, e.g. ambient air. Preferably, the exhausted air and fresh air form a smaller part of the air stream. Further, the air stream circuit 12 may be temporarily opened, wherein the time of the open air stream circuit 12 is a small part of the total processing time. In any case, at least a part of the air stream passes always the condenser 16 after having passed the evaporator 20.

[0071] The heat pump system with the additional heat exchanger 22 and optionally the internal heat exchanger 30 allows a reduction of the drying time and improves the performance of the heat pump dryer.

[0072] In further embodiments an auxiliary condenser can be provided in the refrigerant circuit, particularly between the main condenser 16 and the expansion device 18.

[0073] Although a 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

[0074]

10 refrigerant circuit

12 air stream circuit

14 compressor

16 first heat exchanger, condenser, gas cooler

18 expansion device

20 second heat exchanger, evaporator, gas heater

22 additional heat exchanger

24 air stream fan

26 laundry drum

28 by-pass line

30 internal heat exchanger

32 high pressure side

34 low pressure side

36 heat exchanger assembly

38 fin

40 air stream channel

42 refrigerant channel

44 first refrigerant channel

46 second refrigerant channel

48 inlet of the refrigerant channel

50 outlet of the refrigerant channel

52 inlet of the first refrigerant channel

54 outlet of the first refrigerant channel

56 inlet of the second refrigerant channel

58 outlet of the second refrigerant channel

Claims

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

- the refrigerant circuit (10) includes a compressor (14), a first heat exchanger (16), an expansion device (18), a second heat exchanger (20) and an additional heat exchanger (22) connected in series and forming a loop,
- the air stream circuit (12) includes at least one air stream fan (24), a laundry treatment chamber (26), the second heat exchanger (20), the additional heat exchanger (22) and the first heat exchanger (16) connected in series and forming a loop,
- the refrigerant circuit (10) and the air stream circuit (12) are thermally coupled by the first heat exchanger (16), the second heat exchanger (20) and the additional 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 (24) is provided for cooling down the air stream and heating up the refrigerant, and
- the additional heat exchanger (22) is arranged between first heat exchanger (16) and the second heat exchanger (24) for pre-heating the air stream and cooling down the refrigerant,

characterized in, that
the additional heat exchanger (22) on the one hand and the first heat exchanger (16) or the second heat exchanger (20) on the other hand are formed as one heat exchanger assembly (36) including one air stream channel (40) and at least one refrigerant channel (42, 44, 46).

2. The laundry dryer according to claim 1, wherein the heat exchanger assembly (36) comprises common fins (38) and air stream channel (40) between said fins (38) and at least one refrigerant channel (42,44,46) in thermal connection with the fins (38) so as to define the first heat exchanger (16) or the second heat exchanger (20) and the additional heat exchanger side (22), the first heat exchanger (16) or the second heat exchanger (20) and the additional heat exchanger side (22) share the common fins (38).

3. The laundry dryer according to claim 2, wherein the refrigerant channel (42,44,46) passes through the common fins (38).

4. The laundry dryer according to any one of the preceding claims, wherein an inlet (48) of the refrigerant channel (42) is arranged at the second heat exchanger (20) and an outlet (50) of the refrigerant channel (42) is arranged at the additional heat exchanger (22).

5. The laundry dryer according to claim 4, wherein the inlet (48) of the refrigerant channel (42) is connected to the outlet of the expansion device (18) and an outlet (50) of the refrigerant channel (42) is connected to the inlet outlet of the compressor (14).

6. The laundry dryer according to claim 4 or 5, wherein at least a portion of the refrigerant channel (42), extending between the inlet (48) and the outlet (50), crosses the heat exchanger assembly (36) so as to pass from the second heat exchanger (20) to the additional heat exchanger (22).

7. The laundry dryer according to any one of the preceding claims, wherein the refrigerant circuit (10) includes an internal heat exchanger (30), wherein a high pressure side (32) of said internal heat exchanger (30) is interconnected between the first heat exchanger (16) and the expansion device (18) and a low pressure side (34) of said internal heat exchanger (30) is interconnected between the second heat exchanger (20) and the additional heat exchanger (22), so that the additional heat exchanger (22) receives the refrigerant via said low pressure side (34) of the internal heat exchanger (30).

8. The laundry dryer according to any claims 7, wherein a first refrigerant channel (44) corresponds with the second heat exchanger (20) and a second refrigerant channel (46) corresponds with the additional heat exchanger (22), and wherein an inlet (52) of the first refrigerant channel (44) is connected to the outlet of the expansion device (18) and an outlet (54) of the first refrigerant channel (44) is connected to an inlet of the low pressure side (34) of the internal heat exchanger (30) and an inlet (56) of the second refrigerant channel (46) is connected to an outlet of the low pressure side (34) of the internal heat exchanger (30) and an outlet (58) of the second refrigerant channel (46) is connected the inlet of the compressor (14).

9. The laundry dryer according to any one of the preceding claims 1 to 3 or 7, wherein a first refrigerant channel (44) corresponds with the additional heat exchanger (22) and is part of the low pressure portion of the refrigerant circuit (10), whereas the second refrigerant channel (46) corresponds with the first heat exchanger (16) and is part of the high pressure portion of the refrigerant circuit.

10. The laundry dryer according to claim 9, wherein the inlet (52) of the first refrigerant channel (44) is connected to the refrigerant outlet of the evaporator (20) and the outlet (54) of the first refrigerant channel (44) is connected to the inlet of the compressor (14) and the inlet (56) of the second refrigerant channel (46) is connected to the outlet of the compressor (14) and the outlet (58) of the second refrigerant channel (46) is connected the inlet of the expansion device (18).

11. The laundry dryer according to claim 10 and 7, wherein the inlet (52) of the first refrigerant channel (44) is connected to the outlet of the low pressure side (34) of the internal heat exchanger (30) and the outlet (54) of the first refrigerant channel (44) is connected to the inlet of the compressor (14) and the inlet (56) of the second refrigerant channel (46) is connected to the outlet of the compressor (14) and the outlet (58) of the second refrigerant channel (46) is connected the inlet of the high pressure side (32) of the internal heat exchanger (30).

12. The laundry dryer according to any one of the preceding claims, wherein the refrigerant circuit (10) comprises a by-pass line (28) so that the refrigerant can completely or partially by-pass said additional heat exchanger (22).

13. The laundry dryer according to claim 12, wherein the by-pass line (28) includes at least one on-off valve for opening and closing said by-pass line (28) or the by-pass line (28) includes at least one control valve for a continuous opening of said by-pass line (28) or the by-pass line (28) includes at least one three-way valve for an alternating opening and closing of said by-pass line (28) and a refrigerant side of the additional heat exchanger (22).

14. The laundry dryer according to claim 12 or 13, wherein the by-pass line (28) is controlled or controllable by the temperature of the refrigerant in at least one position of the refrigerant circuit (10) or the by-pass line (28) is controlled or controllable by the temperature of the air stream in at least one position of the air stream circuit (12).

15. The laundry dryer according to any one of the preceding claims 12 to 14, wherein the by-pass line (28) is controlled or controllable by one of the following,

- the temperature of the refrigerant at the refrigerant outlet of the second heat exchanger (20),
- the temperature difference of the refrigerant at the refrigerant inlet and outlet of the second heat exchanger (20),
- the temperature difference of the refrigerant at the refrigerant outlet of the second heat exchanger (20) and the temperature of the air stream at the air stream outlet of the second heat exchanger (20).

FIG 1

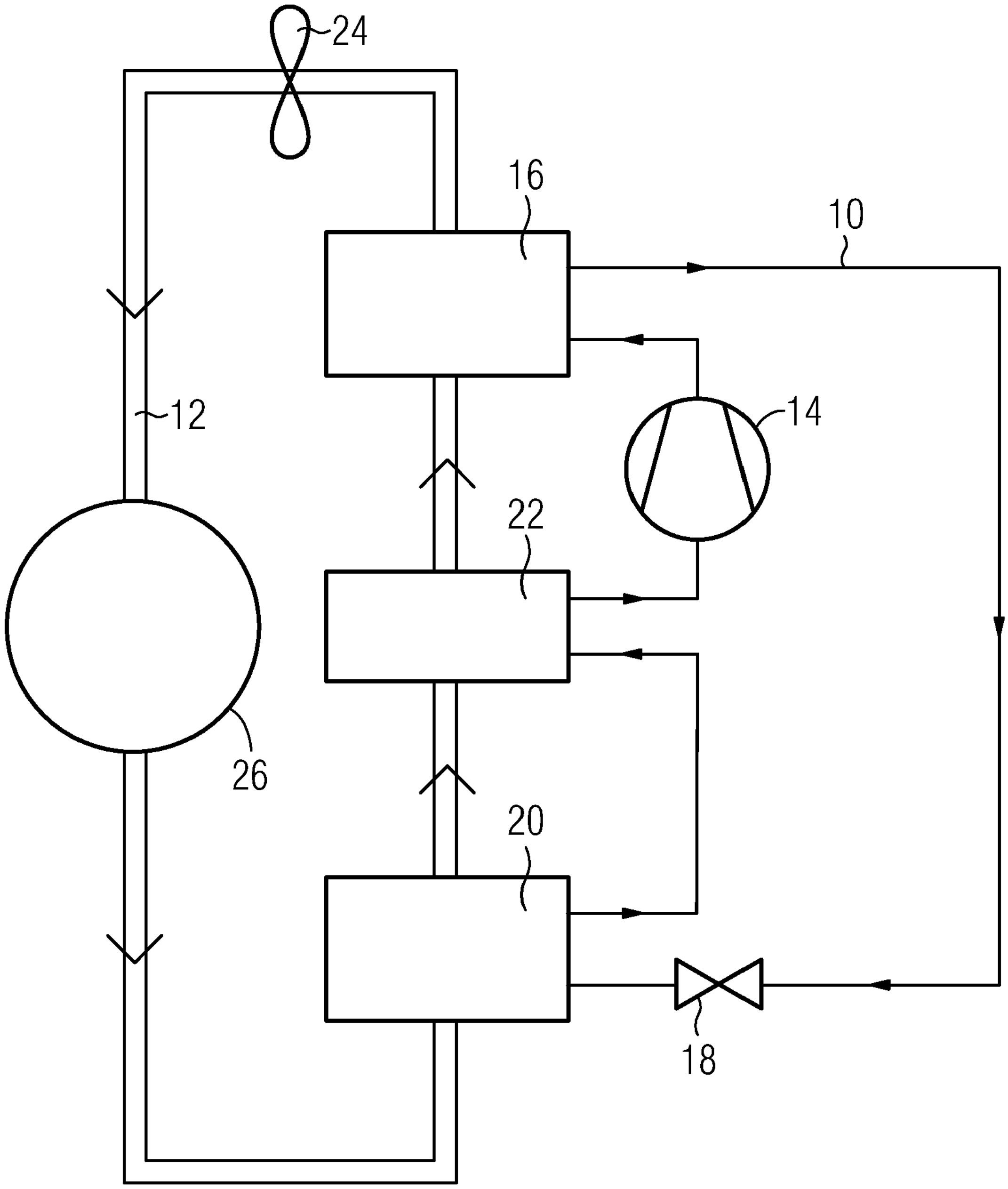


FIG 2

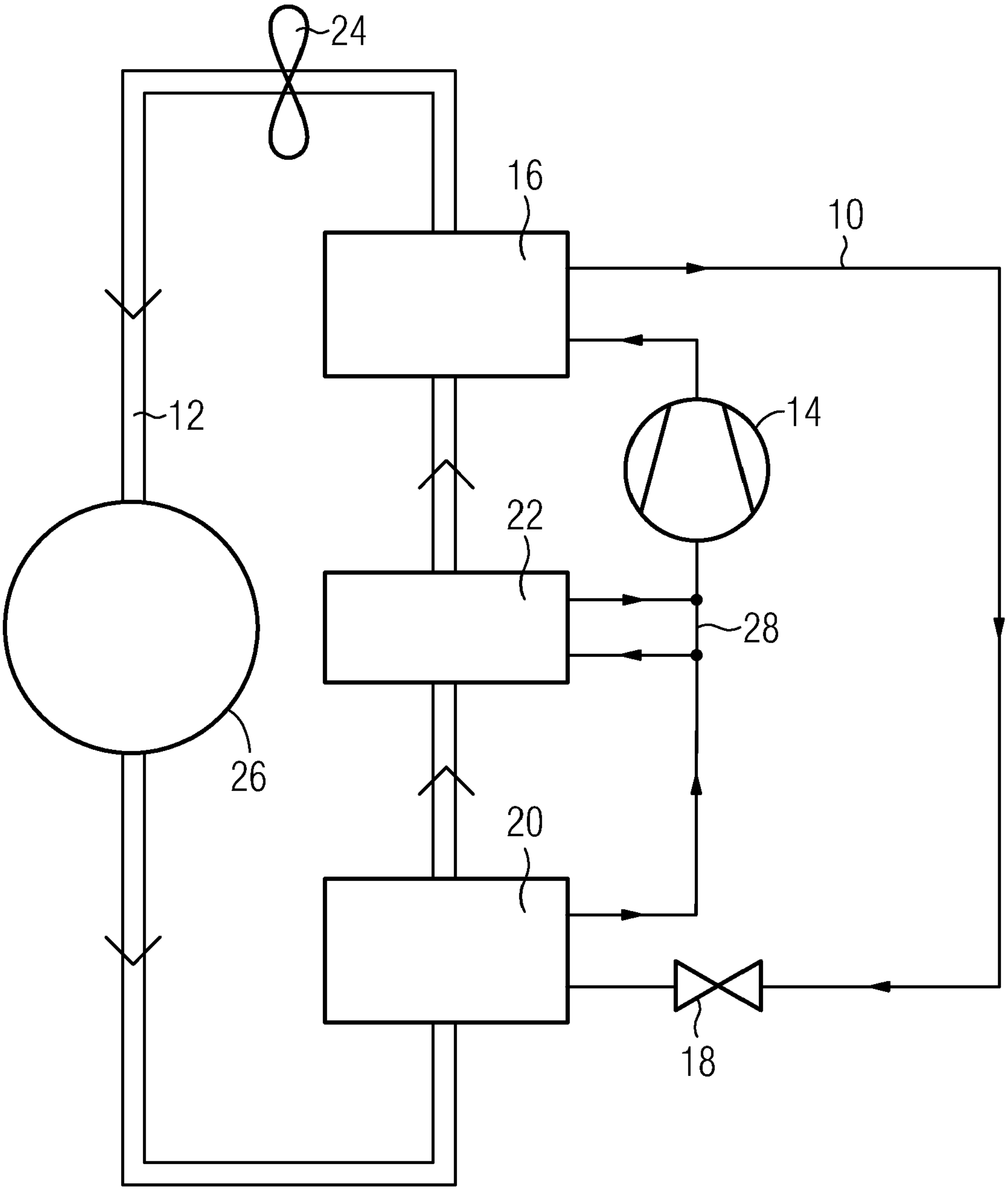


FIG 3

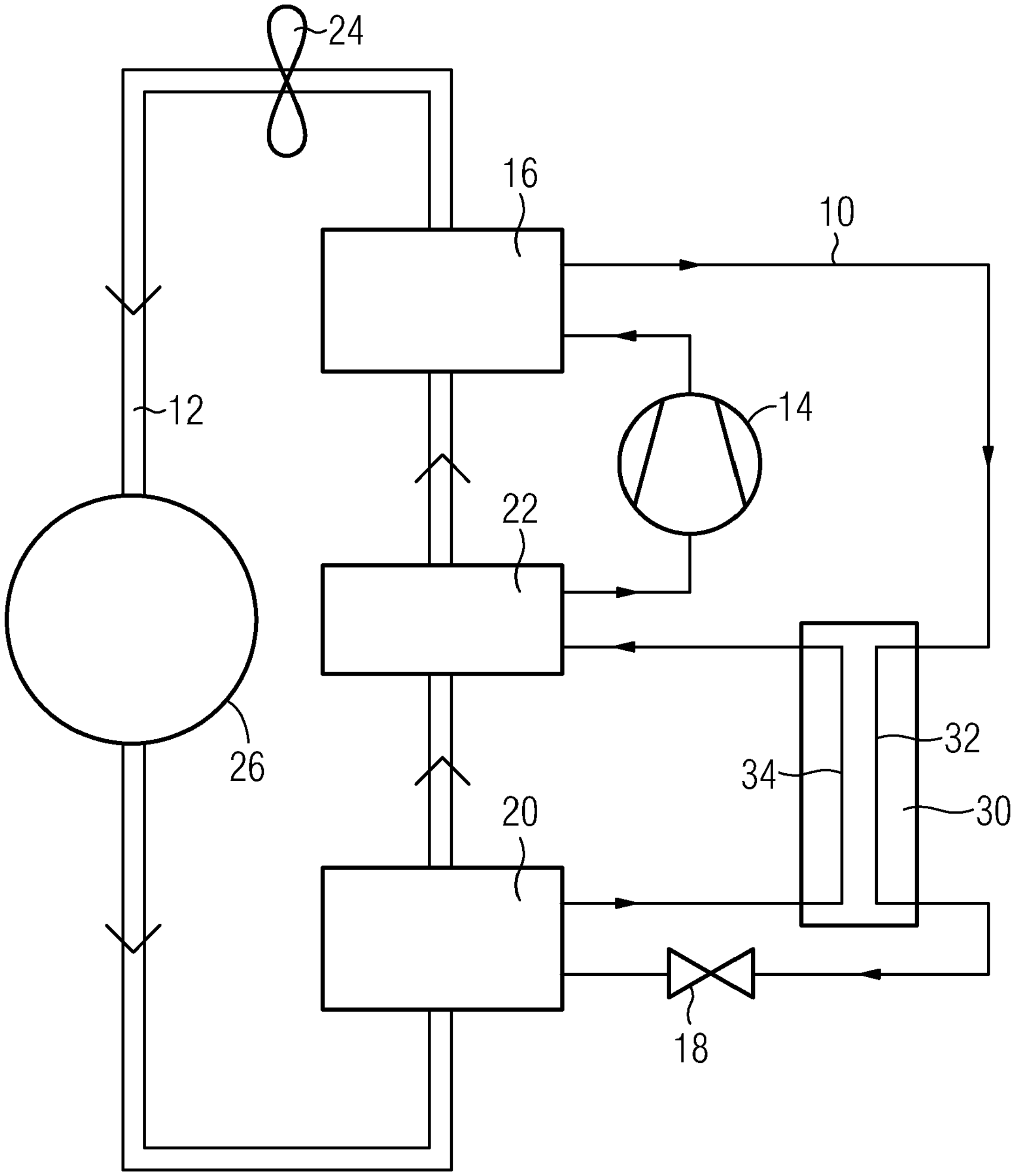


FIG 4

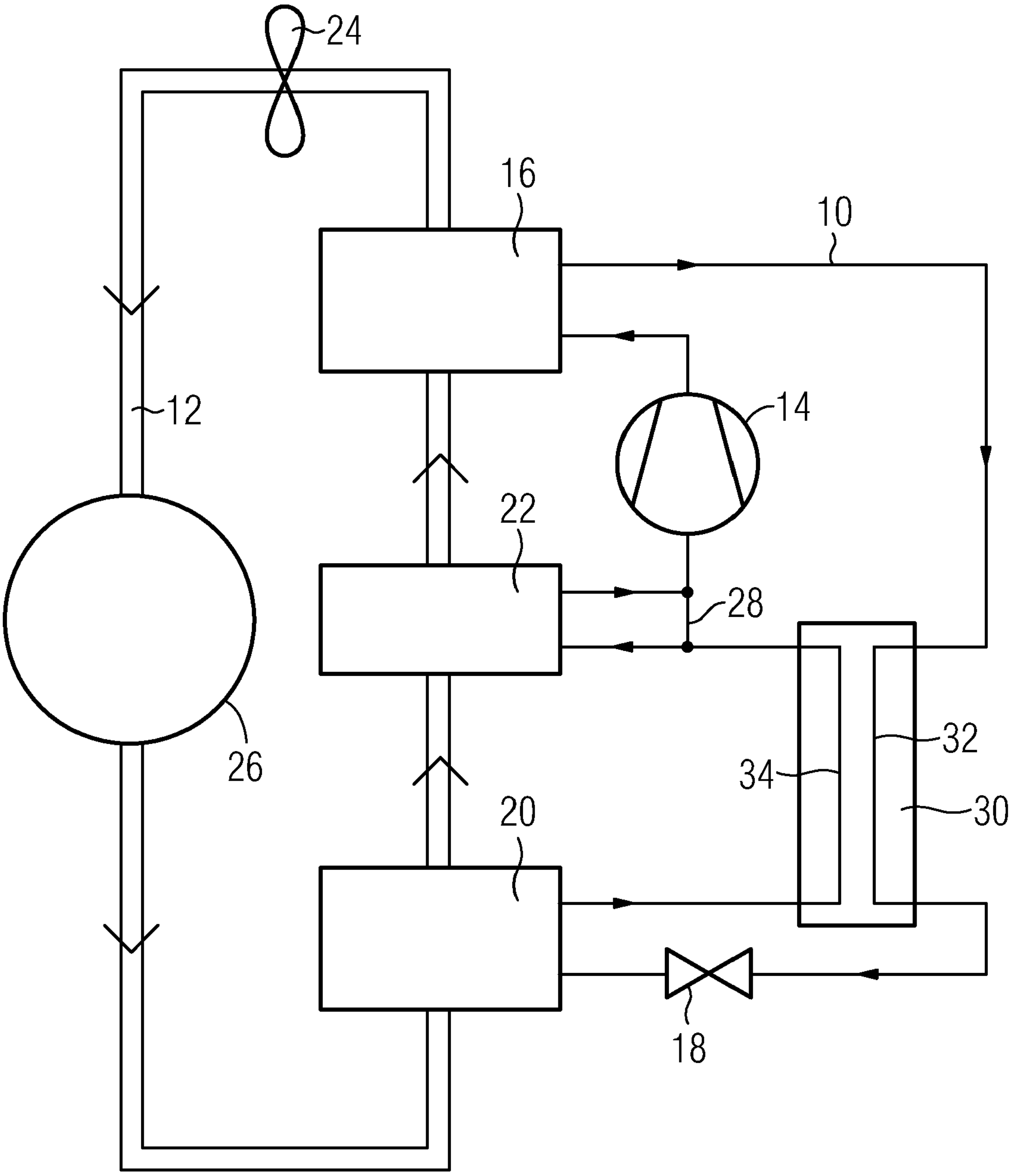


FIG 5

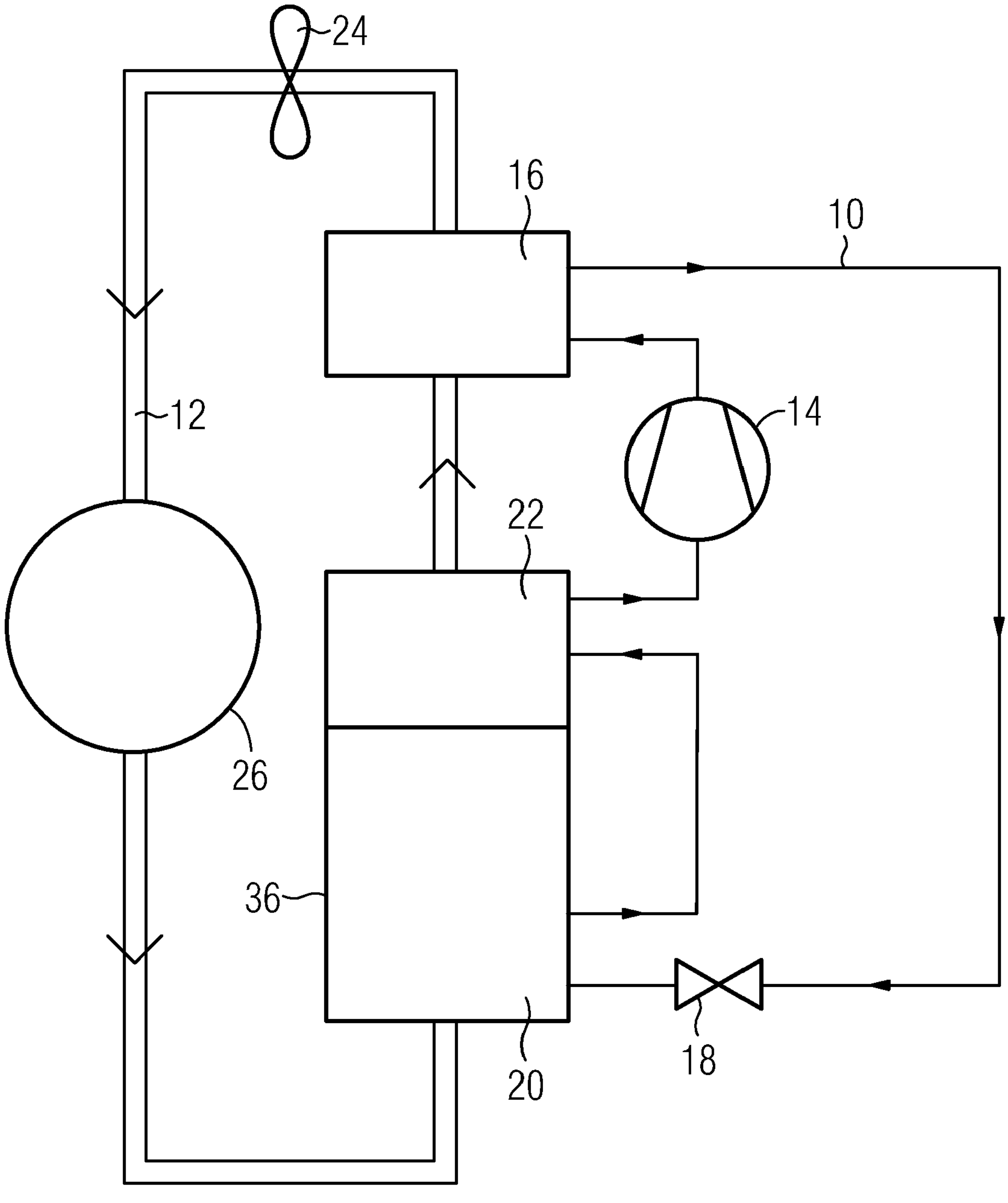


FIG 6

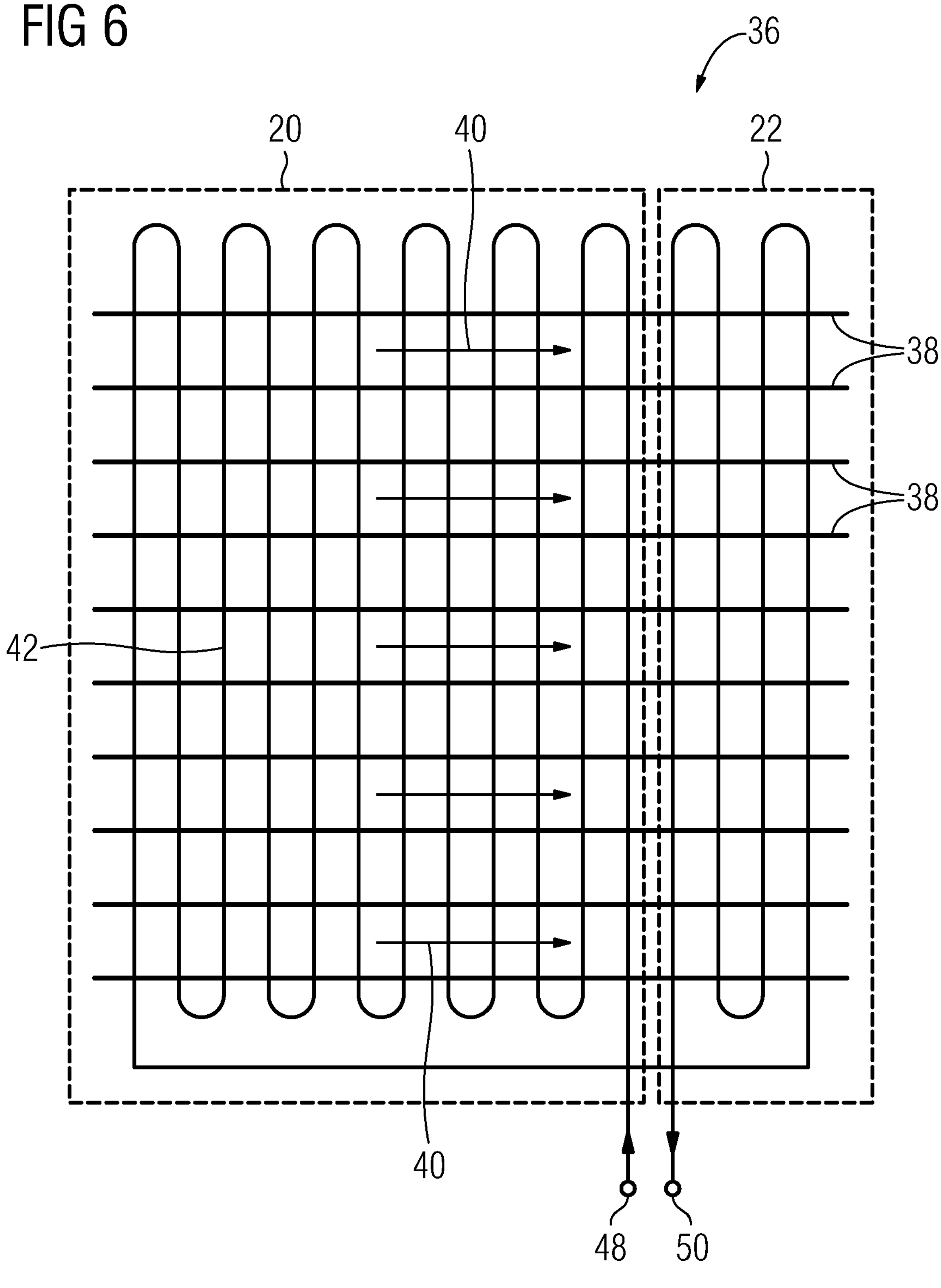


FIG 7

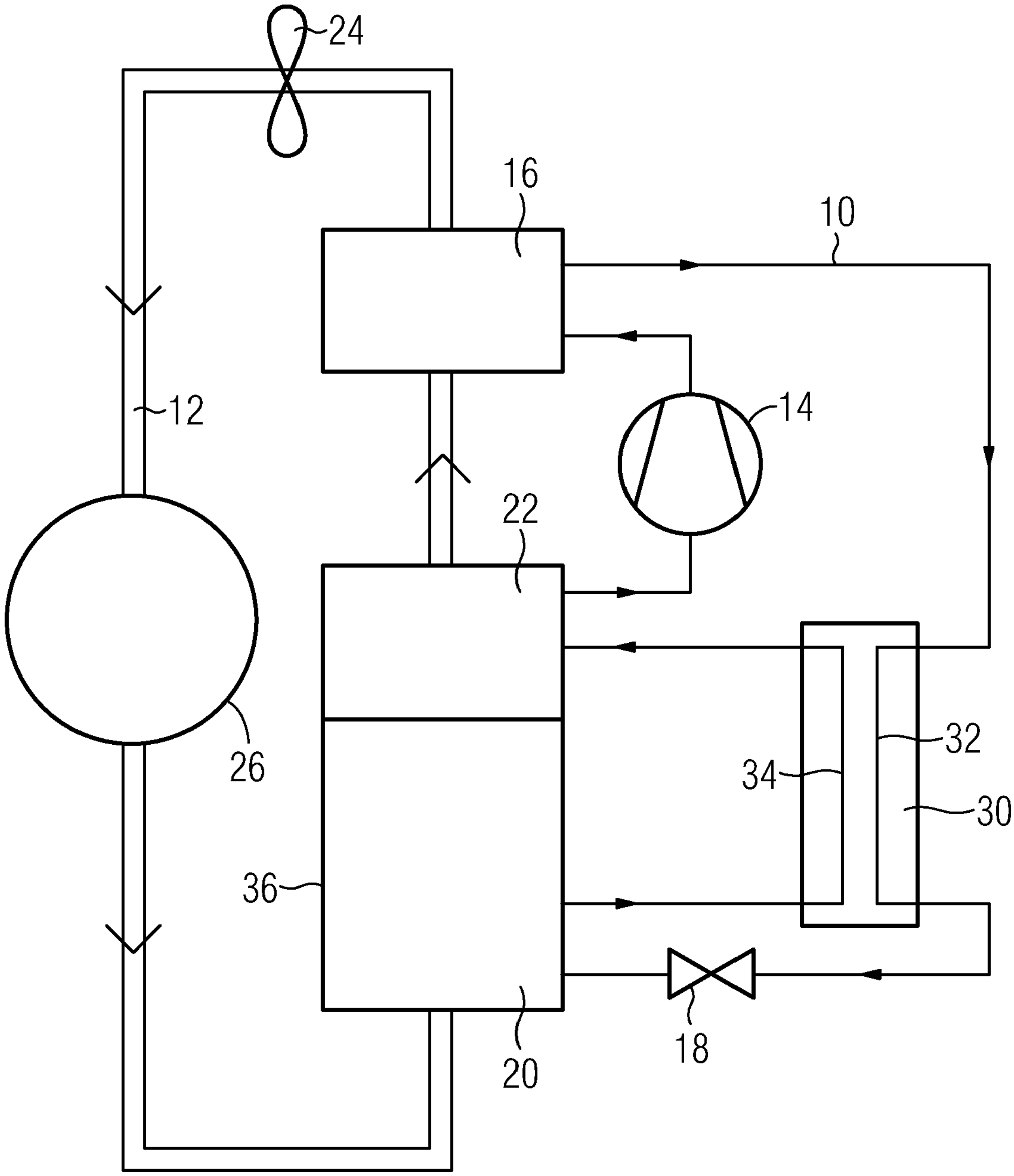


FIG 8

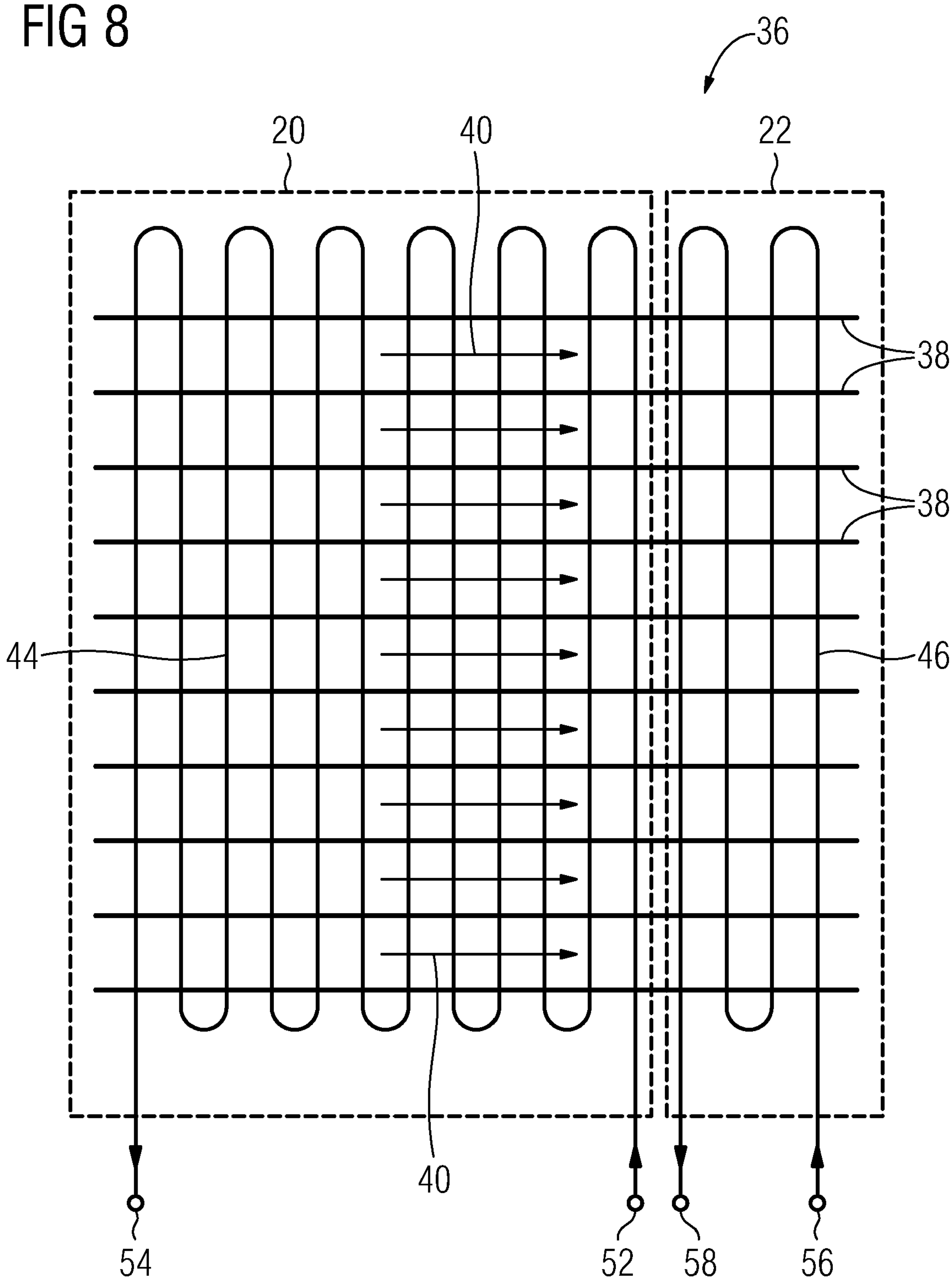


FIG 9

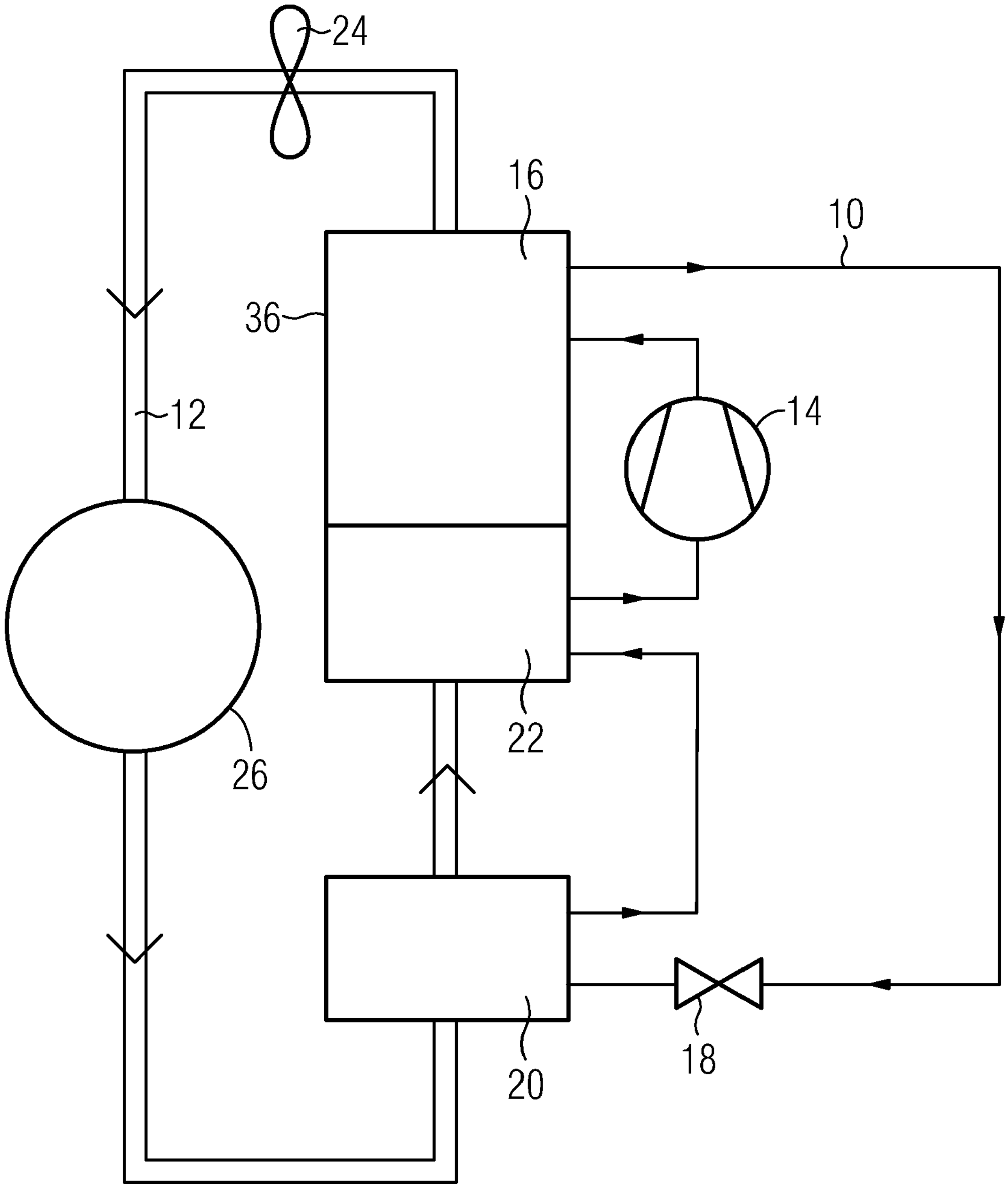


FIG 10

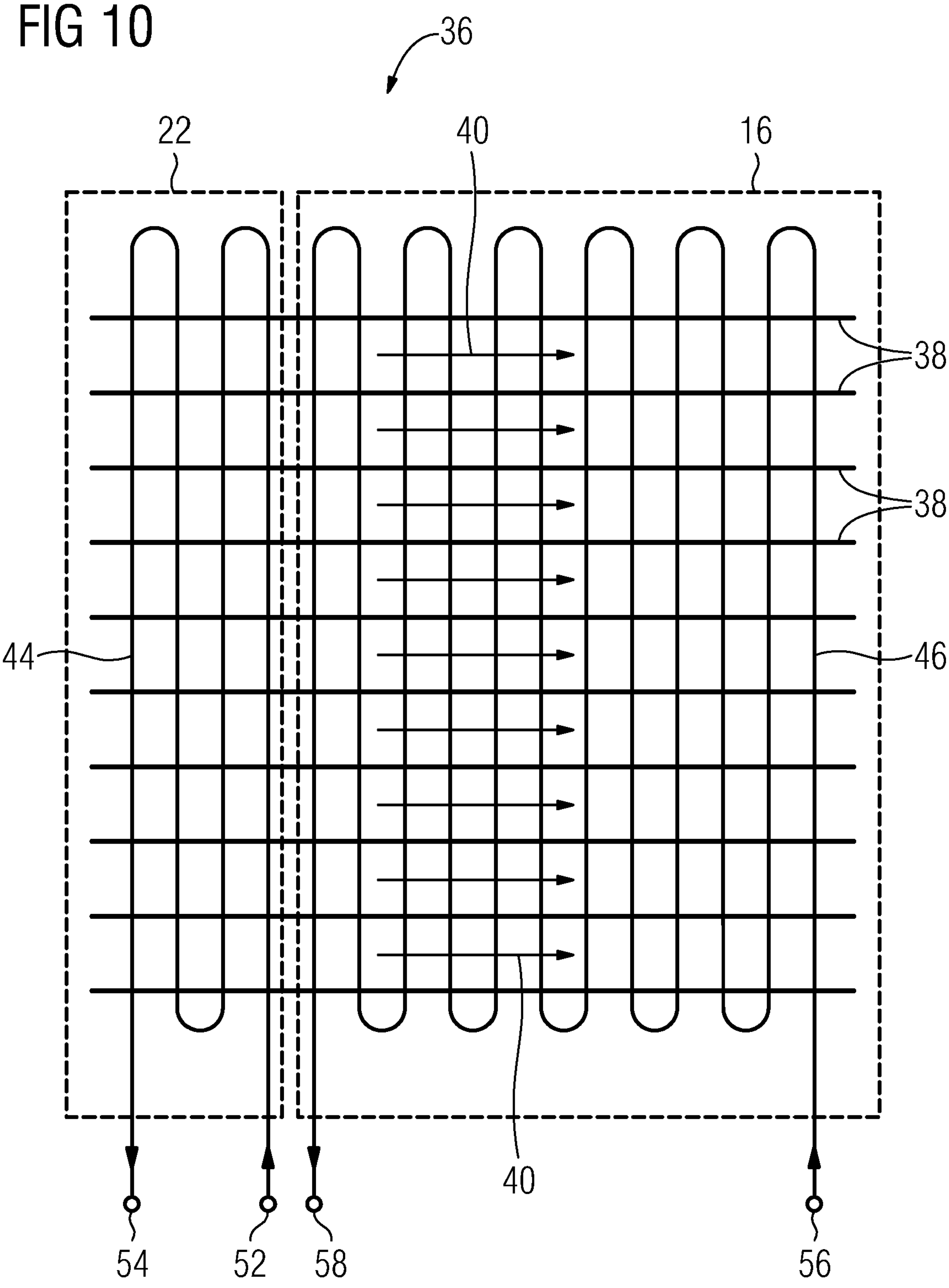


FIG 11

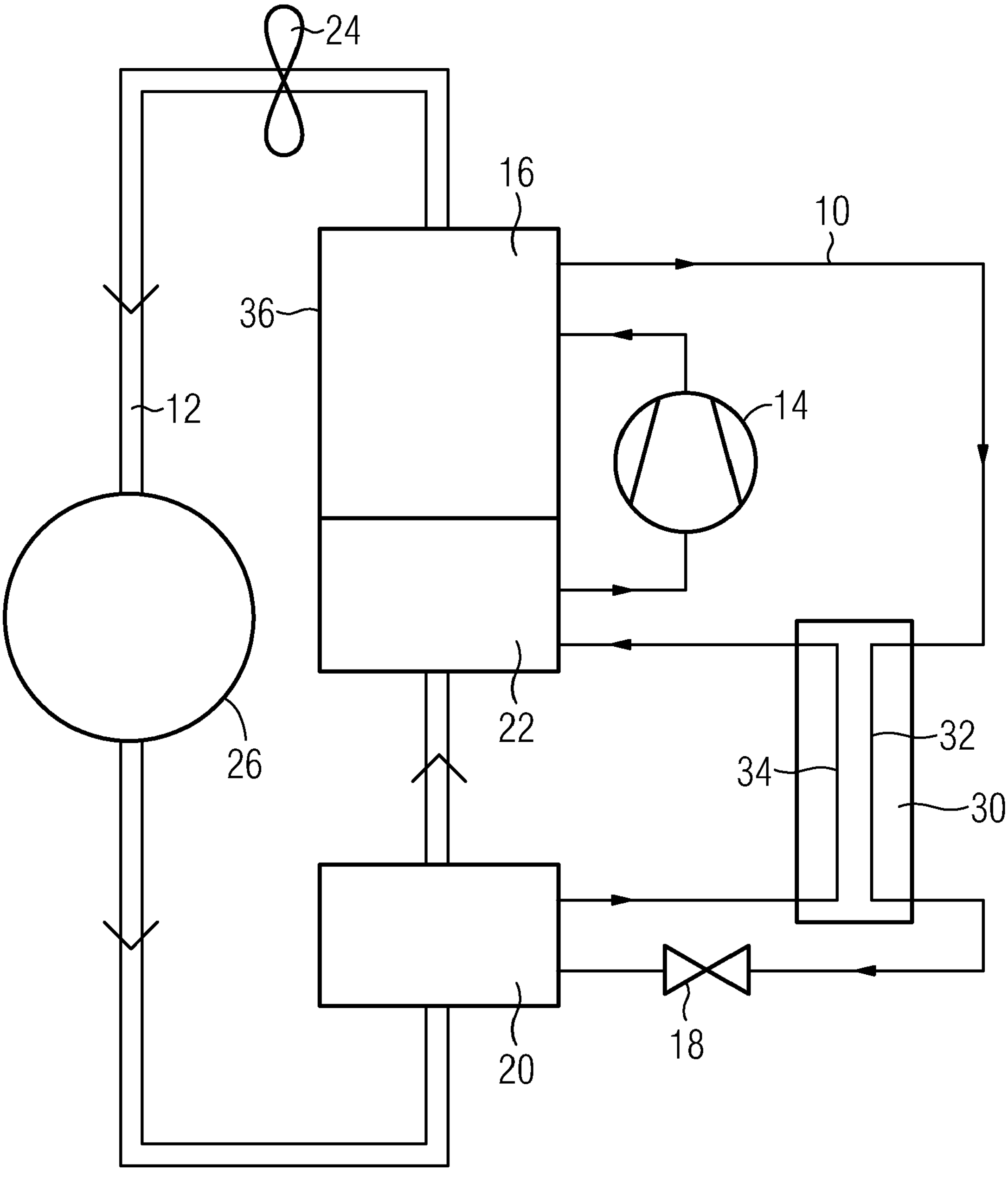
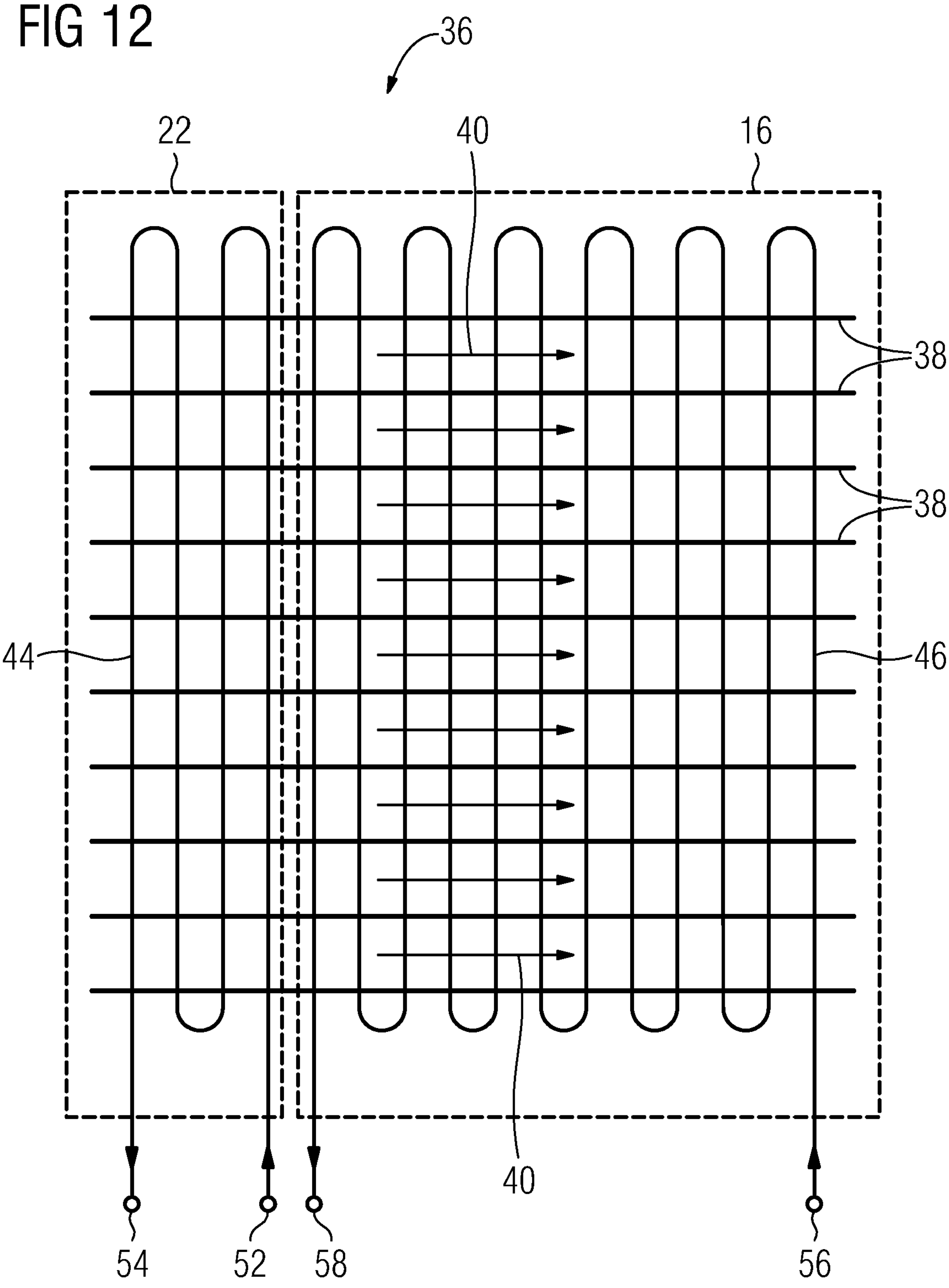


FIG 12



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EUROPEAN SEARCH REPORT

Application Number
EP 11 18 9889

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2009/016173 A1 (ARCELIK AS [TR]; OZTURK UMUT ESAT [TR]) 5 February 2009 (2009-02-05) * paragraphs [0031], [0034]; figures 3,4 *	1,4,9	INV. D06F58/20
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A	EP 2 385 169 A1 (ELECTROLUX HOME PROD CORP [BE]) 9 November 2011 (2011-11-09) * abstract; figure 1 *	1	
A	DE 20 2006 018205 U1 (V ZUG AG [CH]) 15 February 2007 (2007-02-15) * paragraphs [0025], [0026] *	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

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