



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.09.2019 Bulletin 2019/36

(51) Int Cl.:
D06F 58/20 (2006.01) D06F 58/28 (2006.01)

(21) Application number: **19156133.1**

(22) Date of filing: **08.02.2019**

(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
Designated Validation States:
KH MA MD TN

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(30) Priority: **02.03.2018 ES 201830209**

(54) **CLOTHES DRYING APPARATUS WITH HEAT PUMP**

(57) A clothes drying apparatus (1) comprises a heat pump (11) including a compressor (12), a condenser (9), an expansion means (13), and an evaporator (6) connected by fluid conduits (14-17) carrying working fluid (F) and comprises a control unit (18) connected to the compressor (12), the control unit (18) being adapted to operate the compressor (12) in a first mode of operation and in a second mode of operation during a drying cycle, wherein the compressor (12) is an AC rotary compressor (12), in the first mode of operation, the AC rotary compressor (12) is constantly switched on, and in the second mode of operation, the AC rotary compressor (12) is alternately switched on and off. Further, a method for operating a clothes drying apparatus (1) comprising a heat pump (11) including a AC rotary compressor (12) in a first and second mode of operation is disclosed.

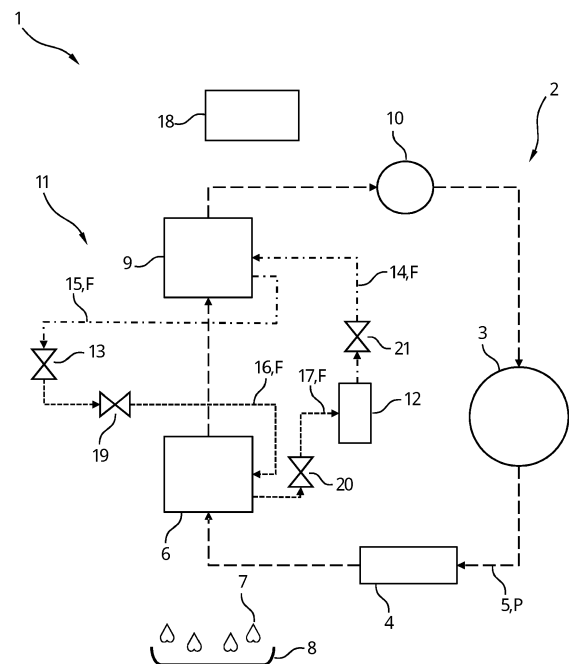


Fig.1

Description

[0001] The invention relates to a clothes drying apparatus comprising a heat pump including a compressor, a condenser, an expansion means, and an evaporator connected by fluid conduits carrying working fluid, and comprising a control unit connected to the compressor, the control unit being adapted to operate the compressor. The invention also relates to a method for operating a clothes drying apparatus comprising a heat pump including a compressor, a condenser, an expansion means, and an evaporator connected by fluid conduits carrying working fluid. The invention is particularly useful for household appliances.

[0002] The use of heat pumps in clothes drying appliances is widely known.

[0003] For example, WO 2007/077084 A1 discloses a domestic appliance for the care of washed articles, in particular a tumble drier. Said appliance comprises a container for receiving the washed articles, a process air supply that is connected to the container, allowing process air to flow through the container, and a first heat exchanger which is coupled to the process air supply and is designed to dehumidify the process air that exits the container.

[0004] EP 2 985 466 A1 discloses a rotary compressor which comprises a cylindrical housing, a cylindrical roller accommodated in the housing, a motor shaft leading through the roller having a cam for rolling the roller along a side wall of the housing, and a discharge port leading through a bottom cover. A household appliance, in particular laundry care apparatus, comprises the heat pump.

[0005] To vary an energy consumption of the heat pump, it is known to use BLDC-driven compressors and to vary a speed of the BLDC-driven compressor, i.e. a rotational speed of the BLDC motor **driving the compressor**. However, BLDC-driven compressors have the disadvantage that they are expensive and use additional components like an inverter.

[0006] It is the **object** of the present invention to at least partially overcome the problems associated with the prior art. It is a particular object of the present invention to be able to vary the energy consumption of the heat pump in a particular cost-effective manner.

[0007] The object is achieved according to the features of the independent claims. Advantageous embodiments can be found, e.g., in the dependent claims and/or in the description.

[0008] The object is achieved by a clothes drying apparatus, comprising a heat pump including a compressor, a condenser, an expansion means, and an evaporator connected by fluid conduits carrying working fluid, and comprising a control unit connected to the compressor, the control unit being adapted to operate the compressor in a first mode of operation and in a second mode of operation during a drying cycle, wherein the compressor is an AC rotary compressor, in the first mode of operation, the AC rotary compressor is constantly switched on, and

in the second mode of operation, the AC rotary compressor is alternately switched on and off.

[0009] This clothes drying apparatus gives the advantage that in the first mode of operation a particularly fast drying can be achieved ("speed mode") while in the second mode of operation a particularly energy-saving drying can be achieved ("eco mode"). The modes of operation may be selected by a user and/or may be automatically selected by the clothes drying apparatus. The energy-saving effect of the second mode of operation is achieved by not operation the AC rotary compressor in its switched-off state. Then, thermal inertia of the condenser and the evaporator still allows clothes to be dried in the switched-off state. If the drying effectiveness in the switched-off state falls under a pre-determined level, the compressor is switched on again. Therefore, the alternative switching on and off of the AC rotary compressor achieves a reduction of the total energy consumption during a drying cycle.

[0010] The clothes drying apparatus gives the further advantage that it can be more cost-effective than using a BLDC-driven compressor. While BLDC-driven compressors have a higher efficiency, they are also more expensive and need additional components like an inverter electronic to be operated. A clothes drying apparatus using the AC rotary compressor is also more robust.

[0011] The clothes drying apparatus may be a clothes dryer or a washing machine / clothes dryer combination. The clothes drying apparatus may be a domestic or household appliance.

[0012] In particular, the AC rotary compressor or AC-driven rotary compressor may have a fixed nominal speed in its switched-on state. The AC rotary compressor is a compressor driven by an AC motor.

[0013] The heat pump may comprise the compressor, the condenser, the expansion means (e.g. a capillary or an expansion valve), and the evaporator, connected in this order by the fluid conduits carrying the working fluid (refrigerant). Thus, the heat pump provides a working fluid circuit for letting the working fluid flow through the compressor, the condenser, the expansion means, and the evaporator, in this direction. The fluid conduits may be or comprise pipes etc. The pipes may be made of copper, aluminium etc.

[0014] The working fluid may comprise: flammable refrigerants like R290, R32 and/or R1270 (propylene), etc., and/or fluorinated hydrocarbon compounds (HFC) like R407C and/or R134a etc. The condenser and the evaporator act as heat exchangers positioned in a process air channel (e.g. an open-loop or closed-loop process air channel). Particularly, the condenser may act as a heater for process air flowing through the process air channel while the evaporator may act as a cooling device to cool down the process air. The arrangement and working principle of heat pumps for a clothes drying apparatus is generally known and will thus not be described in greater detail.

[0015] A "drying cycle" may be part of a drying process, in particular a drying program. The drying process may

comprise further cycles like a spinning or spin-dry cycle, an anti-wrinkle cycle etc. During a drying cycle, clothes contained in a clothes compartment of the clothes drying apparatus may be dried by introducing warm and dry process air into the clothes compartment and releasing moist process air from the clothes compartment. The clothes compartment may be a rotatable drum. A drying process may have one or more drying cycles. If a drying process comprises multiple drying cycles, they may be separated by at least one further cycle, e.g. a spin-dry cycle.

[0016] The control unit is adapted to selectively switch the AC rotary compressor on and off. The control unit may be a central control unit of the clothes drying apparatus controlling operation of the drying cycle.

[0017] It is an embodiment that the control unit is adapted to repeatedly switch on and off the AC rotary compressor. This gives the advantage that a drying efficiency can be held on a high level during the second mode of operation. In particular, there may be two or more time slots for switching on and/or switching off of the AC rotary compressor during a drying cycle. A duration of the time slots may be pre-defined. Alternatively or additionally, a duration of the time slots may be set based on input from sensors of the clothes drying apparatus, e.g. from one or more temperature sensors, a moisture sensor etc.

[0018] It is an embodiment that the control unit is adapted to vary a duration of time slots for switching the AC rotary compressor on and off. This advantageously allows adapting the level of drying efficiency, e.g. based on an amount (e.g. a weight) of the clothes, a water content (e.g. a degree of dryness) of the clothes, a type of the clothes, a selected duration of a drying cycle or drying program etc. The time slots for switching on and switching off of the AC rotary compressor may be different, i.e. have a different length or duration.

[0019] It is an embodiment that the control unit is adapted to vary a duration of the time slots during a drying cycle. This advantageously allows a further optimization of the level of drying efficiency.

[0020] It is an embodiment that the duration of the time slots (on-slots or off-slots) is at least three minutes. Varying the duration of the on-slots and/or off-slots may affect a temperature stability and/or the drying time in relation to the energy consumption.

[0021] It is an embodiment that the heat pump comprises open fluid conduits for carrying the working fluid, wherein, in its switched off state, the AC rotary compressor blocks the working fluid from flowing between its high-pressure side and its low-pressure side, and/or wherein the expansion means is selectively switchable between an open state and a closed state, and the control unit is adapted to open the expansion means when the AC rotary compressor is switched on and to close the expansion means when the AC rotary compressor is switched off. This gives the advantage of a particularly simple, cost-effective and robust arrangement is provided in which the thermal inertia of the evaporator and of the

condenser can be reliably maintained for a relatively long time in the switched off state of the compressor. An "open fluid conduit" may be understood to mean a fluid conduit that has no dedicated cut-off means to stop a flow of working fluid from flowing through the it. That the control unit is adapted to open the expansion means may include opening the expansion means or keeping the expansion means open. In analogy, that the control unit is adapted to close the expansion means may include closing the expansion means or keeping the expansion means closed. It is advantageous that the expansion means is an expansion valve.

[0022] It is an embodiment that the fluid conduits comprise at least one controllable cut-off means, wherein the at least one controllable cut-off means is open when the AC rotary compressor is switched on during a drying cycle, and wherein the at least one controllable cut-off means is closed when the AC rotary compressor is switched off during a drying cycle and is open when the AC rotary compressor is switched on during a drying cycle. This gives the advantage that the thermal inertia of the evaporator and of the condenser can be maintained in a particularly reliable way even if the compressor and/or the expansion means of the heat pump are not able to block or effectively block a flow of the working fluid through them. The controllable cut-off means can be selectively opened and closed by the control unit. The controllable cut-off means can be a valve. The controllable cut-off means may be connected to the control unit to be selectively switched on and off by the control unit. That a fluid conduit comprises a cut-off means may include that the cut-off means is positioned in or between two parts of the fluid conduit and/or may include that the cut-off means is positioned between the fluid conduit and a functional component of the heat pump (e.g. compressor, evaporator, condenser and/or expansion means).

[0023] It is an embodiment that the at least one controllable cut-off means comprises exactly one cut-off means positioned between the expansion means and the evaporator or between the condenser and the expansion means. This advantageously provides a particularly effective way to prevent the working fluid flowing in the heat pump while keeping costs low, in particular if the expansion means is not closable.

[0024] It is an embodiment that the at least one controllable cut-off means comprises exactly one cut-off means positioned between the AC rotary compressor and the condenser or between the evaporator and the AC rotary compressor. This advantageously provides another particularly effective way to prevent the working fluid flowing in the heat pump while keeping costs low, in particular if a high-pressure side and a low-pressure side of the AC rotary compressor is not closed in its switched-off state.

[0025] It is an embodiment that the at least one controllable cut-off means comprises two cut-off means, a first cut-off means of which being positioned between the expansion means and the evaporator or between the

condensor and the expansion means and a second cut-off means being positioned between the evaporator and the AC rotary compressor or between the AC rotary compressor and the condenser. This advantageously provides a particularly effective way to prevent the working fluid flowing in the heat pump while keeping costs low, in particular if the AC rotary compressor is not fluidically closed between its high-pressure side and its low-pressure side during its switch-off state and the expansion means is not closable.

[0026] It is an embodiment that the at least one controllable cut-off means comprises a first cut-off means being positioned between the expansion means and the evaporator or between the condenser and the expansion means, a second cut-off means being positioned between the evaporator and the compressor, and a third expansion means positioned between the compressor and the condenser. This advantageously provides an even more effective way to prevent the working fluid flowing in the heat pump while keeping costs low, in particular if the AC rotary compressor is not fluidically closed between its high-pressure side and its low-pressure side during its switch-off state and the expansion means is not closable. The controllable cut-off means may be valves. The controllable cut-off means may be connected to the control unit to be selectively switched on and off by the control unit.

[0027] The object is also achieved by a method for operating a clothes drying apparatus comprising a heat pump including a compressor, a condenser, an expansion means, and an evaporator, connected by fluid conduits carrying working fluid, wherein, in a first mode of operation, the AC rotary compressor is constantly switched on during a drying cycle, and, in a second mode of operation, the AC rotary compressor is alternately switched on and off during a drying cycle.

[0028] The method may be embodied in analogy to the drying apparatus comprising as described above and gives the same advantages.

[0029] For example, it is an embodiment that, when the AC rotary compressor is switched off, the working fluid is prevented from freely flowing through the heat pump. This enhances the energy-saving effect. That the working fluid is prevented from freely flowing through the heat pump may include that, at least one place of the heat pump (working fluid circuit), the working fluid is blocked or at least severely impeded from flowing.

[0030] The above described features and advantages of the invention as well as their kind of implementation will now be schematically described in more detail by at least one embodiment in the context of one or more figures.

[0031] Fig.1 shows a functional block diagram of a clothes drying apparatus 1 according to the invention.

[0032] The clothes drying apparatus 1 has a closed-loop process air circuit 2 comprising a rotational drum 3 for holding clothes. An output port of the drum 3 is connected to a lint filter 4 via a section of a process air channel

5 (long dashed lines). The lint filter 4 is connected to a first heat exchanger 6 via another section of the process air channel 5. Process air P is guided over a surface of the first heat exchanger 6 where it is cooled down so that the moist process air P from the drum 3 condensates. The resulting condensate 7 may be collected in a tray 8. The collected condensate may be lead to waste or may be re-used, e.g. for cleaning at least the first heat exchanger 6. The heat exchanger 6 is further connected to a second heat exchanger 9 via yet another section of the process air channel 5. At the second heat exchanger 9, the drier process air P coming from the first heat exchanger 6 is heated up. The second heat exchanger 9 is connected to a fan 10 for moving the process air P within the process air circuit 2 via yet another section of the process air channel 5. The fan 10 is connected to an inlet port of the drum 3 via yet another section of the process air channel 5. Thus, dry and warm process air P is introduced into the drum 3 to dry the clothes. The fan 10 may also be placed at another position within the process air circuit 2, e.g. between the drum 3 and the lint filter 4. The process air circuit 2 may have additional components (not shown) like an additional electric heater, an additional fan, further lint filters etc.

[0033] The first heat exchanger 6 and the second heat exchanger 9 are also components of a heat pump 11 of the clothes drying apparatus 1. The first heat exchanger 6 corresponds to an evaporator of the heat pump 11 while the second heat exchanger 9 corresponds to its condenser. The heat pump 11 further comprises an AC rotary compressor 12 and an expansion means 13, e.g. a capillary or an expansion valve.

[0034] A high-pressure side or port of the AC rotary compressor 12 is connected to the condenser (second heat exchanger 9) via a first fluid conduit 14 for working fluid F. The condenser 9 is further connected to a high-pressure side of the expansion means 13 via a second fluid conduit 15 for the working fluid F. A low-pressure side of the expansion means 13 is connected to the evaporator (first heat exchanger 6) via a third fluid conduit 16 for the working fluid F. The evaporator 6 is connected to a low-pressure side of the AC rotary compressor 12 via a fourth fluid conduit 17 for the working fluid F.

[0035] When the AC rotary compressor 12 is switched on, pressurized working fluid F flows from the high-pressure side of the AC rotary compressor 12, through the first conduit 14, through the condenser 9, through the second conduit 15, through the expansion means 13 (where it is expanded at its low-pressure side), through the third conduit 16, through the evaporator 6, and through the fourth conduit 17 to the low-pressure side of the AC rotary compressor 12. In the AC rotary compressor 12, the working fluid F is compressed and is then again emitted at the high-pressure side of the AC rotary compressor 12.

[0036] When the AC rotary compressor 12 is switched off, the working fluid F is not moved by the AC rotary compressor 12 anymore but may - if not prevented - move

to equilibrate pressure between the high-pressure section of the heat pump 11 and the low-pressure section of the heat pump 11. Conduits 14 and 15 that carry high-pressure working fluid F are shown as dashed-dotted lines, while conduits 16 and 17 that carry low-pressure working fluid F are shown as dotted lines.

[0037] The clothes drying apparatus 1 also comprises a control unit 18 controlling operation of the AC rotary compressor 12, in particular for switching the AC rotary compressor 12 on and off. The control unit 18 may also control operation of the drum 3 and the fan 10, as well as further components of the clothes drying apparatus 1.

[0038] The control unit 18 is adapted to operate the AC rotary compressor 12 in a first mode of operation and in a second mode of operation during a drying cycle, wherein in the first mode of operation, the AC rotary compressor 12 is constantly switched on, and in the second mode of operation, the AC rotary compressor 12 is alternately switched on and off, in particular repeatedly. The control unit 18 may be adapted to vary a duration of time slots for switching the AC rotary compressor 12 on and off. The control unit 18 may further be adapted to vary a duration of the time slots during a drying cycle.

[0039] In a first variant of the clothes drying apparatus 1, the heat pump 11 comprises open conduits 14 to 17. To prevent the working fluid F from flowing to equalize pressure when the AC rotary compressor 12 is switched off, the AC rotary compressor 12 is embodied such that its high-pressure side and its low-pressure side are hermetically sealed from each other in the switched-off state. Thus, the switched-off AC rotary compressor 12 blocks the working fluid F from flowing from its high-pressure side to its low-pressure side. Additionally or alternatively, the expansion means 13 is selectively switchable by the control unit 18 between an open state and a closed state and the control unit 18 is adapted to open the expansion means 13 when the AC rotary compressor 12 is switched on and to close the expansion means 13 when the AC rotary compressor 12 is switched off. Thus, the expansion means 13 blocks the working fluid F from flowing from its high-pressure side to its low-pressure side.

[0040] In a second variant of the clothes drying apparatus 1, the clothes drying apparatus 1 comprises a controllable first cut-off means 19 connected to the control unit 18, the first cut-off means 19 being positioned between the expansion means 13 and the evaporator 6. The control unit 18 controls the first cut-off means 19 such that it is open when the AC rotary compressor 12 is switched on and it is closed when the AC rotary compressor 12 is switched off during a drying cycle. This variant may be particularly advantageous if the high-pressure side and the low-pressure side of the AC rotary compressor 12 are hermetically sealed from each other in the switched-off state but the expansion means 13 is not closable, i.e. always open. Alternatively, the controllable first cut-off means 19 may be positioned between the condenser 9 and the expansion means 13.

[0041] In a third variant of the clothes drying apparatus

1, the clothes drying apparatus 1 additionally comprises a controllable second cut-off means 20 or a controllable third cut-off means 21 connected to the control unit 18. The second cut-off means 20 is positioned between the evaporator 6 and the low-pressure-side of the AC rotary compressor 12. The third cut-off means 21 is positioned between the high-pressure-side of the AC rotary compressor 12 and the condenser 9. The control unit 18 controls the second cut-off means 20 or the third cut-off means 21 such that it is open when the AC rotary compressor 12 is switched on and it is closed when the AC rotary compressor 12 is switched off during a drying cycle. This variant may be particularly advantageous if the high-pressure side and the low-pressure side of the AC rotary compressor 12 are open against each other in the switched-off state and the expansion means 13 is not closable.

[0042] In a fourth variant of the clothes drying apparatus 1, the clothes drying apparatus 1 comprises the controllable first cut-off means 19, the controllable second cut-off means 20 and the controllable third cut-off means 21. This variant particularly reliably blocks the working fluid from moving during a switched-off state of the AC rotary compressor 12, e.g. if the high-pressure side and the low-pressure side of the AC rotary compressor 12 are open against each other in the switched-off state and the expansion means 13 is not closable.

[0043] Of course, the invention is not restricted to the described embodiment(s).

[0044] For example, the clothes drying apparatus 1 may have no lint filter 4.

[0045] Also, the clothes drying apparatus 1 may comprise an additional fan for cooling the AC rotary compressor 12.

List of Reference Signs

[0046]

1	Clothes drying apparatus
2	Process air circuit
3	Drum
4	Lint filter
5	Process air channel
6	First heat exchanger / evaporator
7	Condensate
8	Tray
9	Second heat exchanger / condenser
10	Fan
11	Heat pump
12	AC rotary compressor
13	Expansion means
14	First conduit
15	Second conduit
16	Third conduit
17	Fourth conduit
18	Control unit
19	First cut-off means

20 Second cut-off means
 21 Third cut-off means
 F Working fluid
 P Process air

Claims

1. A clothes drying apparatus (1),

- comprising a heat pump (11) including a compressor (12), a condenser (9), an expansion means (13), and an evaporator (6) connected by fluid conduits (14-17) carrying working fluid (F) and
- comprising a control unit (18) connected to the compressor (12), the control unit (18) being adapted to operate the compressor (12) in a first mode of operation and in a second mode of operation during a drying cycle,

wherein

- the compressor (12) is an AC rotary compressor (12),
- in the first mode of operation, the AC rotary compressor (12) is constantly switched on, and
- in the second mode of operation, the AC rotary compressor (12) is alternately switched on and off.

2. The clothes drying apparatus (1) according to claim 1, wherein the control unit (18) is adapted to repeatedly switch on and off the AC rotary compressor (12).

3. The clothes drying apparatus (1) according to any of the preceding claims, wherein the control unit (18) is adapted to vary a duration of time slots for switching on and switching off of the AC rotary compressor (12).

4. The clothes drying apparatus (1) according to claim 3, wherein the control unit (18) is adapted to vary a duration of the time slots during a drying cycle.

5. The clothes drying apparatus (1) according to any of the preceding claims, wherein

- the heat pump (11) comprises open fluid conduits (14-17) for carrying the working fluid (F), wherein
- in its switched off state, the AC rotary compressor (12) blocks the working fluid (F) from flowing between its high-pressure side and its low-pressure side, and/or wherein
- the expansion means (13) is selectively switchable between an open state and a closed state and the control unit (18) is adapted to open the

expansion means (13) when the AC rotary compressor (12) is switched on and to close the expansion means (13) when the AC rotary compressor (12) is switched off.

6. The clothes drying apparatus (1) according to any of the preceding claims, wherein

- the fluid conduits (14-17) comprise at least one controllable cut-off means (19-21), wherein
- the at least one controllable cut-off means (19-21) is open when the AC rotary compressor (12) is switched on during a drying cycle, and wherein
- the at least one controllable cut-off means (19-21) is closed when the AC rotary compressor (12) is switched off during a drying cycle and is open when the AC rotary compressor (12) is switched on during a drying cycle.

7. The clothes drying apparatus (1) according to claim 6, wherein the at least one controllable cut-off means (19-21) comprises exactly one cut-off means (19) positioned between the expansion means (13) and the evaporator (6) or between the condenser (9) and the expansion means (13).

8. The clothes drying apparatus (1) according to claim 6, wherein the at least one controllable cut-off means (19-21) comprises

- a first cut-off means (19) being positioned between the expansion means (13) and the evaporator (6) or between the condenser (9) and the expansion means (13),
- a second cut-off means (20) being positioned between the evaporator (6) and the compressor (12), and
- a third expansion means (21) positioned between the compressor (12) and the condenser (9).

9. A method for operating a clothes drying apparatus (1) comprising a heat pump (11) including a compressor (12), a condenser (9), an expansion means (13), and an evaporator (6) connected by fluid conduits (14-17) carrying working fluid (F), wherein,

- in a first mode of operation, the AC rotary compressor (12) is constantly switched on during a drying cycle, and,
- in a second mode of operation, the AC rotary compressor (12) is alternately switched on and off during a drying cycle.

10. The method according to claim 9, wherein, when the AC rotary compressor (12) is switched off, the working fluid (F) is prevented from freely flowing through

the heat pump (11).

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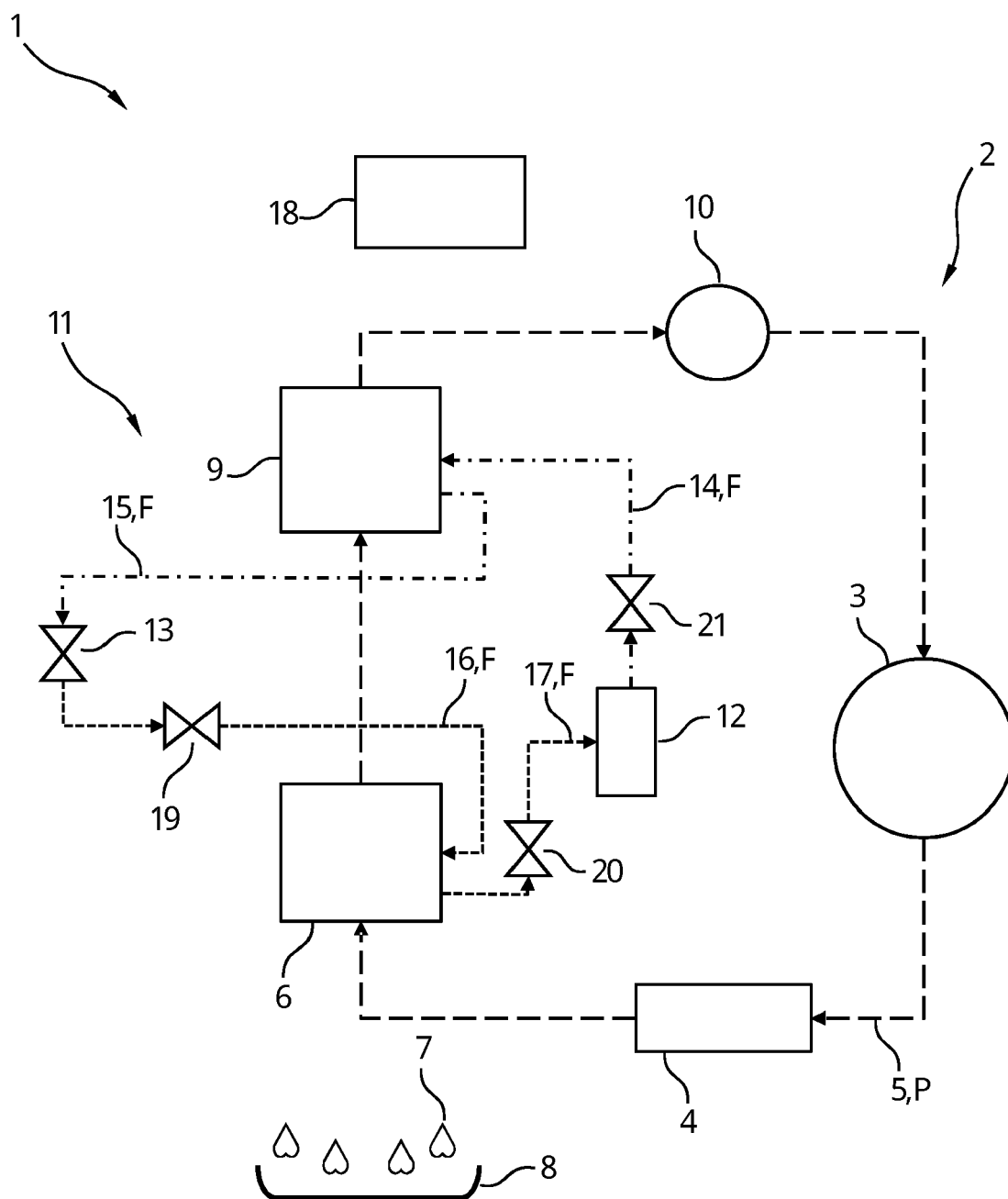


Fig.1



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Application Number
EP 19 15 6133

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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