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(54) **CLOTHES DRYING APPARATUS**

(57) A clothes drying apparatus (1), comprising a heat pump (2) having a rotary compressor (3) for compressing a working fluid (F) flowing through the heat pump (2), wherein the compressor (3) is a multi-chamber

rotary compressor having at least two independently operable compression chambers (4, 5). The invention is particularly useful for household appliances, e.g. for clothes dryers having a closed-loop process air circuit.

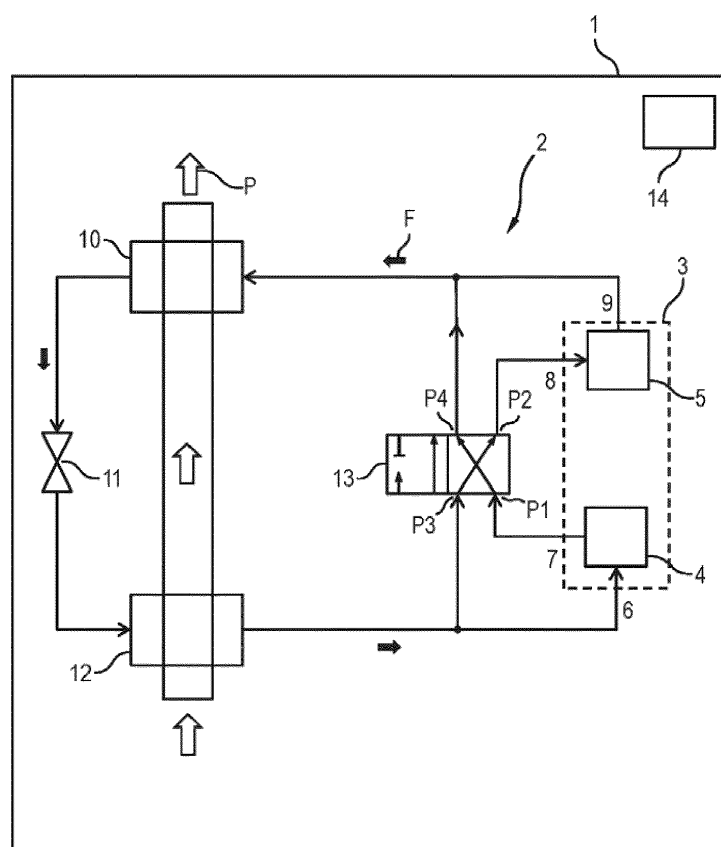


Fig.1

Description

[0001] The invention relates to a clothes drying apparatus comprising a heat pump having a rotary compressor for compressing a working fluid flowing through the heat pump. The invention is particularly useful for household appliances, e.g. for clothes dryers having a closed-loop process air circuit.

[0002] There are household clothes dryers known that comprise a heat pump having a rotary compressor for compressing a working fluid flowing through the heat pump wherein a cooling capacity of the heat pump may be varied by varying a rotating velocity of the rotary compressor. To this effect, the rotary compressor comprises a BLDC motor for rotating the rotatable parts and an inverter.

[0003] EP 2 612 695 A1 discloses an appliance for drying laundry including a drying-air moisture-condensing system comprising a heat pump system with a variable-output compressor, and at least one drying air variable-speed fan for promoting the recirculation of the drying air, the appliance being adapted to perform at least one laundry drying cycle in at least a first drying mode wherein the compressor is driven to a first compressor mode having a compressor power consumption course and/or a compressor rotational speed course and/or a frequency course of the supply current/voltage of the compressor motor and the fan is driven to a first fan mode having a speed course, and at least a second drying mode wherein the compressor is driven to a second compressor mode comprising a compressor power consumption course and/or a compressor rotational speed course and/or a frequency course of the supply current/voltage of the compressor motor and the fan is driven to a second fan mode having a speed course, wherein for at least a portion of the drying cycle, a compressor power consumption and/or a compressor rotational speed and/or a frequency of the supply current/voltage of the compressor of the second compressor mode is/are higher than the one/s of the first compressor mode and the speed of the second fan mode is higher than the speed of the first fan mode.

[0004] 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 provide a operation of a compressor of a heat pump of a clothes drying apparatus providing variable cooling capacities on a more cost-effective basis.

[0005] The object is achieved according to the features of the independent claim. Advantageous embodiments can be found, e.g., in the dependent claims, in the subsequent description and in the figures of the attached drawing.

[0006] Accordingly, the object is achieved by a clothes drying apparatus, comprising a heat pump having a rotary compressor for compressing a working fluid flowing through the heat pump, wherein the compressor is a multi-chamber rotary compressor having at least two inde-

pendently operable compression chambers. Such a clothes drying apparatus allows the selective use of these compression chambers to adjust the cooling capacity in a particularly cost-effective, robust and easy-to-implement manner.

[0007] For example, the clothes drying apparatus may be a clothes dryer or a combined clothes washing/drying apparatus ("washer-dryer"). The clothes drying apparatus may be a household appliance or domestic appliance.

[0008] The heat pump may comprise a working fluid circuit which comprises - in that flow direction of the working fluid - the compressor, a condenser, an expansion valve, and an evaporator. The compressor compresses or pressurizes the working fluid and circulates it through the heat pump. These components may be connected by respective pipes, tubes etc. The condenser and/or the evaporator may be heat exchangers to exchange heat between the working fluid and process air used for drying the clothes.

[0009] The working fluid - also called a refrigerant - may e.g. be R134a or R290.

[0010] That at least two compression chambers are independently operable may include that the compression chambers can independently compress the working fluid. In one variant, the at least two compression chambers are operable in an "active" mode in which working fluid guided through a compression chamber is compressed by / in this chamber. At least one of the compression chambers is operable in an "inactive" mode in which working fluid guided through this compression chamber is not compressed by / in this chamber.

[0011] It is an embodiment that the compressor is an AC rotary compressor. The AC rotary compressor has the advantage that it is significantly more inexpensive than a rotary compressor having a BLDC motor and an inverter. In particular, the AC rotary compressor may be operated at a constant rotation speed of the AC motor. This also gives the advantage of a particularly robust and long-lasting design. Different cooling capacities may solely be provided by activating/using the compression chambers in certain combinations to compress the working fluid.

[0012] It is another embodiment that the compressor is operable in at least two modes with a full mode (also be called a "speed mode" or such) using all compression chambers to compress the working fluid and at least one reduced mode (also be called an "eco" mode or such) in which at least one compression chamber is inactive regarding the compression of the working fluid. While the full mode achieves full cooling capacity, the reduced mode(s) achieve(s) a reduced or smaller cooling capacity. If, for example, the compressor comprises three compression chambers, the full mode may be achieved by using all three compression chambers. There could be up to six reduced modes, using only one of each three compression chambers (i.e. three single-chamber modes) or using combinations of two of the three compression chambers (i.e. three two-chamber modes).

[0013] It is an embodiment that the working fluid flows through the at least one inactive compression chamber. When the working fluid flows through an inactive compression chamber, it is not compressed or pressurized but the inactive compression chamber is used as conduit. This embodiment gives the advantage that a connection arrangement for the working fluid may be particularly simple.

[0014] It is an embodiment thereof that active compression chambers are fluidically connected in parallel and that inactive compression chambers are fluidically connected to an active compression chamber in series. Therefore, for operating in the full mode, all compression chambers are fluidically connected in parallel.

[0015] It is another embodiment that the working fluid circumvents the at least one inactive compression chamber. This embodiment gives the advantage that the compressor as such does not or not significantly need to be adapted to the different operating modes.

[0016] The different modes may be implemented by selectively operating at least one multi-way valve (e.g. at least one 3-way valve and/or at least one 4-way valve) integrated in the working fluid circuit.

[0017] It is yet another embodiment that each compression chamber is connected to a respective fluid inlet and fluid outlet. This achieves the advantage that each compression chamber can be operated independently of the other compression chamber(s).

[0018] It is another embodiment that the compressor is a two-chamber rotary compressor, i.e. having exactly two compression chambers, in particular exactly two independently operable compression chambers.

[0019] It is yet another embodiment that the clothes drying apparatus comprises a 4/2-way distributor valve, wherein an inlet of a first compression chamber is connected to an outlet of an evaporator of the heat pump, an outlet of the first compression chamber is connected to a first port of the valve, an inlet of the second compression chamber is connected to a second port of the valve, an outlet of the second compression chamber is connected to an inlet of a condenser of the heat pump, a third port of the valve is connected to the outlet of the evaporator, a fourth port of the valve is connected to the inlet of the condenser, in the full mode, the first port is connected to the fourth port and the third port is connected to the second port, and in the reduced mode, the first port is connected to the second port and the third port is disconnected from the fourth port. This embodiment gives the advantage that several cooling capacities can be achieved by a particularly cost-efficient and easy-to-implement design.

[0020] Instead of a 4/2-way distributor valve, any other arrangement of valves that achieves the same functionality can be used, e.g. two 3/2-way distributor valves.

[0021] It is also an embodiment that at least two compression chambers have a different cooling capacity. This allows for a particularly wide range of selectable cooling capacities. For example, in one variant, one of

the compression chambers has a cooling capacity of 40 % while the other compression chamber has a cooling capacity of 60 %. Thus, the rotary compressor can be operated at 40 %, 60 %, or $(40 \% + 60 \%) = 100 \%$ of the cooling capacity, if so arranged.

[0022] 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 with the drawings.

Fig.1 shows components of a clothes drying apparatus having a heat pump with a two-chamber compressor with the compressor being operable in a first mode full;

Fig.2 shows a cross-sectional side view of one possible two-chamber compressor and

Fig.3 shows the clothes drying apparatus of Fig.1 with the compressor being operable in a second mode reduced;

[0023] Fig.1 shows a clothes drying apparatus in form of a household clothes dryer 1 being operated in a full mode or speed mode. The clothes dryer 1 comprises a heat pump 2 having a rotary compressor 3 for compressing a working fluid F, e.g. R134a or R290, flowing through the heat pump 2. The compressor 3 is a two-chamber rotary compressor having two independently operable compression chambers, namely a first compression chamber 4 and a second compression chamber 5. As also shown in Fig.2, the first compression chamber 4 is connected to or has a fluid inlet 6 and a fluid outlet 7. The second compression chamber 5 is connected to or has a fluid inlet 8 and a fluid outlet 9. The fluid inlets 6, 8 and the fluid outlets 7, 9 are accessible from the outside.

[0024] The fluid outlet 9 of the second chamber 5 is connected to a fluid inlet of a condenser 10 of the heat pump 2. The condenser 10 is a fluid/air heat exchanger to exchange heat between the working fluid F and process air P.

[0025] A fluid outlet of the condenser 10 is connected to a fluid inlet of an expansion valve 11 of the heat pump 2. A fluid outlet of the expansion valve 11 is connected to a fluid inlet of an evaporator 12 of the heat pump 2. The evaporator 12 is also a fluid/air heat exchanger to exchange heat between the working fluid F and the process air P. A fluid outlet of the evaporator 12 is connected to the fluid inlet 6 of the first chamber 4 of the compressor 3.

[0026] Regarding the process air P, warm and moist process air P coming from a clothes drum (not shown, e.g. a horizontally rotatable drum) is channeled through the evaporator 12. In the evaporator 12, the working fluid F takes up heat from the process air P such that the process air P cools down and condensate rains out from it. Then, the cooler and dryer process air P is channeled through condenser 10. In the condenser 10, the working fluid F of the condenser 10 transfers heat to the process air P. After the condenser 10 the then warmer process

air P is introduced into the clothes drum.

[0027] The heat pump 2 also comprises a 4/2 distributor valve 13 having four ports P1, P2, P3 and P4. The outlet 7 of the first compression chamber 4 is connected to a first port P1 of the valve 13. The inlet 8 of the second compression chamber 5 is connected to a second port P2 of the valve 13. A third port P3 of the valve 13 is connected to the outlet of the evaporator 12. A fourth port P4 of the valve 13 is connected to the inlet of the condenser 10.

[0028] The valve 13 has two positions which can be set by a control module 14. The control module 14 can also be used to control other functions of the clothes dryer 1. Each of the two positions of the valve 13 corresponds to a respective cooling mode.

[0029] Therefore, the heat pump 2 comprises a working fluid circuit in which the working fluid F is circulated in the described direction. Its functional components compressor 3, condenser 10, expansion valve 11, evaporator 12, and valve 13 may be connected by pipes tubes etc. The process air P may circulates in a closed-loop process air circuit that comprises the clothes drum, the evaporator 12, the condenser 10, a fan or blower (not shown) for circulating the process air, eventually an additional heater etc.

[0030] In the shown full mode, the first port P1 is connected to the fourth port P4 and the third port P3 is connected to the second port P2. Therefore, in the full mode, the working fluid F coming from the evaporator 12 is lead to the inlet 6 of the first chamber 4 as well as to the inlet 8 of the second chamber 5. Both compression chambers 4, 5 are active such the working fluid F is compressed in both chambers 4 and 5. The part of the working fluid F being compressed in the first chamber 4 is released from the first chamber 4 though its outlet 7 and through the valve 13 to the inlet of the condenser 10. The part of the working fluid F being compressed in the second chamber 5 is released from the second compression chamber 5 though its outlet 9 to the inlet of the condenser 10. Therefore, the two compression chambers 4 and 5 are both active and fluidically connected in parallel. If, for example, the cooling capacity achieved by the first chamber 4 is 40 % and the cooling capacity achieved by the second chamber 4 is 60 % then their combined, parallel active operation achieves 100 % or full cooling capacity.

[0031] Fig.3 shows the household clothes dryer 1 in a reduced mode or eco mode in which the first port P1 of the valve 13 is connected to the second port P2 and the third port P3 is disconnected or blocked, as is the fourth port P4. The first chamber 4 is inactive. Thus, the working fluid F coming from the evaporator 12 is lead to the inlet 6 of the first chamber 4, through the first compression chamber 4 without compression, to the outlet 7, to the first port P1, to the second port P2, to the inlet port 8 of the second compression chamber, through the second compression chamber 5 where it is compressed, then through the outlet 9, and to the inlet of the condenser 10. A direct connection between the outlet of the evaporator

12 and the inlet of the condenser 10 is blocked by the disconnection between the ports P3 and P4.

[0032] Therefore, the two compression chambers 4 and 5 are fluidically connected in series. Since the first chamber 4 is inactive, the cooling capacity achieved in the reduced mode corresponds to the cooling capacity of the second compression chamber 5, i.e. 40 %.

[0033] In effect, different cooling capacities can be achieved by simply switching the valve 13 between its two positions. For this, the compressor 3 may be operated at a constant rotation speed. Therefore, a cost-effective and robust AC rotary compressor may be used as the compressor 3.

[0034] For example, depending on the concrete layout of the compression chambers 4 and 5, the compressor displacement may e.g. be 4 cc, 5 cc, 5,5 cc, or 6 cc, etc. for the eco mode and e.g. 8 cc, 10 cc, 11 cc, or 12 cc etc. for the full mode. If e.g. assuming a compressor displacement in the eco mode of 4 cc and of 12 cc in the full mode, a drying time per kg of to-be-dried clothes may be approx. cut in half when operating in the full mode in comparison to using the eco mode. Alternatively, by operating in the eco mode, a reduction in the energy consumption of approx. 30 % may be achieved in comparison to using the full mode.

[0035] Of course, the invention is not restricted to the described embodiments.

[0036] For example, instead of the 4/2-way distributor valve 13, any other arrangement of valves that achieves the same functionality can be used, e.g. a combination of two 3/2-way distributor valves. Also, these valves could be used to control an inactivation of the compression chamber 4, e.g. by using different control procedures.

LIST OF REFERENCE NUMERALS

[0037]

1	household clothes dryer
2	heat pump
3	compressor
4	first compression chamber
5	second compression chamber
6	fluid inlet of the first compression chamber
7	fluid outlet of the first compression chamber
8	fluid inlet of the second compression chamber
9	fluid outlet of the second compression chamber
10	condenser
11	expansion valve
12	evaporator
13	distributor valve
14	control module
F	working fluid
P	process air

Claims

1. A clothes drying apparatus (1), comprising a heat pump (2) having a rotary compressor (3) for compressing a working fluid (F) flowing through the heat pump (2), wherein the compressor (3) is a multi-chamber rotary compressor having at least two independently operable compression chambers (4, 5). 5
2. The clothes drying apparatus (1) according to claim 1, wherein the compressor (3) is operable in at least two modes with 10
 - a full mode using all compression chambers (4, 5) to compress the working fluid (F) and 15
 - at least one reduced mode in which at least one compression chamber (4) is inactive regarding compression of the working fluid (F).
3. The clothes drying apparatus (1) according to claim 2, wherein the working fluid (F) flows through the at least one inactive compression chamber (4). 20
4. The clothes drying apparatus (1) according to claim 2, wherein the working fluid (F) circumvents the at least one inactive compression chamber (4). 25
5. The clothes drying apparatus (1) according any of the preceding claims, wherein each compression chamber (4, 5) is connected to a respective fluid inlet (6, 8) and fluid outlet (7, 9). 30
6. The clothes drying apparatus (1) according to any of the preceding claims 3 to 5, wherein, 35
 - for operating in the full mode, all compression chambers (4, 5) are fluidically connected in parallel and,
 - for operating in at least one reduced mode, at least one inactive compression (4) chamber is fluidically connected to an active compression chamber (5) in series. 40
7. The clothes drying apparatus (1) according any of the preceding claims, wherein the compressor (3) is a two-chamber rotary compressor. 45
8. The clothes drying apparatus (1) according to claim 7, wherein 50
 - the clothes drying apparatus (1) further comprises a 4/2-way distributor valve (13),
 - an inlet (6) of a first compression chamber (4) is connected to an outlet of an evaporator (12) of the heat pump (2), 55
 - an outlet (7) of the first compression chamber (4) is connected to a first port (P1) of the valve (13),
 - an inlet (8) of the second compression chamber (5) is connected to a second port (P2) of the valve (13),
 - an outlet (9) of the second compression chamber (5) is connected to an inlet of a condenser (10) of the heat pump (2),
 - a third port (P3) of the valve (13) is connected to the outlet of the evaporator (12),
 - a fourth port (P4) of the valve (13) is connected to the inlet of the condenser (10),
 - in the full mode, the first port (P1) is connected to the fourth port (P4) and the third port (P3) is connected from the second port (P2), and
 - in the reduced mode, the first port (P1) is connected to the second port (P2) and the third port (P3) is disconnected from the fourth port (P4).
9. The clothes drying apparatus (1) according any of the preceding claims, wherein at least two compression chambers (4, 5) have different cooling capacities.
10. The clothes drying apparatus (1) according any of the preceding claims, wherein the compressor (3) is an AC rotary compressor.
11. The clothes drying apparatus (1) according to claim 10, wherein the compressor (3) is operated at a constant rotation speed.

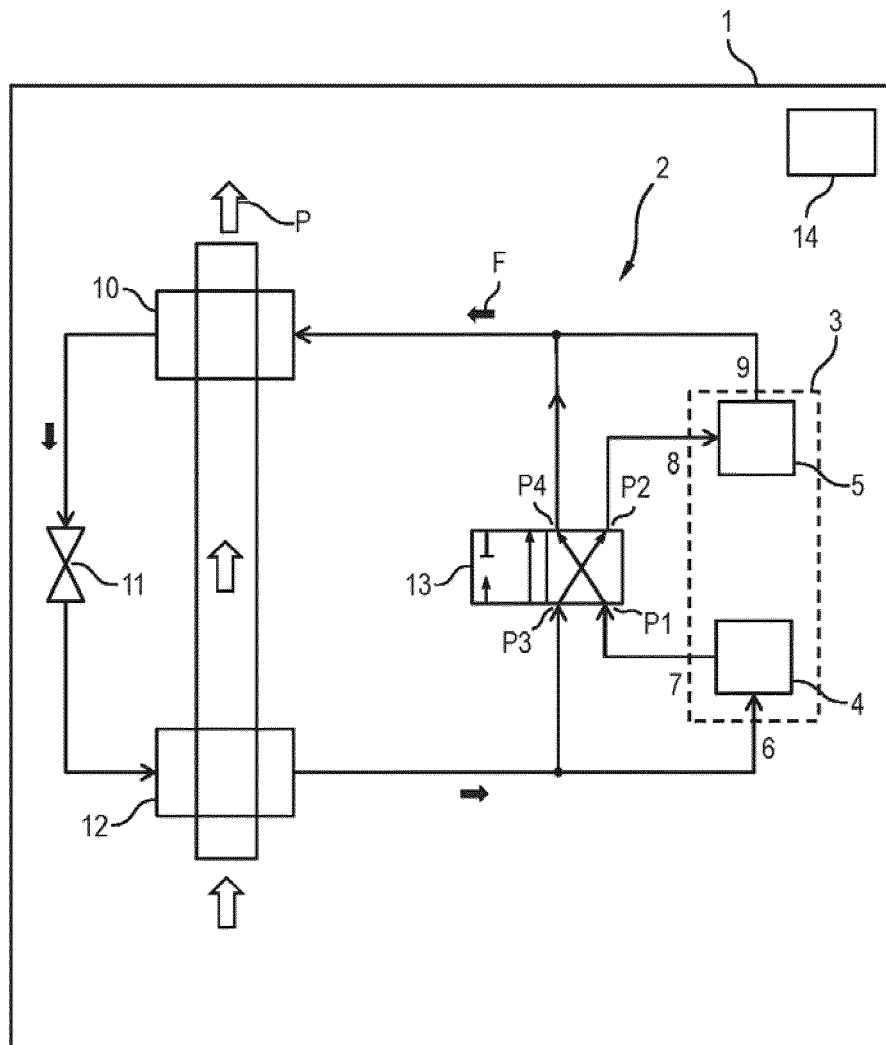


Fig.1

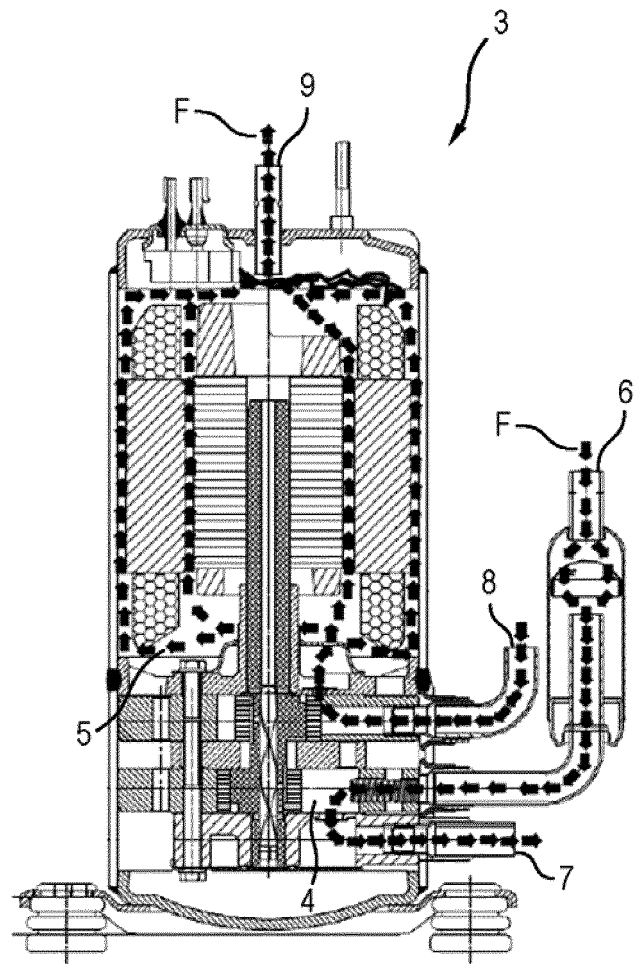


Fig.2

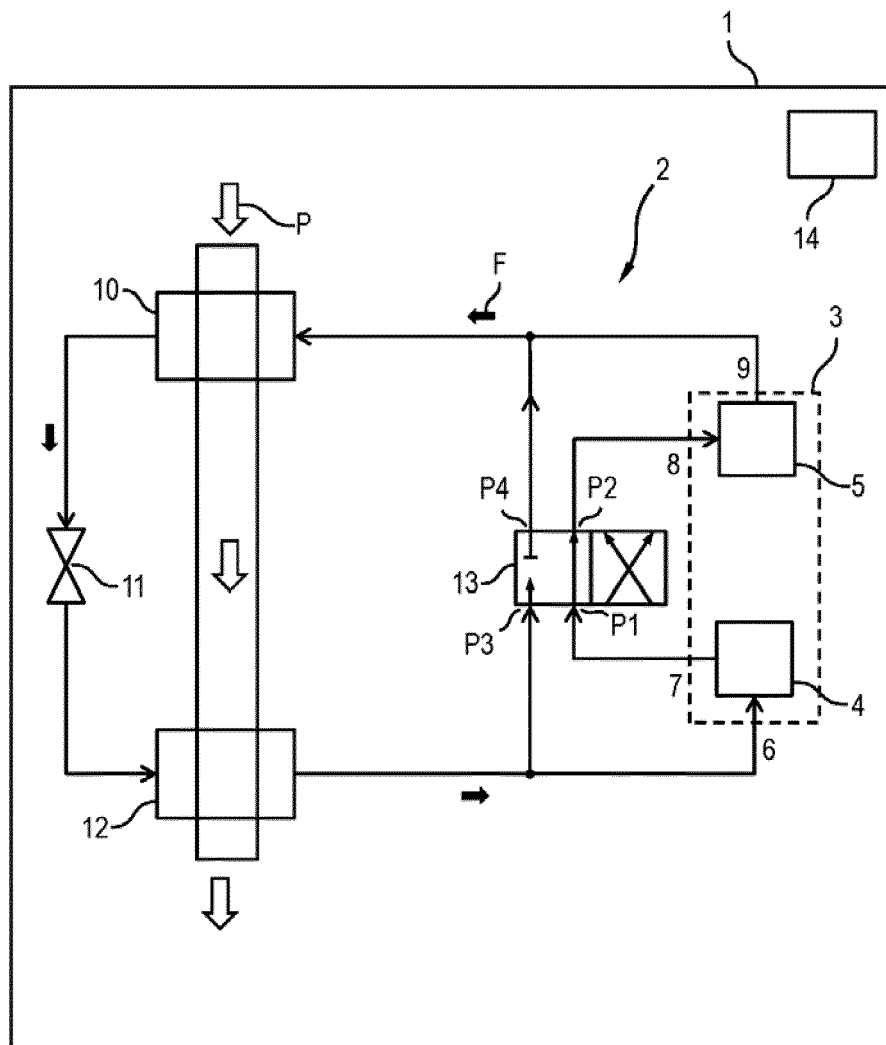


Fig.3



EUROPEAN SEARCH REPORT

Application Number
EP 16 38 2595

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 2 March 2017	Examiner Bermejo, Marco
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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EP 16 38 2595

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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