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(54) **RECOVERY OF HEAT GENERATED BY COMPRESSOR DRIVER**

(57) The present invention discloses a heat pump system including a refrigerant circuit, a compressor driver and an additional heat exchanger. The refrigerant circuit includes a compressor for compressing a refrigerant, a condenser downstream of the compressor for cooling the refrigerant, a throttling device downstream of the condenser for lowering the pressure of the refrigerant, and an evaporator downstream of the throttling device for vaporizing the refrigerant. The compressor driver is electrically connected with the compressor for powering the

compressor, and the compressor driver generates heat in operation. The additional heat exchanger is connected with the compressor driver to obtain the heat generated by the compressor driver, and the additional heat exchanger is placed in the refrigerant circuit for transferring the obtained heat to the refrigerant passing therethrough. In this way, the additional heat exchanger performs like an additional evaporator to increase the evaporation capacity, thereby reducing the possibility of liquid refrigerant entering the compressor.

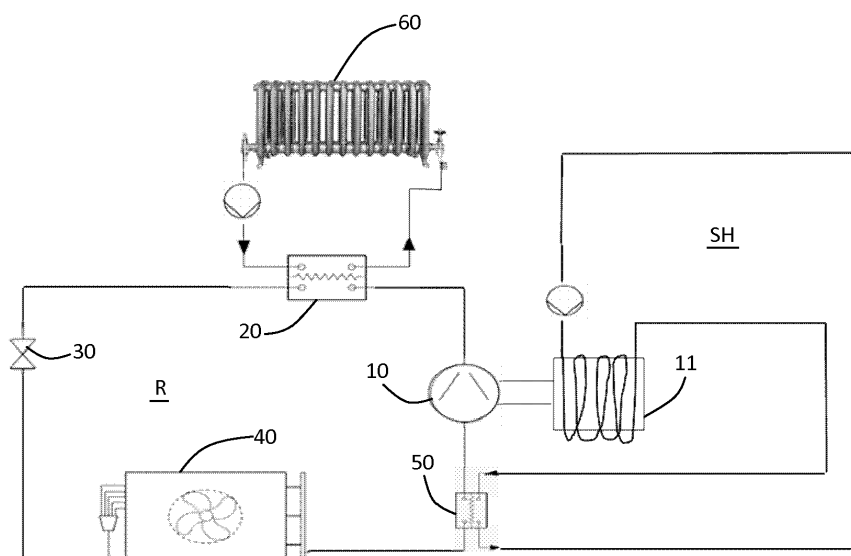


Fig. 1

Description

FIELD OF THE INVENTION

[0001] The present invention relates to a heat pump system, and more particularly to a heat pump system that can recover heat generated by a compressor driver in its operation.

BACKGROUND OF THE INVENTION

[0002] A basic heat pump system typically has a refrigerant circuit including a compressor, a condenser, an expansion valve, and an evaporator. These components are generally serially connected via conduits or piping. The compressor generally compresses a refrigerant from a low pressure gas state to a high pressure gas state. The gas refrigerant leaves from the compressor and then flows through the condenser for being condensed at a substantially constant pressure to a saturated liquid state. The expansion valve is used to control the amount of refrigerant entering into the evaporator. The liquid refrigerant from the condenser flows through the expansion valve, results in the pressure of the liquid is decreased. The evaporator then evaporates the refrigerant to change its state from liquid to gas by absorbing heat from a secondary flow, such as an air flow passing through the evaporator. The refrigerant discharged from the evaporator goes back to the compressor to repeat the cycle. In theory, the evaporation of the refrigerant is finished in the evaporator, and the refrigerant sucked into the compressor should be complete gas state. However, errors could not be totally avoided for an actual product to some extent, therefore, the refrigerant sucked into the compressor from the evaporator may not be changed into the super-heated vapor that has evaporated beyond the saturated state. As a result, noise is increased and performance of the compressor is deteriorated.

[0003] The compressor generally compresses or expands the refrigerant by using a piston connected to a motor. Usually, a compressor driver is connected between the mains supply and the compressor, and is also connected with a control board of the heat pump system. The compressor driver receives the control commands and the speed set-point from the control board, and then converts the power with the normal shape of the mains supply into a waveform that is suitable for powering the motor of the compressor to achieve a required speed set-point. The compressor driver generally includes a casing, and a lot of electronic components and specific circuits contained therein, such as MCU, IGBT(Insulated Gate Bipolar Transistor) modules, EMC filters, and PFC (Power Factor Correction) circuits. These electronic parts generate heat during the driver operation. To avoid thermal overload, the driver is usually equipped with a heat sink, like fins attached to the casing to dissipate heat with forced air flow, in the period, the heat sink may reach a temperature of 90° to 125° during the driver operation.

However, up to now, the heat generated by the compressor driver is dissipated into the ambient air without recycling.

SUMMARY OF THE INVENTION

[0004] It is an object of present invention to provide a heat pump system that can recover heat generated by the compressor driver and use the heat to increase the evaporation capacity, thereby reducing the possibility of liquid refrigerant entering the compressor and improving performance and efficiency of the system.

[0005] According to one aspect of the present invention there is provided a heat pump system including a refrigerant circuit, a compressor driver and an additional heat exchanger. The refrigerant circuit includes a compressor for compressing a refrigerant, a condenser downstream of the compressor for cooling the refrigerant, a throttling device downstream of the condenser for lowering the pressure of the refrigerant, and an evaporator downstream of the throttling device for vaporizing the refrigerant. The compressor driver is electrically connected with the compressor for powering the compressor, and the compressor driver generates heat in operation. The additional heat exchanger is connected with the compressor driver to obtain the heat generated by the compressor driver, and the additional heat exchanger is placed in the refrigerant circuit for transferring the obtained heat to the refrigerant passing therethrough. In this way, the additional heat exchanger performs like an additional evaporator to increase the evaporation capacity. Even if the liquid refrigerant could not be phase changed into a complete gas state in the evaporator, the additional heat exchanger can further heat the refrigerant to change its state into the super-heated vapor that has evaporated beyond the saturated state. Therefore, the possibility of liquid refrigerant entering the compressor can be reduced, and performance and efficiency of the system can be improved accordingly.

[0006] In one embodiment, the additional heat exchanger transfers the obtained heat to the refrigerant after the refrigerant flowing through the evaporator.

[0007] Preferably, the additional heat exchanger is placed at an inlet of the compressor.

[0008] In an alternative embodiment, the additional heat exchanger transfers the obtained heat to the refrigerant before the refrigerant flowing through the evaporator.

[0009] Preferably, the additional heat exchanger is disposed at an inlet of the evaporator.

[0010] In one embodiment, the additional heat exchanger is connected with the compressor driver via fluid pipes, and a working medium flows in the fluid pipes to transfer the heat from the compressor driver to the additional heat exchanger.

[0011] Preferably, the working medium is in liquid form.

[0012] In a preferred embodiment, the refrigerant circuit has a first heat exchanger operating as the condens-

er in a heating mode and operating as the evaporator in a cooling mode, and a second heat exchanger operating as the evaporator in the heating mode and operating as the condenser in the cooling mode.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

Fig.1 is a diagram showing the configuration of a heat pump system in accordance with a first embodiment of present invention;

Fig.2 is a diagram showing the configuration of a heat pump system in accordance with a second embodiment of present invention;

Fig.3 is a diagram showing the configuration of a heat pump system in accordance with a third embodiment of present invention;

Fig. 4 is a diagram showing the configuration of a heat pump system in accordance with a fourth embodiment of present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] Reference will now be made to the drawing figures to describe the preferred embodiments of the present invention in detail. However, the embodiments can not be used to restrict the present invention. Changes such as structure, method and function obviously made to those of ordinary skill in the art are also protected by the present invention.

[0015] Refer to Fig.1, a heat pump system according to a first embodiment of present invention can be used for heating building interiors. The heat pump system includes a refrigerant circuit R and a superheating circuit SH. The refrigerant circuit R typically includes a compressor 10, a first heat exchanger 20 operating as a condenser, a throttling device 30, and a second heat exchanger 40 operating as an evaporator. The compressor 10 generally uses electrical power to compress a refrigerant from a low pressure gas state to a high pressure gas state thereby increasing the temperature, enthalpy and pressure of the refrigerant. The first heat exchanger 20 can be a plate-type heat exchanger. The refrigerant leaving from the compressor 10 flows through the first heat exchanger 20 for being condensed at a substantially constant pressure to a saturated liquid state. In this process, a heat transfer medium, such as water passing through the first heat exchanger 20 obtains heat from the refrigerant flow and flows through a space heating/cooling circuit 60 to dissipate heat into building interiors. The

space heating/cooling circuit 60 can be placed within a building (now shown) and allows hot or cold water acting as the heat transfer medium to pass therethrough for heating or cooling the building interiors.

[0016] The throttling device 30 can take form of an electronic expansion valve for being used to control the amount of the refrigerant entering into the second heat exchanger 40. The liquid refrigerant from the first heat exchanger 20 flows through the electronic expansion valve 30, result in the pressure of the liquid is decreased. In the process, the refrigerant evaporates partially causing the refrigerant to change to a mixed liquid-gas state, reducing its temperature down to a value that makes possible heat exchanges in the second heat exchanger 40. The second heat exchanger 40 is a heat exchanger where the heat energy available in a working medium, like air flow is transferred to the refrigerant flow that evaporates inside from liquid to gas. The gas refrigerant discharged from the second heat exchanger 40 is sucked into the compressor 10 and repeats the refrigerant cycle for heating purpose.

[0017] An additional heat exchanger 50 that can take form of a plate-type heat exchanger is connected in the refrigerant circuit R. Along the flowing direction of the refrigerant, the additional heat exchanger 50 is placed after the second heat exchanger 40 that is acting as the evaporator, and preferably at an inlet of the compressor 10. A compressor driver 11 is electrically connected with the compressor 10 to convert the power with the normal shape of the mains supply into a waveform that is suitable for powering a motor of the compressor to achieve a required speed set-point. The compressor driver 11 includes a casing, and a lot of electronic components and specific circuits contained in the casing, such as MCU, IGBT(Insulated Gate Bipolar Transistor) modules, EMC filters, and PFC (Power Factor Correction) circuits. These electronic parts generate heat during the driver operation, and in order to avoid thermal overload, the driver can be equipped with a heat sink, like fins attached to the casing to dissipate heat with forced air flow.

[0018] The additional heat exchanger 50 is connected with the compressor driver 11 via fluid pipes to form the super-heating circuit SH. The fluid pipes can be made from appropriate metallic material, like aluminum, copper, or alloy containing aluminum or copper. Part of the fluid pipes encircles the casing of the compressor driver 11 or attached the heat sink so that the heat generated by the compressor driver 11 can be absorbed by a working medium flowing in the fluid pipes. The working medium can be in liquid form, like water. In an alternative embodiment, the working medium can also be in gaseous state, and in this embodiment, the forced air flow passing through the heat sink for absorbing heat generated by the compressor driver 11 can be collected and guided into the fluid pipes to act as the working medium. The working medium is pumped to circulate in the super-heating circuit SH. The working medium obtains heat when it passes through the compressor driver 11, and transfers

the obtained heat to the refrigerant when it passes through the additional heat exchanger 50. In present embodiment, the additional heat exchanger 50 performs like an additional evaporator to increase the evaporation capacity, by this means, even if the liquid refrigerant could not be phase changed into a complete gas state in the second heat exchanger 40, the additional heat exchanger 50 can further heat the refrigerant to change its state into the super-heated vapor that has evaporated beyond the saturated state. Therefore, the possibility of liquid refrigerant entering the compressor can be reduced, and performance and efficiency of the system can be improved accordingly.

[0019] Fig. 2 shows a second embodiment that the heat pump system works for cooling interiors of buildings. Compared with the first embodiment, the refrigerant cycle is inverted for cooling purpose. In this embodiment, the first heat exchanger 20 operates as the evaporator, and the second heat exchanger 40 operates as the condenser. In the first heat exchanger 20 (evaporator), the heat transfer medium, like water dissipates heat to the refrigerant for vaporizing the refrigerant, and the water becoming cold passes through the space heating/cooling circuit 60 for cooling the building interiors. Along the flowing direction of the refrigerant, the additional heat exchanger 50 is placed after the first heat exchanger 20 acting as the evaporator now, preferably at the inlet of the compressor 10. By this means, the refrigerant after flowing through the evaporator can be further heated in the additional heat exchanger 50, thereby reducing the possibility of liquid refrigerant entering the compressor 10.

[0020] Fig. 3 shows a third embodiment that the heat pump system works for heating purpose. Compared with the first embodiment, the only difference is the place of the additional heat exchanger. In this embodiment, along the flowing direction of the refrigerant, the additional heat exchanger 50 is placed before the second heat exchanger 40 that is acting as the evaporator now, preferably at an inlet of the second heat exchanger 40. In this way, the temperature of the refrigerant is increased before the refrigerant entering into the evaporator, and more energy are used to change the refrigerant phase from liquid form into gaseous state, thereby reducing the possibility of liquid refrigerant entering the compressor 10. Fig. 4 shows a fourth embodiment that the heat pump system works for cooling purpose. Compared with the second embodiment, the only difference is the place of the additional heat exchanger. In this embodiment, along the flowing direction of the refrigerant, the additional heat exchanger 50 is placed before the first heat exchanger 20 that is acting as the evaporator now, preferably at the inlet of the first heat exchanger 20. In this way, the temperature of the refrigerant is increased before the refrigerant entering into the evaporator, and more energy are used to change the refrigerant phase from liquid form into gaseous state, thereby reducing the possibility of liquid refrigerant entering the compressor 10.

[0021] It would be apparent to those skilled in the art

that, the refrigerant circuit R can further include a reversing valve, like a four-way valve for switching the refrigerant cycle between a heating mode and a cooling mode. In this embodiment, the first heat exchanger 20 operates as the condenser in the heating mode and operating as the evaporator in the cooling mode, and the second heat exchanger 40 operates as the evaporator in the heating mode and operates as the condenser in the cooling mode. Two additional heat exchangers 50 can be placed in the refrigerant circuit R, and be selectively energized in the heating mode and the cooling mode respectively to increase the evaporation capacity of the system. For example, one additional heat exchanger can be placed after the second heat exchanger 40 (as shown in Fig. 1) or before the second heat exchanger 40 (as shown in Fig. 3) for being energized in the heating mode, and the other additional heat exchanger can be placed after the first heat exchanger 20 (as shown in Fig. 2) or before the first heat exchanger 20 (as shown in Fig. 4) for being energized in the cooling mode. In this case, a three-way valve (not shown) can be provided and connected with the two additional heat exchangers to energize appropriate one of them in the heating or cooling mode to increase the evaporation capacity with additional energy obtained from the compressor driver 11, thereby reducing the possibility of liquid refrigerant entering the compressor 10.

[0022] It is to be understood, however, that even though numerous, characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosed is illustrative only, and changes may be made in detail, especially in matters of number, shape, size, and arrangement of parts within the principles of the invention to the full extent indicated by the broadest general meaning of the terms in which the appended claims are expressed.

Claims

1. A heat pump system comprising:

a refrigerant circuit (R) comprising a compressor (10) for compressing a refrigerant, a condenser (20, 40) downstream of the compressor for cooling the refrigerant, a throttling device (30) downstream of the condenser for lowering the pressure of the refrigerant, and an evaporator (40, 20) downstream of the throttling device for vaporizing the refrigerant;

a compressor driver (11) electrically connected with the compressor for powering the compressor, said compressor driver generating heat in operation; **characterized in that**

an additional heat exchanger (50) is connected with the compressor driver to obtain the heat generated by the compressor driver, and said additional heat exchanger is disposed in the re-

frigerant circuit for transferring the obtained heat to the refrigerant passing therethrough.

2. A heat pump system according to claim 1, **characterized in that** said additional heat exchanger transfers the obtained heat to the refrigerant after the refrigerant flowing through the evaporator. 5
3. A heat pump system according to claim 2, **characterized in that** said additional heat exchanger is placed at an inlet of the compressor. 10
4. A heat pump system according to claim 1, **characterized in that** said additional heat exchanger transfers the obtained heat to the refrigerant before the refrigerant flowing through the evaporator. 15
5. A heat pump system according to claim 4, **characterized in that** said additional heat exchanger is disposed at an inlet of the evaporator. 20
6. A heat pump system according to claim 1, **characterized in that** said additional heat exchanger is connected with the compressor driver via fluid pipes, and a working medium flows in the fluid pipes to transfer the heat from the compressor driver to the additional heat exchanger. 25
7. A heat pump system according to claim 6, **characterized in that** said working medium is in liquid form. 30
8. A heat pump system according to claim 1, **characterized in that** said refrigerant circuit has a first heat exchanger (20) operating as the condenser in a heating mode and operating as the evaporator in a cooling mode, and a second heat exchanger (40) operating as the evaporator in the heating mode and operating as the condenser in the cooling mode. 35

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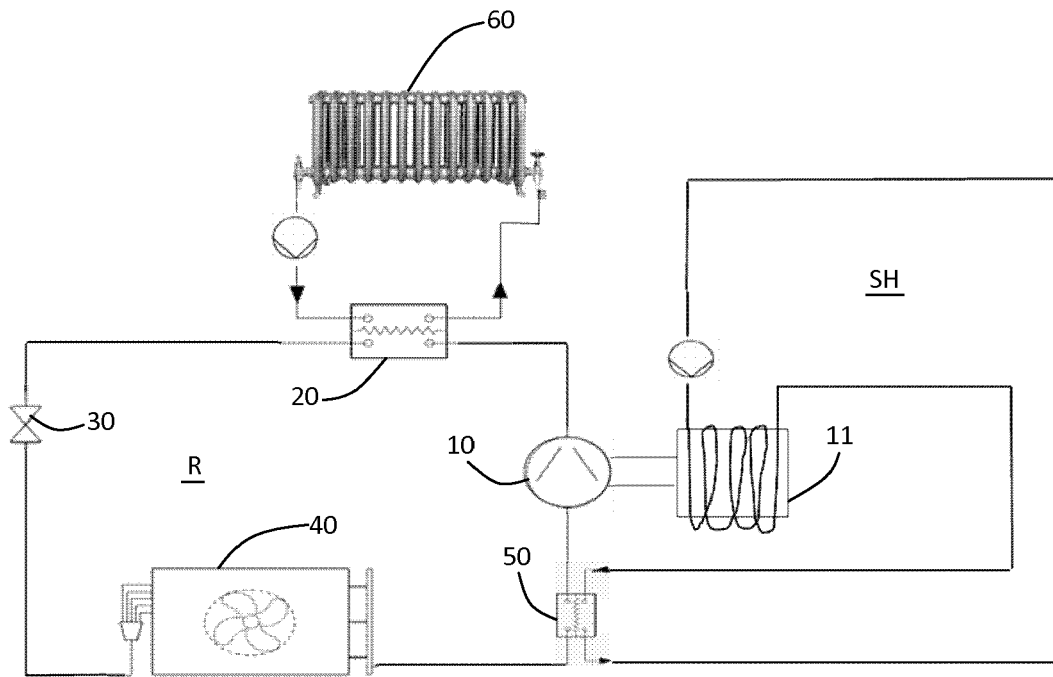


Fig. 1

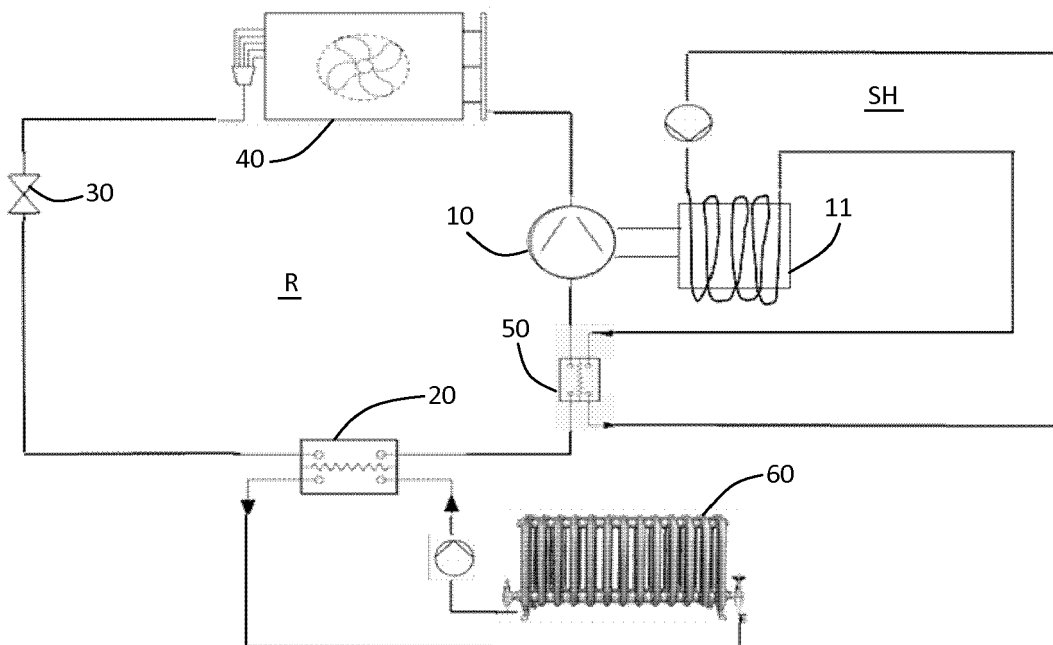


Fig. 2

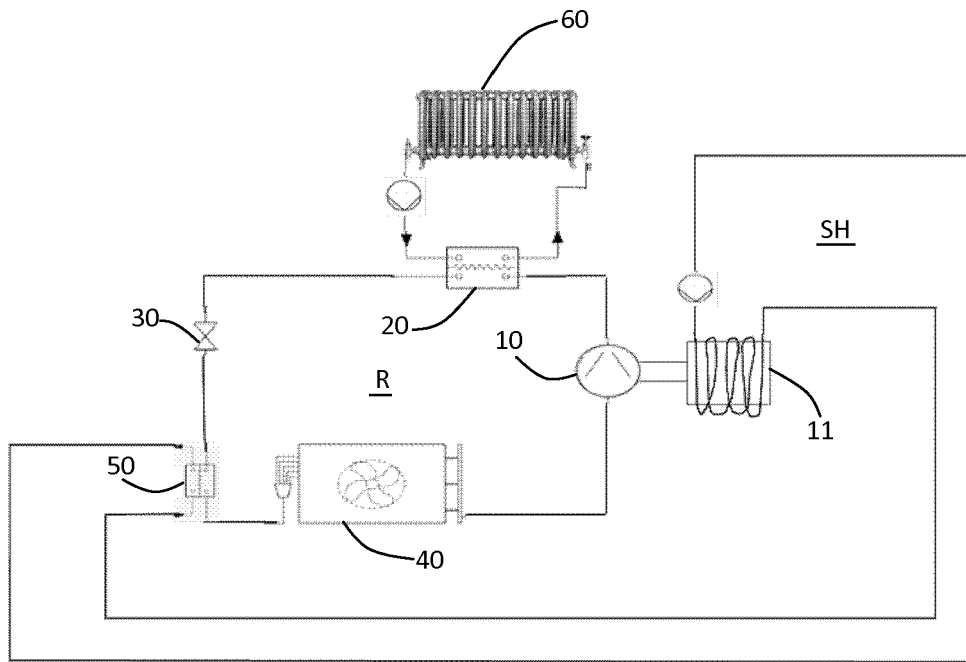


Fig. 3

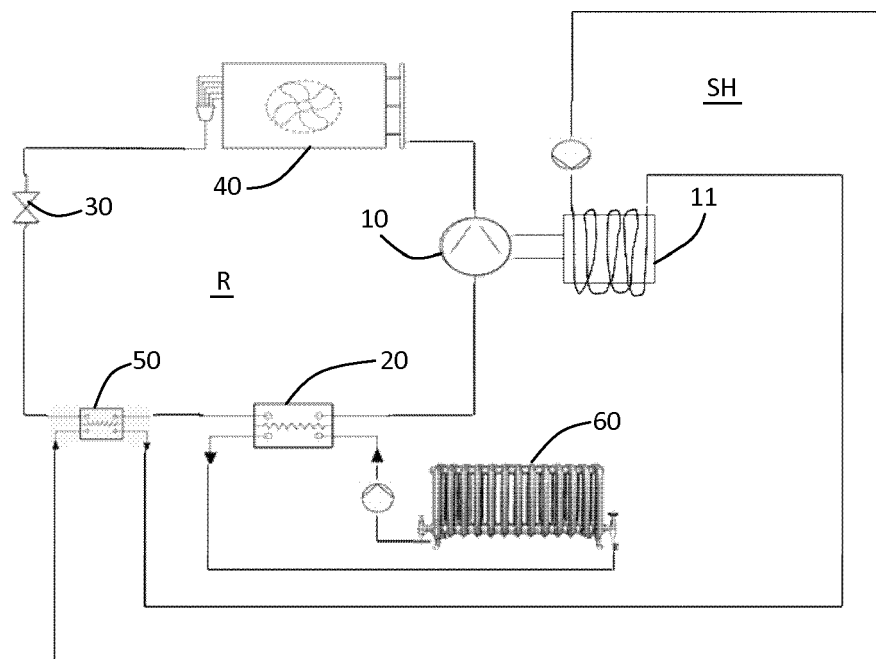


Fig. 4



EUROPEAN SEARCH REPORT

Application Number
EP 16 15 9292

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Place of search Munich		Date of completion of the search 12 August 2016	Examiner Ritter, Christoph
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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