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(54) Energy control for vapour injection

(57) The present invention discloses a heat pump system including a compressor for compressing a refrigerant, a condenser downstream of the compressor for cooling the refrigerant, a main expansion valve downstream of the condenser for lowering the pressure of the refrigerant, an evaporator downstream of the main expansion valve for vaporizing the refrigerant, an economizer heat exchanger for allowing a refrigerant flow downstream of the condenser and an economizer flow tapped upstream or downstream of the economizer heat exchanger itself to transfer heat therein, and an economizer expansion valve for controlling the amount of economizer flow entering the economizer heat exchanger through the economizer flow inlet. The economizer heat exchanger has a refrigerant flow inlet and a refrigerant flow outlet, and an economizer flow inlet and an economizer flow outlet. Wherein, opening of the economizer expansion valve is adjusted according to the temperature at the refrigerant flow outlet T3 and/or the temperature at the economizer flow inlet T2. In this way, the control of the economizer expansion valve and thus the amount of injected vapor is smooth and stable.

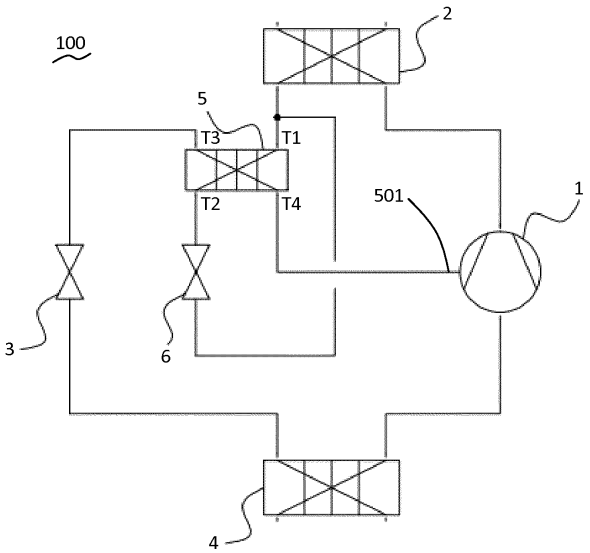


Fig. 1

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a heat pump system wherein an economizer heat exchanger is used as an evaporator for the vapor injection into a compressor.

BACKGROUND OF THE INVENTION

[0002] A basic heat pump system typically has a compressor, a condenser, an expansion device, and an evaporator. These components are generally serially connected via conduits or piping and are well known in the art. It would be desirable to achieve increased capacity or increased efficiency operation for the heat pump system. One way of achieving increased capacity or increased efficiency operation is the inclusion of an economizer circuit into the heat pump system. An economizer circuit essentially provides heat transfer between a main refrigerant flow downstream of the condenser and a second refrigerant flow (namely an economizer flow) in an economizer heat exchanger. Under certain operational conditions, the second refrigerant flow is tapped upstream or downstream of the economizer heat exchanger.

[0003] Fig.1 discloses the upstream solution. A compressor 1 discharges high temperature and high pressure gas into a condenser 2, then the refrigerant flow is divided into two parts: one part (the main refrigerant flow) enters an economizer heat exchanger 5 directly, and the other part (the economizer flow) passes through an economizer expansion valve 6 then enters the economizer heat exchanger 5 as vapor/liquid mixture at an intermediate pressure. In this way, the main refrigerant flow from the condenser 2 is subcooled by the economizer flow before passing through a main expansion valve 3 and entering the evaporator 4, and the economizer flow is superheated in the economizer heat exchanger 5 and injected through a vapor injection line 501 to an intermediate-pressure point of the compressor 1 after leaving the economizer heat exchanger 5, thereby achieving a higher mass flow in the compressor 1 and thus a higher heating capacity. Since the injected vapor is at an intermediate pressure, it requires less energy to compress it to a pressure discharging to the condenser than if it has been injected at an evaporator pressure for suction of the compressor. This results in a reduction of specific work in the compressor which in turn results in improved system efficiency.

[0004] Fig. 2 discloses the downstream solution. In this case, the compressor 1 discharges the refrigerant flow into the condenser 2, then the refrigerant flow passes through the economizer heat exchanger 5 where it will be subcooled. After that, the refrigerant flow is divided into two parts: one part (the main refrigerant flow) passes through the main expansion valve 3 and then continues the refrigerant cycle through the evaporator 4 and compressor suction; the other part (the economizer flow) is evaporated with the heat form the main refrigerant flow and then enters the compressor via the vapor injection line 501.

[0005] In any of the two solutions, the superheating control can be achieved according to the temperature at the compressor injection inlet port. As an economizer circuit shown in Fig. 8, a valve 66 is a thermostatic expansion valve, and a temperature sensing bulb 76 is placed at the compressor injection inlet port to monitor the temperature change of the economizer heat exchanger 5. The change in the working conditions causes the valve 66 to open or close, thereby adjusting the amount of the economizer flow to be injected into the compressor 1. Fig. 9 shows an alternative case wherein a valve 67 is an electronic expansion valve. The electronic expansion valve 67 works the same with the thermostatic expansion valve 66, except that the conditions at the compressor injection inlet port are detected in electronic form by a temperature sensor 77 and a pressure sensor 86.

[0006] Figs. 10 and 11 show the temperature distribution of the main refrigerant flow and the economizer flow inside and along the economizer heat exchanger 5 when the economizer expansion valve is closed and widely open, respectively. Refer to Fig. 10, when the valve is closed, no economizer flow (shown in broken line) is produced and no heat exchange exists in the economizer heat exchanger 5, therefore, the temperature at refrigerant flow inlet T1 equals to the temperature at refrigerant flow outlet T3, and the temperature at economizer flow inlet T2 equals to the temperature at economizer flow outlet T4. Since there is no economizer flow now, the temperatures at economizer flow inlet and outlet T2, T4 depend on the conditions. Refer to Fig. 11, when the economizer expansion valve is widely open, the main refrigerant flow is subcooled, which result in the temperature at refrigerant flow outlet T3 decreases and tends to the temperature at economizer flow inlet T2, and the economizer flow is superheated and therefore the temperature at economizer flow outlet T4 increases. However, as the opening of the economizer expansion valve is adjusted step by step, the temperature at compressor injection inlet port, namely T4, does not increase regularly or proportionally, in fact, change of T4 is almost nothing in a long period after starting opening the economizer expansion valve, and the T4 goes up sharply when it is getting to the superheating target. Obviously, this is difficult to predict where the superheating starts and ends, it is also difficult to control the economizer expansion valve and thus the amount of injected vapor into the compressor in a stable and reliable way, especially in the case to reach a small superheating target.

SUMMARY OF THE INVENTION

[0007] It is an object of present invention to provide a heat pump system wherein the amount of injected vapor

is controlled in a reliable and stable way.

[0008] According to one aspect of the present invention there is provided a heat pump system including a compressor for compressing a refrigerant, a condenser downstream of the compressor for cooling the refrigerant, a main expansion valve downstream of the condenser for lowering the pressure of the refrigerant, an evaporator downstream of the main expansion valve for vaporizing the refrigerant, an economizer heat exchanger for allowing a refrigerant flow downstream of the condenser and an economizer flow tapped upstream or downstream of the economizer heat exchanger itself to transfer heat therein, and an economizer expansion valve for controlling the amount of economizer flow entering the economizer heat exchanger through the economizer flow inlet. The economizer heat exchanger has a refrigerant flow inlet and a refrigerant flow outlet, and an economizer flow inlet and an economizer flow outlet. Wherein, opening of the economizer expansion valve is adjusted according to the temperature at the refrigerant flow outlet T3 and/or the temperature at the economizer flow inlet T2. In this way, the control of the economizer expansion valve and thus the amount of injected vapor is smooth and stable.

[0009] When the opening is adjusted according to the temperatures T3 and T2, it will be appreciated to use the temperature difference T3-T2 because using temperature difference can remove the influence of working conditions.

[0010] In one embodiment, the temperature at the refrigerant flow outlet T3 and the temperature at the economizer flow inlet T2 are both detected by temperature sensors.

[0011] In an alternative embodiment, the temperature at the refrigerant flow outlet T3 is detected by a temperature sensor, and the temperature at the economizer flow inlet T2 is detected by a pressure sensor and converted via a function to temperature.

[0012] Preferably, the pressure sensor detects a pressure at the economizer flow inlet.

[0013] Alternatively, the pressure sensor detects a pressure at the economizer flow outlet since it substantially equals to a pressure at the economizer flow inlet.

[0014] The economizer expansion valve can be an electronic expansion valve.

[0015] The economizer expansion valve can also be a thermostatic expansion valve, and in this case, the opening of the economizer expansion valve is adjusted according to the temperature at the refrigerant flow outlet T3. The temperature T3 is detected by a temperature sensing bulb, and the thermostatic expansion valve automatically controls its opening according to the detected temperature T3.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] 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 shows one example of a heat pump system including an economizer circuit for vapor injection application;

Fig. 2 shows another example of a heat pump system including an economizer circuit for vapor injection application;

Fig. 3 is a schematic view showing a first embodiment of the economizer circuit included in the heat pump system as shown in Fig. 1 or 2;

Fig. 4 is a schematic view showing a second embodiment of the economizer circuit included in the heat pump system as shown in Fig. 1 or 2;

Fig. 5 is a schematic view showing a third embodiment of the economizer circuit included in the heat pump system as shown in Fig. 1 or 2;

Fig. 6 is a schematic view showing a fourth embodiment of the economizer circuit included in the heat pump system as shown in Fig. 1 or 2;

Fig. 7 is a diagram schematically showing variations of a temperature at refrigerant flow outlet, a temperature at economizer flow inlet, and the difference between these two temperatures along opening of an economizer expansion valve;

Fig. 8 is a schematic view showing an economizer circuit in the state of art, wherein the economizer circuit includes a thermostatic expansion valve;

Fig. 9 is a schematic view showing another economizer circuit in the state of art, wherein the economizer circuit includes an electronic expansion valve;

Fig. 10 shows temperature distribution of an refrigerant flow passing through an economizer heat exchanger of the economizer circuit as shown in Fig. 9 or 10, wherein the expansion valve is closed;

Fig. 11 shows temperature distributions of an refrigerant flow and an economizer flow passing through an economizer heat exchanger of the economizer circuit as shown in Fig. 9 or 10, wherein the expansion valve is widely open.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] 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.

[0018] Heat pumps can be used for heating purpose, like supplying hot sanitary water, or heating building interiors. Refer to Figs. 1 and 2, a heat pump system typically includes a compressor 1, a condenser 2, a main expansion valve 3, and an evaporator 4. These components are generally serially connected via conduits or piping. The compressor 1 generally uses electrical power to compress a refrigerant form a low pressure gas state to a high pressure gas state thereby increasing the temperature, enthalpy and pressure of the refrigerant. The condenser 2 is typically in form of a heat exchanger well known in the state of art. The gas refrigerant leaves from the compressor 1 and then flows through the condenser 2 for being condensed at a substantially constant pressure to a saturated liquid state. The main expansion valve 3 is used to control the amount of refrigerant entering into the evaporator 4. The liquid refrigerant from the condenser 2 flows through the main expansion valve, 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 evaporator. The evaporator 4 is a heat exchanger where the heat energy available in a secondary flow, such as an external air flow, passes through it and transfers to the refrigerant flow that evaporates inside from liquid to gas. Heat pumps can further include components in the refrigerant circuit for inversion of the refrigerant cycle, thus, heat pumps can also be used for cooling building interiors.

[0019] The heat pump system is provided with an economizer circuit including an economizer heat exchanger 5 and an economizer expansion valve 6. The economizer heat exchanger 5 includes a refrigerant flow inlet and a refrigerant flow outlet for allowing a main refrigerant flow to pass therethrough, and an economizer flow inlet and an economizer flow for allowing an economizer flow to pass therethrough. The economizer flow is a secondary refrigerant flow tapped upstream of the economizer heat exchanger (as shown in Fig. 1) or downstream of the economizer heat exchanger (as shown in Fig. 2), which passes through the economizer expansion valve 5 via the economizer flow inlet and outlet sequentially. The economizer flow is superheated by the main refrigerant flow, and injected through a vapor injection line 501 to an intermediate-pressure point of the compressor 1. In this way, the compressor achieves a higher mass flow and thus has a higher heating capacity.

[0020] The economizer expansion valve 6 is used to control the amount of economizer flow entering the economizer heat exchanger 5, and accordingly the amount of gas injected into the compressor 1. With reference to Fig. 7, as the economizer expansion valve 6 opens step by step, the temperature at refrigerant flow outlet T3 decreases and the temperature at economizer flow inlet T2 increases. As shown by the curves 91 and 93 in this figure, the variation of each of T2 and T3 is regular and stable, so it's possible to predict how far the superheating is away from the target, and then adjust the opening of the economizer expansion valve 6 to a desired size. The curve 93 represents the variation of the temperature difference T3-T2 along opening of the valve, which is regular and stable as well. Since T2 and T3 both depend on working conditions, it would be complicated to control because a corresponding working condition has to be considered. Accordingly, in a preferred embodiment, control of the opening of the economizer expansion valve 6 is based on the temperature difference T3-T2 because this temperature difference can remove the influence of working conditions. In other words, the curve 91/92 representing the temperature variation of T2/T3 is different in different working conditions, however, the curve 93 representing the variation of temperature difference T3-T2 is almost the same in every working condition.

[0021] Fig. 3 shows a first embodiment of the economizer circuit provided in the heat pump system aforementioned. The economizer circuit includes an economizer expansion valve 61, a first temperature sensor 71, and a second temperature sensor 72. In this embodiment, the economizer expansion valve is an electronic expansion valve. The first temperature sensor 71 can be placed at the economizer flow inlet to detect the temperature T2 thereof, and the second temperature sensor 72 can be placed at the refrigerant flow outlet to detect the temperature T3 thereof. The signals representing temperatures T2 and T3 can feed to a controller (not shown) of the system, then the controller can calculate the temperature difference between T2 and T3, and adjust the opening size of the economizer expansion valve 61 according to the relationship as shown by the curve 93 in the Fig. 7.

[0022] Fig. 4 shows an alternative embodiment of the economizer circuit. Since the economizer flow passing through the economizer flow inlet and outlet is saturated vapor and the temperature T2 is the evaporation temperature, the temperature T2 can also be detected by a pressure sensor and then converted via a function to temperature. In other words, the first temperature sensor 71 in the first embodiment can be replaced by a pressure sensor 81 in present embodiment, and the detected pressure can be converted to a corresponding temperature T2. Refer to Fig. 5, as the economizer flow passes through the economizer flow inlet and outlet at a substantially constant pressure, the pressure sensor 81 can be placed at the economizer flow outlet to detect a pressure thereof which is substantially equals to the pressure at the economizer flow inlet. The controller receives the signal representing the pressure value and converts it to a corresponding temperature at the economizer flow inlet T2.

[0023] Fig. 6 shows a further embodiment of an economizer circuit employing a thermostatic expansion valve 62. The valve 62 has a temperature sensing bulb 73 placed at the refrigerant flow outlet to sense the temper-

ature T3 thereof. It would be apparent to those skilled in the art that, the bulb 73 can cause the valve to open against the spring pressure in the valve body as the temperature on the bulb increases, and cause the valve to close when the temperature decreases. Therefore, the economizer expansion valve 62 automatically controls its opening according to the detected temperature T3. Those skilled in the art will also understand that the economizer expansion valve can be adjusted only based on the temperature at the economizer flow inlet T2. For example, the economizer expansion valve can be an electronic expansion valve, and a temperature sensor is placed at the economizer inlet to detect the temperature T2. The controller receives the signal representing temperature T2, and controls the opening of the economizer expansion valve according to the relationship as shown by the curve 92 of the Fig. 7 in a specific working condition.

[0024] 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 compressor for compressing a refrigerant, a condenser downstream of the compressor for cooling the refrigerant, a main expansion valve downstream of the condenser for lowering the pressure of the refrigerant, an evaporator downstream of the main expansion valve for vaporizing the refrigerant;
an economizer heat exchanger for allowing a refrigerant flow downstream of the condenser and an economizer flow tapped upstream or downstream of the economizer heat exchanger itself to transfer heat therein, said economizer heat exchanger having a refrigerant flow inlet and a refrigerant flow outlet, and an economizer flow inlet and an economizer flow outlet;
an economizer expansion valve for controlling the amount of economizer flow entering the economizer heat exchanger through the economizer flow inlet, wherein
opening of the economizer expansion valve is adjusted according to the temperature at the refrigerant flow outlet (T3) and/or the temperature at the economizer flow inlet (T2).

2. A heat pump system according to claim 1, wherein the opening of the economizer expansion valve is adjusted according to the temperature difference at the refrigerant flow outlet and at the economizer flow inlet (T3-T2).

3. A heat pump system according to claim 2, wherein the temperature at the refrigerant flow outlet (T3) and the temperature at the economizer flow inlet (T2) are both detected by temperature sensors.

4. A heat pump system according to claim 2, wherein the temperature at the refrigerant flow outlet (T3) is detected by a temperature sensor, and the temperature at the economizer flow inlet (T2) is detected by a pressure sensor and converted via a function to temperature.

5. A heat pump system according to claim 4, wherein the pressure sensor detects a pressure at the economizer flow inlet.

6. A heat pump system according to claim 4, wherein the pressure sensor detects a pressure at the economizer flow outlet substantially equals to a pressure at the economizer flow inlet.

7. A heat pump system according to claim 2, wherein the economizer expansion valve is an electronic expansion valve.

8. A heat pump system according to claim 2, wherein the economizer expansion valve is a thermostatic expansion valve, and the opening of the economizer expansion valve is adjusted according to the temperature at the refrigerant flow outlet (T3).

9. A heat pump system according to claim 8, wherein said thermostatic expansion valve comprises a temperature sensing bulb placed at the refrigerant flow outlet to detect the temperature thereof (T3), and said thermostatic expansion valve automatically controls its opening according to said detected temperature (T3).

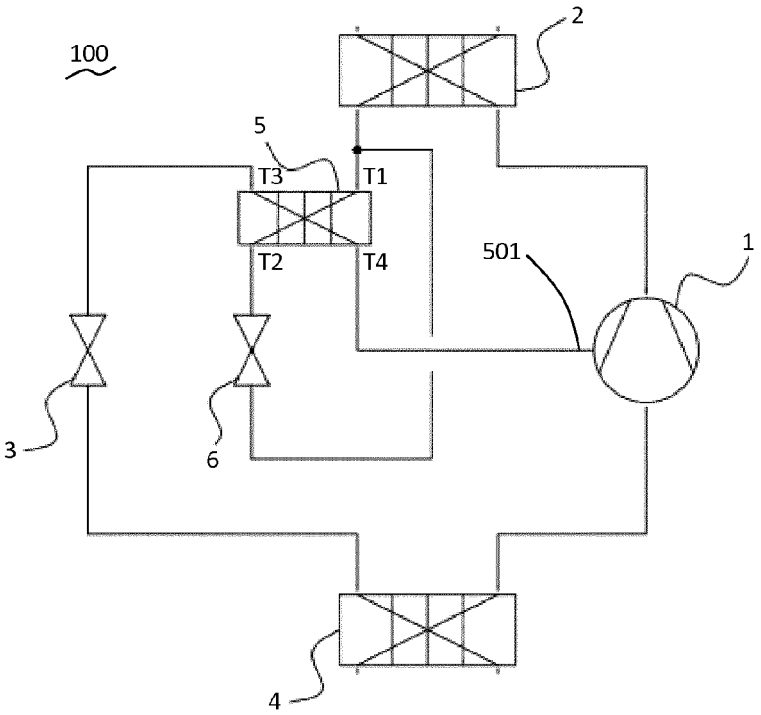


Fig. 1

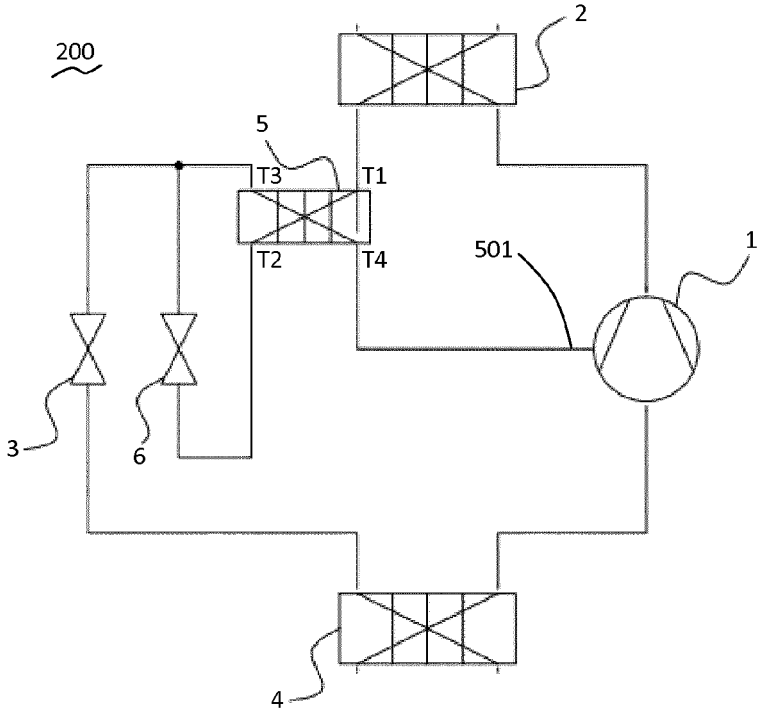


Fig. 2

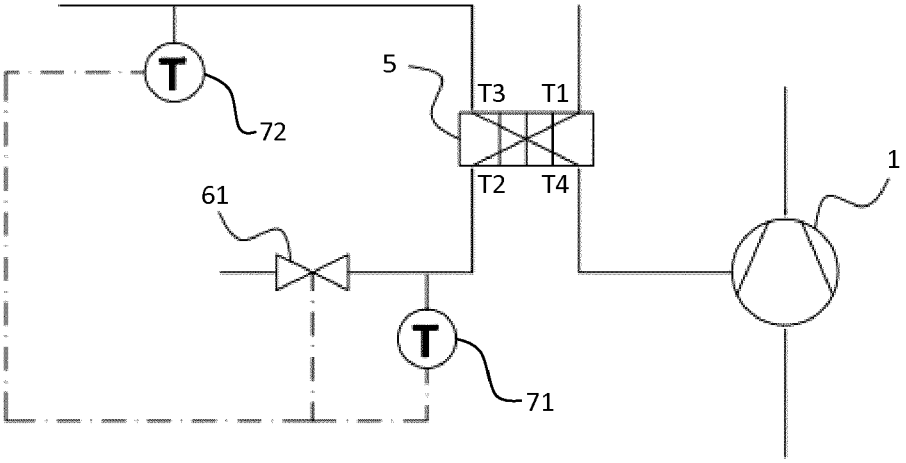


Fig. 3

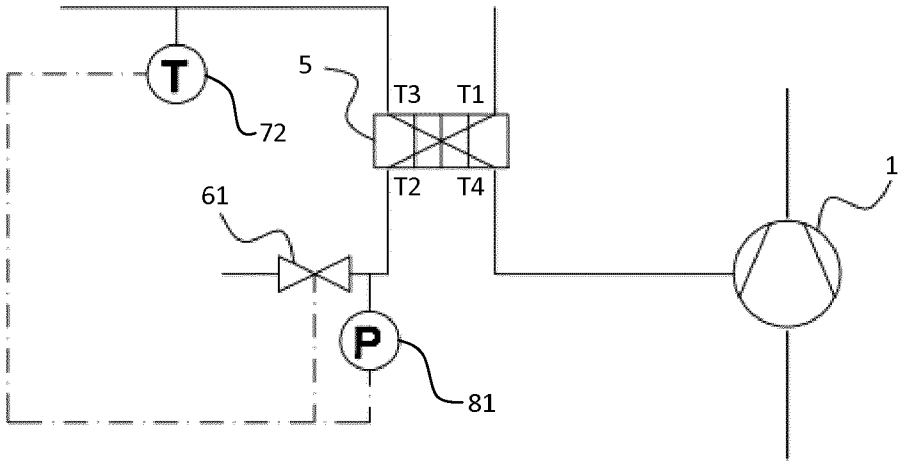


Fig. 4

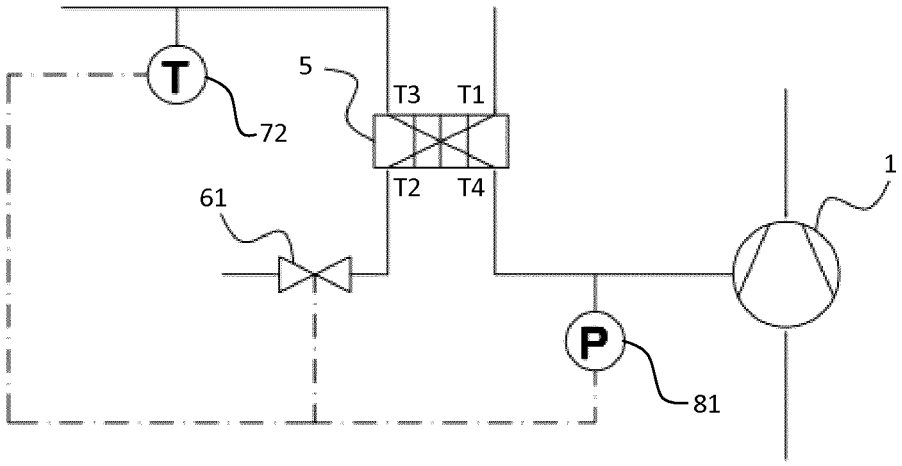


Fig. 5

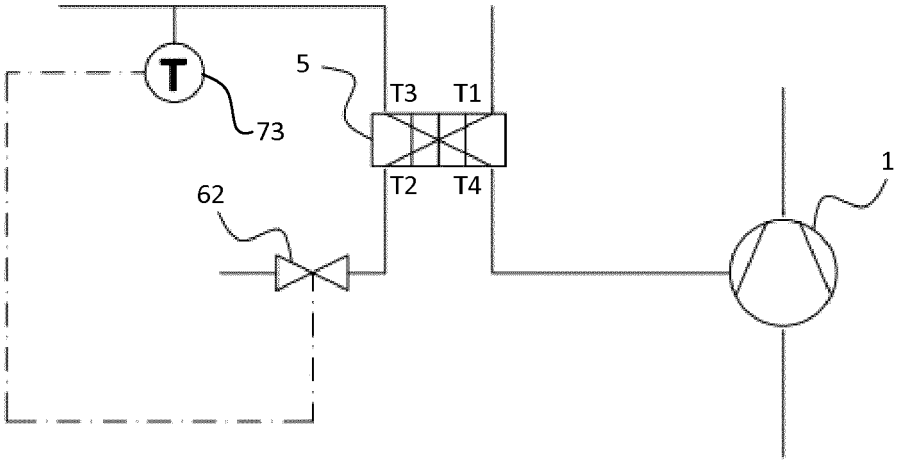


Fig. 6

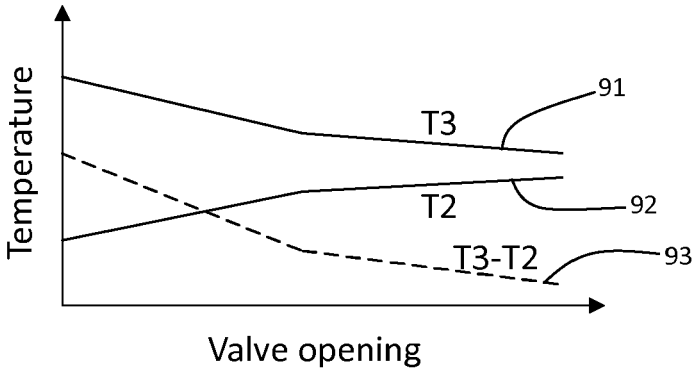


Fig. 7

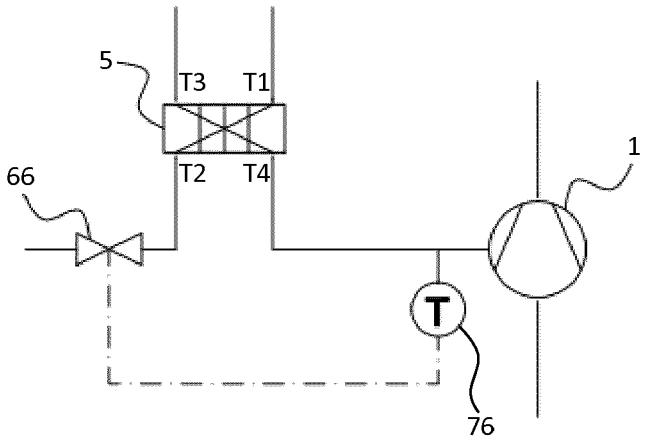


Fig. 8(State of art)

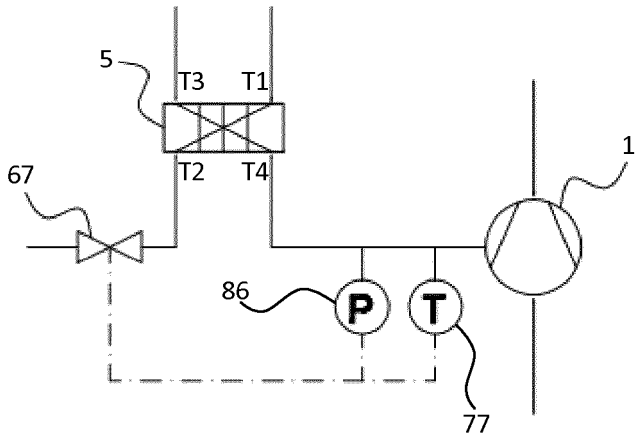


Fig. 9(State of art)

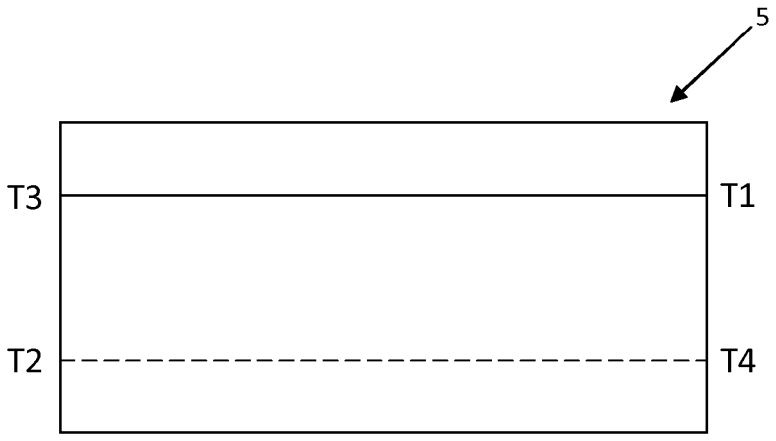


Fig. 10(State of art)

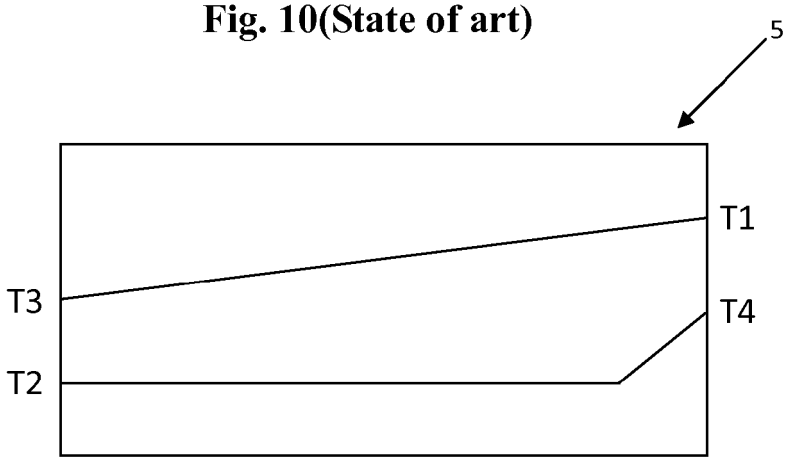


Fig. 11(State of art)

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EUROPEAN SEARCH REPORT

Application Number
EP 14 19 4026

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP 2010 007975 A (DAIKIN IND LTD) 14 January 2010 (2010-01-14) * abstract; figure 1 * * paragraphs [0037], [0046] *	1-9	INV. F25B1/10
X	US 6 474 087 B1 (LIFSON ALEXANDER [US]) 5 November 2002 (2002-11-05) * column 2, line 17 - column 3, line 29; figure 1 *	1	

TECHNICAL FIELDS SEARCHED (IPC)

F25B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	20 April 2015	Ritter, Christoph

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2010007975 A	14-01-2010	NONE	
US 6474087 B1	05-11-2002	NONE	

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