

(12)

EUROPEAN PATENT APPLICATION

(21) Application number: 85308395.4

(51) Int. Cl.⁴: F 25 B 13/00

(22) Date of filing: 18.11.85

(30) Priority: 10.12.84 GB 8431120

(43) Date of publication of application:
06.08.86 Bulletin 86/32

(64) Designated Contracting States:
AT BE CH DE FR GB IT LI LU NL SE

(71) Applicant: BORG-WARNER LIMITED
P.O. Box 10 Latchmore Court Braid Street
Hitchin Hertfordshire(GB)

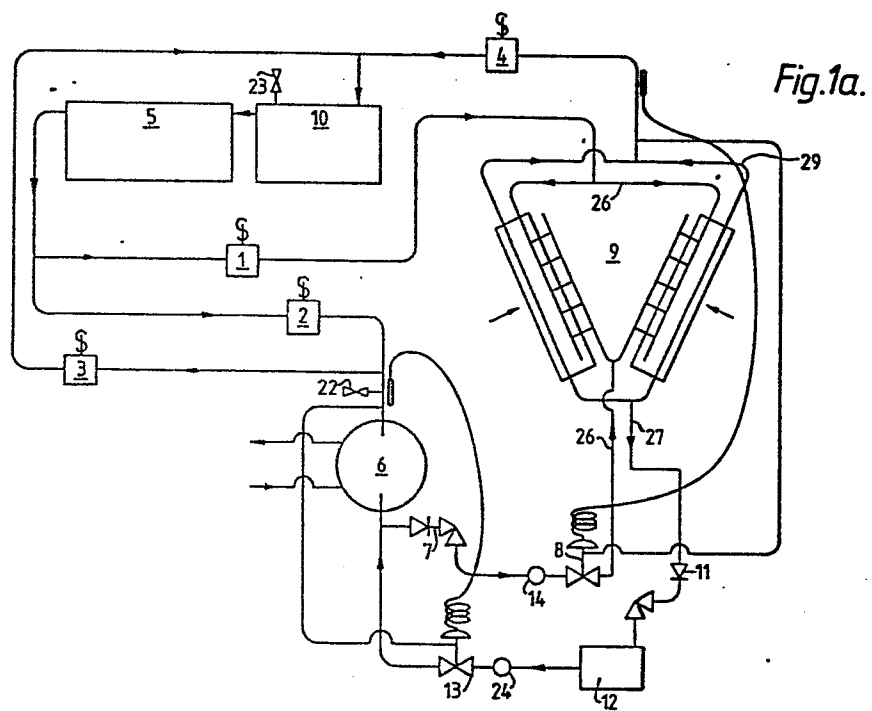
(72) Inventor: Johnson, Bernard W.
21 Greenwood Avenue
Benfleet Essex SS7 1LD(GB)

(72) Inventor: Foley, Peter N.
22 Kingsteignton
Shrewbury Essex SS3 8AY(GB)

(74) Representative: Ayers, Martyn Lewis Stanley et al,
J.A. KEMP & CO. 14 South Square Gray's Inn
London, WC1R 5EU(GB)

(54) Heating/cooling changeover heat pump.

(57) A changeover heating/cooling heat pump has four solenoid valves (1-4) to change between modes. One (3) of them, controlling the delivery of refrigerant from a water/refrigerant heat exchanger (6) provides a pressure limiting function to avoid overpressures at the suction side of the compressor (5). One (17) or two (8,13) refrigerant expansion devices are used; in the case of a single, electronically controlled device (17), the temperature control signal is derived from the outlet of whichever of the heat-exchangers (6, 9) is currently rejecting heat.



DESCRIPTION

TITLE: "HEATING/COOLING CHANGEOVER HEAT PUMP"

The present invention relates to heat pumps and more particularly to a multi-mode heating and cooling heat pump.

According to a first aspect of the present invention, there is provided a multi-mode heat pump having
5 a refrigerant circuit, a refrigerant compressor and first and second heat exchangers for exchanging heat between the refrigerant and a liquid and between refrigerant and air, respectively, the heat pump being operable in modes in which the first heat exchanger rejects heat to the
10 associated liquid medium while the second heat exchanger extracts heat from air and vice versa, and in which changeover between these two modes is achieved by means of solenoid valves for redirecting the flow of refrigerant, one of the solenoid valves being located in the refrigerant
15 line via which the first heat exchanger delivers refrigerant to the compressor and being arranged to limit the pressure of the refrigerant delivered from the first heat exchanger to the compressor. The use of solenoid valves facilitates the changeover between heating and
20 cooling without the use of a complex four-way reversing valve. The changeover can be carried out without stopping the compressor and can enable defrosting of an outdoor heat exchanger, e.g. of the fin and tube type, to

be achieved by suitably timed changeover without interrupting the compressor operation and without necessitating a pump-down cycle.

Further, the change between the heating and cooling modes is achieved without the use of valves controlling the liquid phase of the refrigerant.

The heat pump can be so arranged as to require only one refrigerant expansion device. The superheat control of each appropriate heat exchanger when acting as an evaporator can then be readily achieved, as can the sensitivity of the refrigerant expansion device to equalisation of pressure at the evaporator outlet. The system can avoid detrimental refrigerant bypass by use of simple non-return valves.

The pressure limiting function of the first solenoid valve is important because it can avoid the risk of unacceptably high compressor suction-side pressures occurring when the first heat exchanger changes over from heating to cooling. Immediately after such a change over the refrigerant in the first heat exchanger will be required to sink a lot of heat from the heated liquid working medium and this could give rise to the over-pressure first mentioned. The pressure-limiting solenoid valve prevents liquid flood-back to the compressor while allowing the liquid to be cooled down relatively quickly. This feature thus provides a changeover system which avoids the risk of unacceptably high compressor suction-side

pressures, and which will readily respond to rapid alternative demands for heating or cooling demand imposed by an air conditioned structure.

The second heat-exchanger can be an external/
5 outdoor finned tube heat exchanger, the heat exchange medium, air, being driven through the heat exchanger coil matrix by a motor driven propeller or impeller.

The second heat exchanger, may be arranged so that the air is in contra-flow relative to the refrigerant
10 in both heating and cooling modes, thus optimising performance.

A second aspect of the invention which may be used with or without the first aspect, provides a multi-mode heat pump having a refrigerant circuit, a refrigerant
15 compressor, first and second heat exchangers for exchanging heat between the refrigerant and first and second working media, control valves controlling refrigerant flow so as to establish modes of operation in which the first heat exchanger rejects heat to the associated working medium
20 while the second heat exchanger extracts heat from the associated working medium, and vice versa, and a controllable refrigerant expansion device which, in use of the heat pump, delivers gaseous refrigerant to the appropriate one of the heat exchangers according to the mode of
25 operation of the heat pump, and in which means are provided to derive a control signal to control the operation of the refrigerant expansion device in accordance with the

temperature of the refrigerant outlet of whichever of the heat exchangers is currently rejecting heat.

As will become apparent from the following description, both aspects of the invention may be embodied
5 in a reverse-cycle heat pump comprising: a refrigerant compressor; first and second heat exchangers; first, second, third and fourth refrigerant flow lines for respectively delivering refrigerant:-

1) from the output of the compressor to the
10 first heat exchanger

2) from the output of the compressor to the second heat exchanger

3) from the second heat exchanger to the input of the compressor and

15 4) from the first heat exchanger to the input of the compressor;

respective control valves in the first to fourth refrigerant flow lines and arranged so that in a heating mode the valves in the second and fourth refrigerant flow
20 lines are open and the other two valves closed and, in a heating mode, that the valves in the first and third flow lines are open and those in the second and fourth flow lines closed; and a fifth refrigerant flow line for delivering refrigerant from one heat exchanger to the other
25 via a refrigerant expansion device.

One or two refrigerant expansion devices may be used depending on the configuration of pipework and flow

control valves in the fifth refrigerant flow line.

It will be appreciated that by placing the valves in the first to fourth lines as above, no solenoid valves controlling the liquid phase of the refrigerant are

5 required.

The invention will be further described by way of non-limitative example with reference to the accompanying drawings in which like reference numerals denote like parts and in which:-

10 Figure 1a shows one embodiment of the present invention when operating in the cooling mode;

Figure 1b shows the first embodiment of the present invention when operating in the heating mode;

Figure 2a shows a second embodiment of the
15 present invention when operating in the cooling mode; and

Figure 2b shows the second embodiment when operating in the heating mode.

The embodiment of the invention illustrated in Figures 1 and 2 is a simplified, reverse-cycle heat pump
20 unit in which changeover between the heating and cooling modes can be achieved without the use of the conventional four-way valve. The principal components of the heat pump are the compressor 5, secondary to primary refrigerant heat exchanger 6 and a V-form primary refrigerant to air heat
25 exchanger 9. These elements are connected by pipework as shown. The flow of refrigerant around the system is controlled, according to the operating mode, by four

solenoid valves, 1, 2, 3 and 4 and as will become apparent from the following description they are so positioned in the circulation paths that the vapour, rather than liquid, phase of the refrigerant passes through them.

5 The unit will operate in either of two basic modes which can be readily explained by reference to Figure 1a and 1b, namely:-

COOLING MODE

Refrigerant vapour discharged from the compressor
10 5 passes through open solenoid valve 1 and into the heat exchanger 9. Solenoid valves 2 and 4 are closed.

The refrigerant vapours are condensed and pass as liquid through non-return valve 11, filter drier 12 and sight glass 24 to the thermostatic expansion valve 13. Non
15 return valve 7 inhibits bypass flow of liquid refrigerant to the heat exchanger 6.

Boiling refrigerant at low pressure in heat exchanger 6 cools the secondary refrigerant (a water/glycol mixture for example) used as the cooling medium.

20 The superheated refrigerant vapours are then returned to the compressor 5 suction-side, passing through the open pressure limiting solenoid valve 3 and accumulator 10.

Solenoid valve 3 functions as a compressor
25 suction pressure limiting device to prevent high pressure

-7-

being encountered when, on changeover to cooling, the heat exchanger 6 may be at an unacceptably high temperature, resulting in high refrigerant vapour pressure, for a limited period.

- 5 Changeover to the heating mode is achieved without compressor pump-down by closing solenoid valves 1 and 3 and simultaneously opening solenoid valves 2 and 4.

HEATING MODE

10 The refrigerant vapour discharged from the compressor 5 passes through open solenoid valve 2 and into the heat exchanger 6.

Solenoid valves 1 and 3 are closed.

15 The refrigerant vapours are condensed in heat exchanger 6, the heat passing into the secondary refrigerant which is now being used as the heating medium. The liquid primary refrigerant passes through the non-return valve 7 and sight glass 14 to the thermostatic expansion valve 8.

20 Boiling refrigerant at low pressure in heat exchanger 9 absorbs heat from the source medium, which could be an ambient air stream.

25 The superheated refrigerant vapours are then returned to the compressor 5 suction side, passing through the open solenoid valve 4 and accumulator 10.

When heat exchanger 9 is an outdoor coil in the heating mode, defrost can be achieved by initiating the cooling mode for a limited period with minimal loss of system efficiency.

5 Figures 2a and 2b illustrate a second form of reverse-cycle heating/cooling changeover heat pump having the same basic elements as in Figures 1a and 1b but using only a single refrigerant expansion device, rather than the two devices which have been necessary with existing
10 technology. The refrigerant expansion device is of the electronic type rather than the conventional thermostatic type.

The operation of the unit in the two basic modes can be readily appreciated by reference to Figures 2a and
15 2b and the following description.

COOLING

In this mode, the control logic (not shown) of the unit closes valves 2 and 4, opens valves 1 and 3 and energises relay 18 such that a signal from temperature
20 sensor 20, which detects the temperature of refrigerant leaving evaporator 6, is applied to the control input of refrigerant expansion device 17.

The refrigerant vapour discharged from the compressor 5 passes through open solenoid valve 1 and into
25 the heat exchanger 9. Solenoid valves 2 and 4 are closed.

The refrigerant vapours are condensed in heat exchanger 7 and as liquid, passes through non-return valve 11, filter dehydrater 12 and sight glass 14 to the electronic refrigerant expansion device 17.

5 The electronic refrigerant expansion device 17 responds to a comparison of a) to superheated refrigerant conditions in the heat exchanger 6 as detected by evaporator temperature sensor 20 and b) the simulated saturated temperature condition at the outlet of the expansion device 17 as measured by sensor 19. Suitably,
10 the sensors provide electrical signals which are proportional to the respective temperatures and the comparison between them forms a signal representing the difference between those temperatures. The refrigerant
15 expansion device 17 has a controllable aperture which is opened, to allow more refrigerant to pass, as the temperature difference increases.

Where external equalisation is required, then the pressures at the exits of the heat exchangers 6 and 9 when
20 in their respective cooling operation can be sensed through a three way solenoid valve (or independent solenoid valves) in the appropriate mode, the changeover of valve 25 (or the equivalent independent solenoid valve) being carried out at the same time as the changeover solenoid valves 1 and 3 are
25 energised.

Non-return valves 7 and 15 are closed to liquid refrigerant flow by the high-side pressures.

The refrigerant passes through non return valve 16 and into the heat exchanger 6 where the boiling refrigerant cools the secondary refrigerant (e.g. a water/glycol mixture) which is used as the cooling medium.

5 The superheated refrigerant vapours are then returned to the compressor 5, being passed through the solenoid valve 3, which also acts as a compressor suction-side pressure limiting device, and the accumulator 10.

10 Changeover to the heating mode is achieved by closing solenoid valves 1 and 3 whilst simultaneously opening solenoid valves 2 and 4, changing over the contacts on relay 18 and the three way solenoid valve 25 if equalising pressure sensing is required for the electronic
15 expansion device 17.

HEATING

The refrigerant vapour discharged from the compressor 5 passes through open solenoid valve 2 and into heat exchangers 6. Solenoid valves 1 and 3 are closed.

20 The refrigerant vapours are condensed in heat exchanger 6, the heat passing into the secondary refrigerant circuit, and the liquid refrigerant passes through non-return valve 7, filter drier 12 and sight glass 14 to the electronic
refrigerant expansion device 17.

25 The electronic expansion device 17 is now

-11-

responsive via relay contacts 18 to temperature sensor 21 which senses the temperature of refrigerant at the outlet of heat exchanger 9 and to temperature sensor 19 previously mentioned.

5 Non-return valves 16 and 11 are closed to refrigerant bypass into the low-side of the system by means of the high pressure liquid.

 Boiling refrigerant at low pressure in heat exchanger 9 absorbs heat from the available secondary
10 refrigerant medium, which could be an ambient air stream.

 The superheated refrigerant vapours are then returned to the compressor 5 suction side passing through open solenoid valve 4 and accumulator 10.

 It will be noted that in each of the above
15 embodiments a novel structure for the heat exchanger 9 is provided so as to optimise the heat transfer between the air and the primary refrigerant. Air enters the heat exchanger in the directions indicated by the arrows. Conventionally, a heat exchanger in a reverse cycle heat
20 pump operates in uniflow in one mode and contra-flow in the other mode. In uniflow, the temperature gradient of the air through the matrix of the heat exchanger is opposite to that of the primary refrigerant. As a consequence, in the condensor mode, because the coolest air encounters the
25 warmest refrigerant, which is not as efficient as contra-flow where the coolest air encounters the coolest refrigerant, thus enhancing the sub-cooling.

In the embodiments, the heat exchanger 9 is arranged so that the heat exchange is contra-flow in both modes. This is achieved by duplicating the refrigerant feed lines to and from the heat exchanger 9.

5 In the cooling mode, refrigerant enters heat exchanger 9 via line 26 and exits via line 27, while in the heating mode it enters via line 28 and exits via line 29; the same internal coil matrix is used in both cases.

CLAIMS

1. A multi-mode heat pump having a refrigerant circuit, a refrigerant compressor (5) and first and second heat exchangers (6,9) for exchanging heat between the refrigerant and a liquid and between refrigerant and air, respectively, the heat pump being operable in modes in which the first heat exchanger (6) rejects heat to the associated liquid medium while the second heat exchanger (9) extracts heat from air and vice versa, characterised in that changeover between these two modes is achieved by means of solenoid valves (1-4) for redirecting the flow of refrigerant, one (3) of the solenoid valves being located in the refrigerant line via which the first heat exchanger (6) delivers refrigerant to the compressor (5) and being arranged to limit the pressure of the refrigerant delivered from the first heat exchanger (6) to the compressor (5).

2. A heat pump according to claim 1 characterised in that two (1,2) of the other solenoid valves are located in refrigerant lines connecting the outlet of the compressor (5) to inlets of the first (6) and second (9) heat exchangers respectively and wherein a fourth (4) is connected in a line delivering refrigerant from the outlet of the second heat exchanger (9) to the compressor (5).

3. A heat pump according to claim 1 or 2 characterised in that there are two separate flow paths (26,29) for refrigerant through the second heat exchanger (9), refrigerant passing through one of these paths in one
5 of the modes of operation and through the other, in the other mode of operation.

4. A heat pump according to claim 3 characterised in that the paths are so arranged that in both modes of operation the refrigerant through the second
10 heat exchanger (9) is in contra-flow with respect to the air with which it exchanges heat.

5. A heat pump according to any one of claims 1 to 4 characterised in that there are two refrigerant expansion devices (8,13), operable to deliver gaseous
15 refrigerant to the first (6) and second (9) heat exchangers respectively, the refrigerant flow paths in the heat pump being such that refrigerant is delivered to the that one of the devices (8,13) associated with the heat exchanger (6,9) which is to reject heat to the associated
20 working medium.

6. A heat pump according to any one of claims 1 to 4 characterised in that there is a common refrigerant expansion device (17) which is used in both modes of operation of the heat pump, the expansion device being
25 controlled by a control signal which is selectively derived from the temperature of refrigerant at the outlet of that one of the two heat exchangers (6,9) which is to

-15-

reject heat to the associated working medium.

7. A multi-mode heat pump having a refrigerant circuit, a refrigerant compressor (5), first and second heat exchangers (6,9) for exchanging heat between the refrigerant and first and second working media, control valves (1-4) controlling refrigerant flow so as to establish modes of operation in which the first heat exchanger (6) rejects heat to the associated working medium while the second heat exchanger (9) extracts heat from the associated working medium, and vice versa, characterised by a controllable refrigerant expansion device (17) which, in use of the heat pump, delivers gaseous refrigerant to the appropriate one of the heat exchangers (6,9) according to the mode of operation of the heat pump, and in which means (18,21) are provided to derive a control signal to control the operation of the refrigerant expansion device (17) in accordance with the temperature of the refrigerant outlet of whichever of the heat exchangers is currently rejecting heat.

8. A heat pump according to claim 7 characterised in that the expansion device (17) is an electronically controlled expansion device and respective temperature sensors (20,21) are disposed to sense the temperature of refrigerant at the outlets of the two heat exchangers (6,9) and wherein switching means are provided, operable in accordance with the mode of operation of the heat pump to deliver a temperature-indicating signal from

-16-

the appropriate one of the temperature sensors (20,21) to the control input of the refrigerant expansion device.

Fig. 1a.

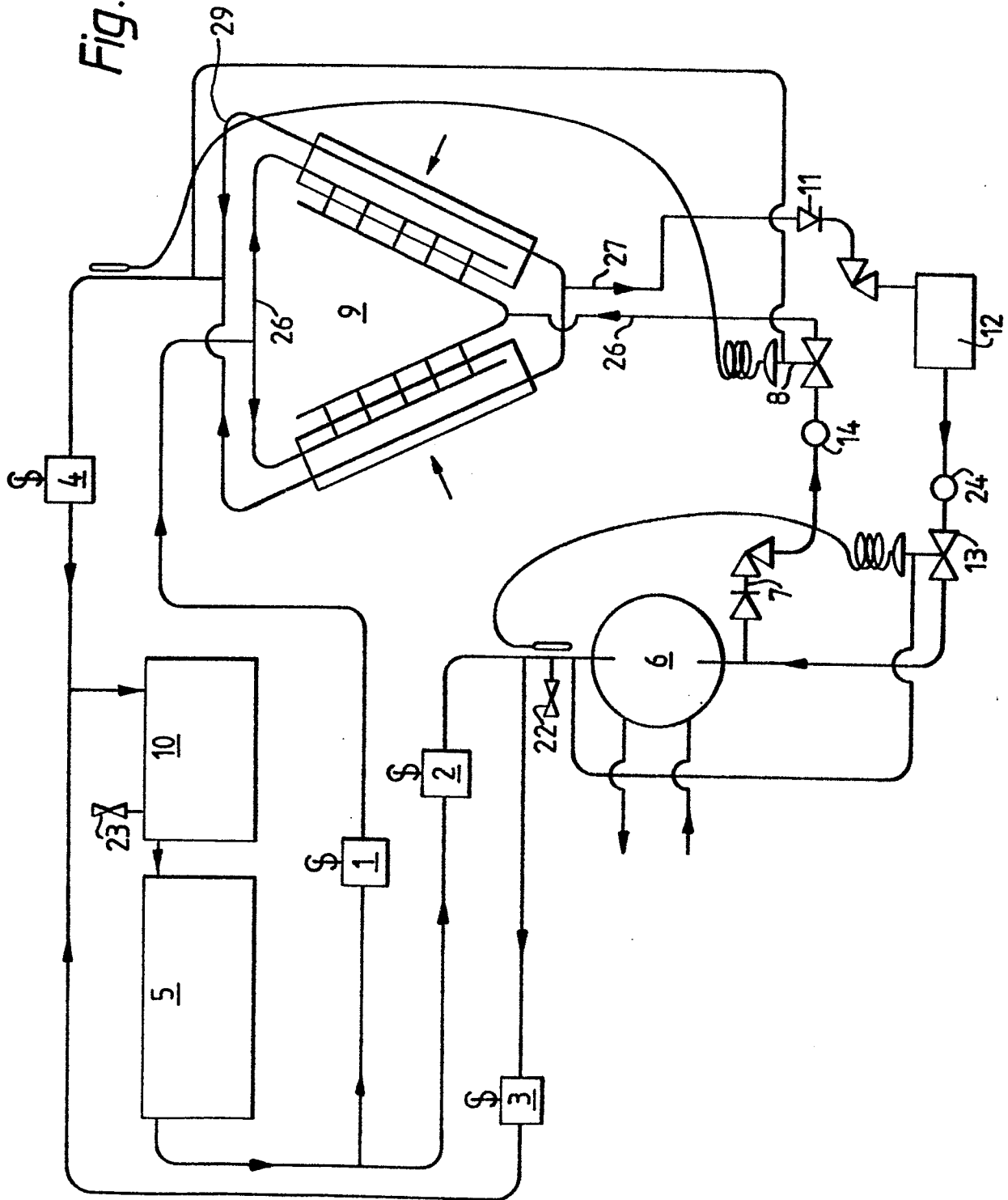


Fig. 1b.

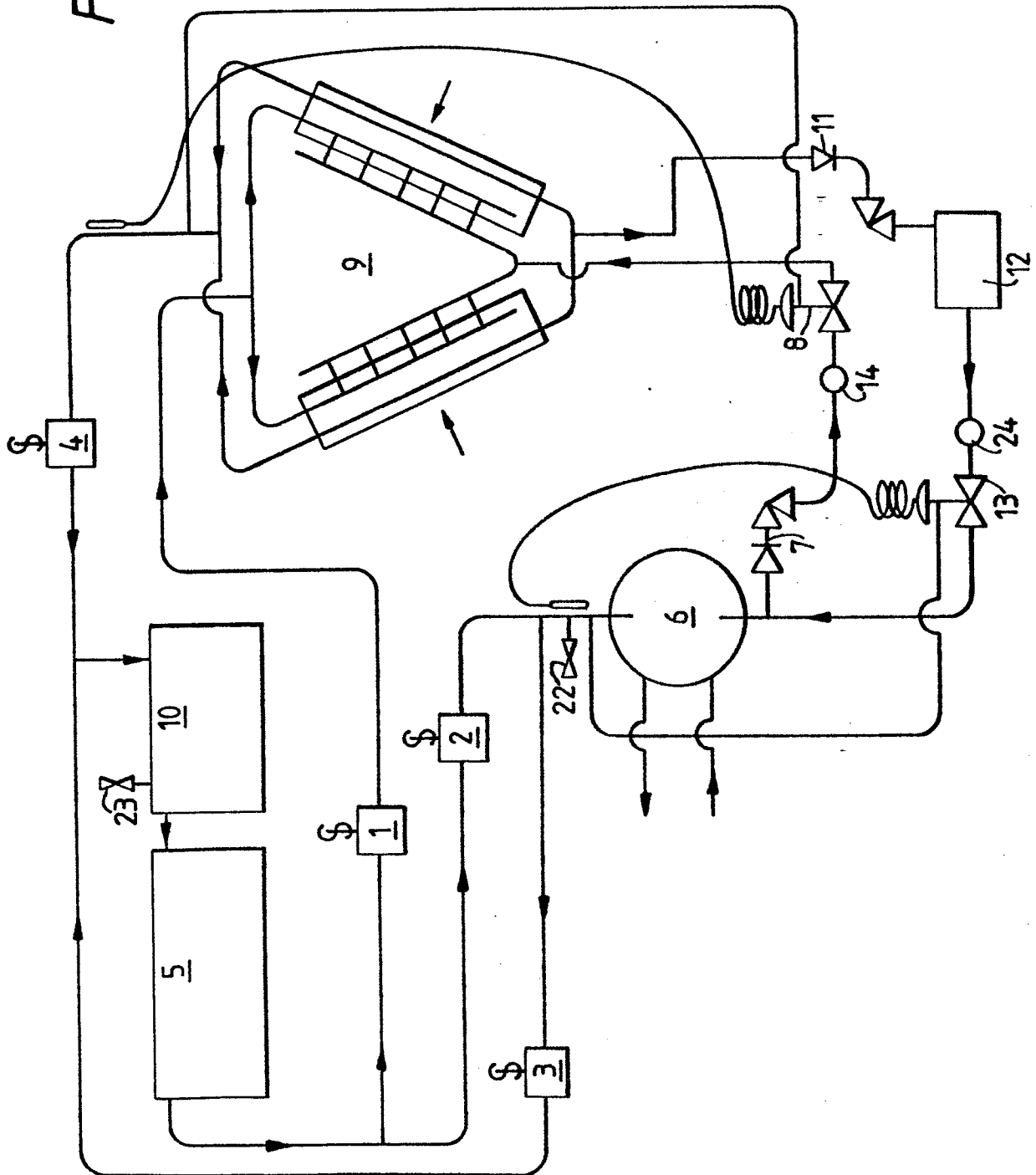


Fig. 2a.

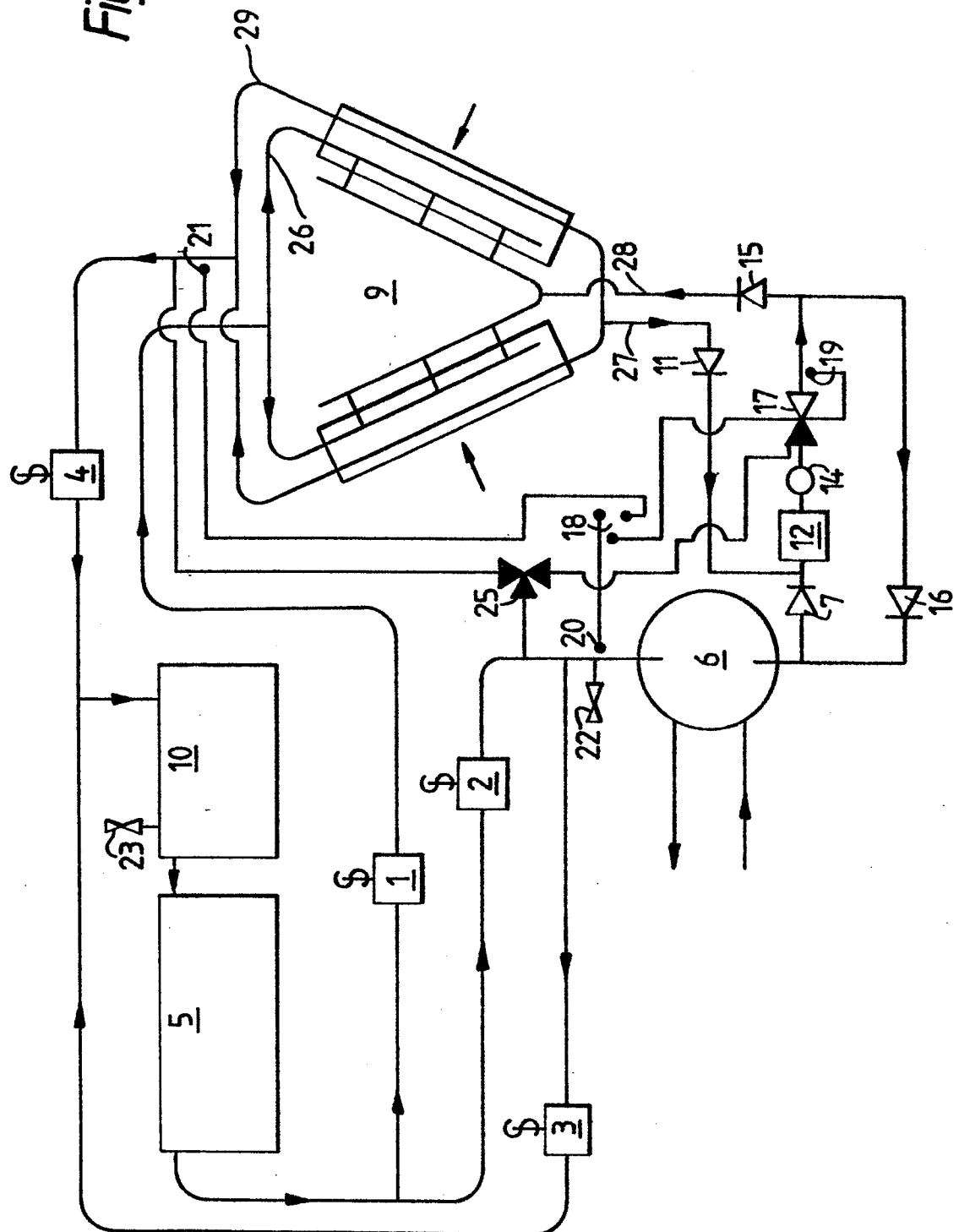
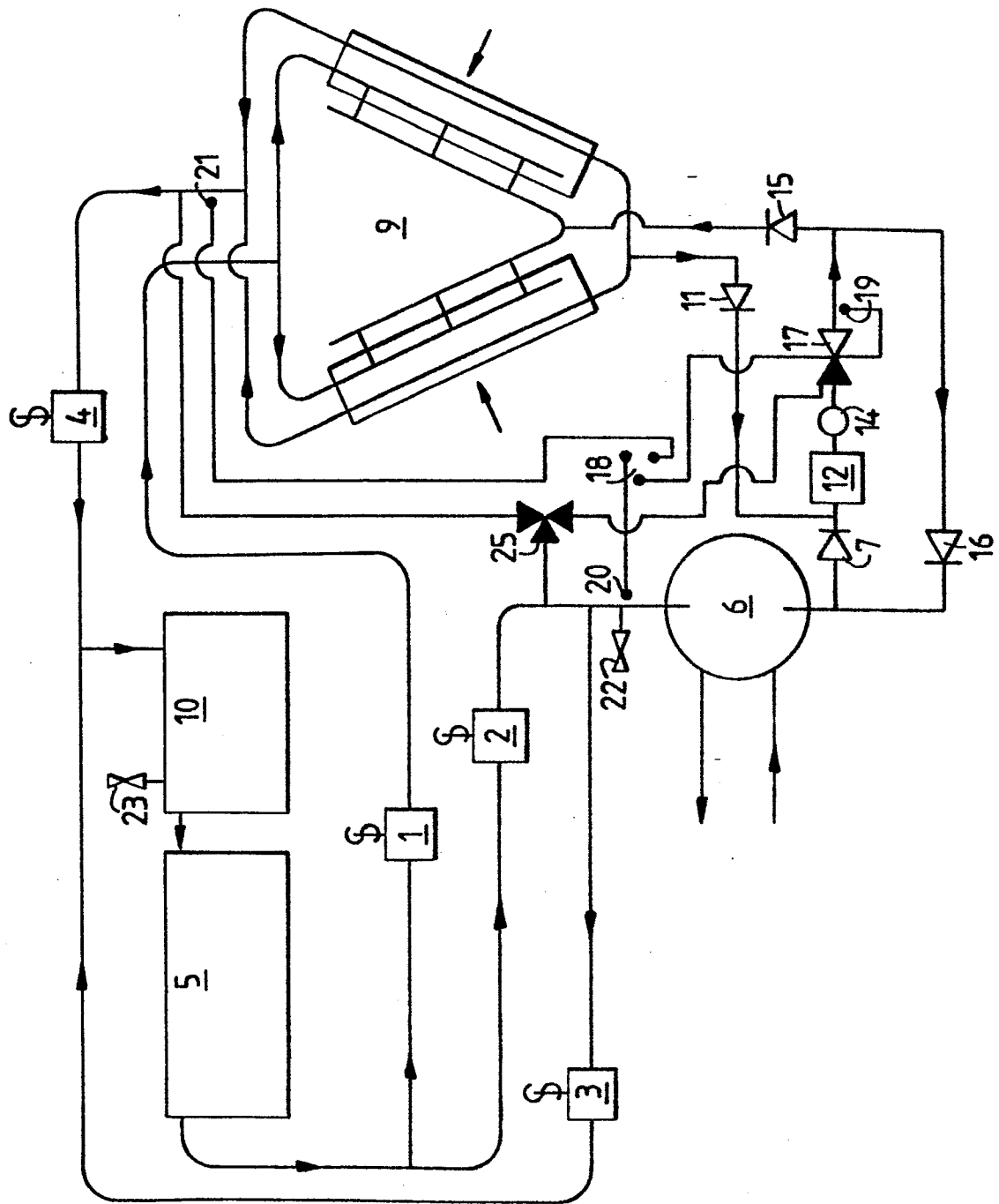


Fig. 2b.





European Patent
Office

EUROPEAN SEARCH REPORT

0189646

Application number

EP 85 30 8395

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
X	DE-A-2 437 019 (BROWN BOVERI-YORK) * The whole document *	1,3,5	F 25 B 13/00
Y		2,4,6	
Y	FR-A-1 240 474 (IDEAL-STANDARD) * The whole document *	2,4	
X	GB-A-2 046 481 (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) * Figures 5,6 *	7,8	
Y		6	
A	DE-A-3 248 356 (MITSUBISHI DENKI) * Figure 2 *	1,6,7	TECHNICAL FIELDS SEARCHED (Int. Cl. 7)
A	GB-A-2 001 422 (CARRIER CORP.) * Figures 1,3,9 *	4	F 25 B
A	US-A-2 182 691 (CRAGO)		
A	US-A-2 474 304 (CLANCY)		
		-/-	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 29-04-1986	Examiner SILVIS H.
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			



DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	US-A-3 365 902 (NUSSBAUM) -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 29-04-1986	Examiner SILVIS H.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	