



(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
05.11.2003 Bulletin 2003/45

(51) Int Cl.7: F25B 1/10, F25B 9/00

(21) Application number: 03252306.0

(22) Date of filing: 11.04.2003

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR
HU IE IT LI LU MC NL PT RO SE SI SK TR
Designated Extension States:
AL LT LV MK

(72) Inventor: Negishi, Masami,
c/o Sanden Corporation
Isesaki-shi, Gunma 372-8502 (JP)

(74) Representative: Haley, Stephen
Gill Jennings & Every,
Broadgate House,
7 Eldon Street
London EC2M 7LH (GB)

(30) Priority: 15.04.2002 JP 2002112015

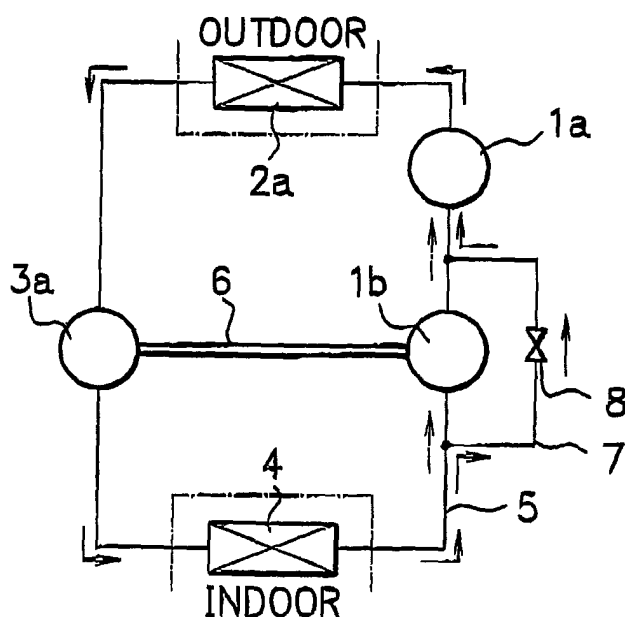
(71) Applicant: Sanden Corporation
Isesaki-shi, Gunma 372-8502 (JP)

(54) Refrigerating system using carbon dioxide as refrigerant

(57) A refrigerating cycle system of a vapor compression system has a constitution wherein a first compressor (1a), a first radiator (2a), an expansion mechanism (3a), a heat absorber (4), and a second compressor (1b) connected sequentially and circularly. A CO₂ refrigerant is circulated in the sequence of the first compressor (1a) → the first radiator (2a) → the expansion mechanism (3a) → the heat absorber (4) → the second compressor (1b) → the first compressor (1a). The rotat-

ing drive shaft of the second compressor (1b) is connected to the rotating output shaft of the expansion mechanism (3a) with a common shaft. Thereby, since the drive force of the second compressor (1b) is obtained from the power generated by the refrigerant expanding action of the expansion mechanism (3a), the power of the first compressor (1a) consumed for elevating the pressure of the refrigerant to a predetermined pressure can be minimized.

FIG. 4



Description

[0001] The present invention relates to a refrigerating cycle system using carbon dioxide as the refrigerant.

[0002] FIG. 7 shows a known refrigerating cycle system using carbon dioxide (CO₂) as the refrigerant.

[0003] This refrigerating cycle system has a compressor 1, a radiator 2, an expansion valve 3, and a heat absorber 4; and circulates a CO₂ refrigerant sequentially in the order of the compressor 1 → the radiator 2 → the expansion valve 3 → the heat absorber 4 → the compressor 1 as shown by arrows in FIG. 7. As a result, the heat of the air in a room is absorbed by the heat absorber 4, and the room is cooled.

[0004] The room-cooling operation of this refrigerating cycle system will be described referring to the Mollier diagram of FIG. 8. The compressor 1 compresses the CO₂ refrigerant (refrigerant pressure: 40 kg/cm²) to a pressure exceeding the critical point of the saturated liquid line and the saturated vapor line, for example, 100 kg/cm² (A → B of FIG. 8). Next, the compressed CO₂ refrigerant is discharged outdoors with the radiator 2 (B → C of FIG. 8). Then, the heat-released CO₂ refrigerant is expanded along the isenthalpic line with the expansion valve 3 to lower the pressure (C → D of FIG. 8). The CO₂ refrigerant that becomes the wet vapor due to this pressure lowering absorbs heat from the air in the room in the heat absorber. Thereby, the room is cooled (D → A of FIG. 8).

[0005] Thus, in order to obtain a desired refrigerating capacity even in summer when the outdoor temperature is high, the refrigerating cycle system that discharges heat outdoors requires a compressor that obtains a high discharging pressure.

[0006] However, even though this refrigerating cycle system employs a compressor 1 of a large refrigerating capacity, the operation efficiency is lower than the operation efficiency of refrigerating cycle systems using chlorofluorocarbon-based and hydrocarbon-based refrigerants.

[0007] In consideration of such problems, the present applicant proposed a refrigerating cycle system as described in Japanese Patent Laid-open No. 11-94379. In this refrigerating cycle system, a compressor 1 is composed of a first compressor (not shown) and a second compressor (not shown); a radiator 2 is composed of a first radiator (not shown) and a second radiator (not shown); and the rotating drive shaft of the second compressor and the rotating output shaft of the expansion mechanism are connected to each other. A CO₂ refrigerant is sequentially circulated in the order of the first compressor → the first radiator → the second compressor → the second radiator → the expansion mechanism → the heat absorber → the first compressor.

[0008] According to this refrigerating cycle system, the refrigerant is compressed by the first compressor, the compressed refrigerant is discharged by the first radiator, the discharged refrigerant is compressed by

the second compressor, and the compressed refrigerant is discharged by the second radiator. The use of the first compressor and the second compressor reduces the power for the entire compressor.

[0009] The object of the present invention is to provide a refrigerating cycle system that has a different structure from the refrigerating cycle system disclosed in Japanese Patent Laid-Open No. 11-94379, that can obtain a desired refrigerating pressure without increasing the power for the entire compressor, and that has an improved refrigerating effect.

[0010] The present invention is a refrigerating cycle system having a refrigerant pipe for circulating a carbon dioxide refrigerant sequentially to a first compressor, a first radiator, an expansion mechanism, and a heat absorber, and discharging heat from the first radiator in a supercritical state, wherein a second compressor is provided in the refrigerant pipe between the heat absorber and the first compressor, and the rotating drive shaft of the second compressor and the rotating output shaft of the expansion mechanism are connected to each other.

[0011] According to the present invention, a CO₂ refrigerant is sequentially circulated in the order of the second compressor → the first compressor → the radiator → the expansion mechanism → the heat absorber → the second compressor to cool rooms and the like. In this refrigerating cycle, since the drive force of the second compressor is obtained from the power generated by the refrigerant expansion action of the expansion mechanism, a small power suffices to drive the first compressor, and energy from external sources can be minimized.

[0012] The above-described object and other objects, features, and advantages of the present invention will be obviously understood from the following description and attached drawings.

[0013] In the Drawings:

FIG. 1 is a refrigerant circuit diagram of a refrigerating cycle system according to the first embodiment;

FIG. 2 is a schematic diagram showing the connecting structure of a second compressor with an expansion mechanism according to the first embodiment;

FIG. 3 is a Mollier diagram of a refrigerating cycle system according to the first embodiment;

FIG. 4 is a refrigerant circuit diagram of a refrigerating cycle system according to the second embodiment;

FIG. 5 is a refrigerant circuit diagram of a refrigerating cycle system according to the third embodiment;

FIG. 6 is a Mollier diagram of a refrigerating cycle system according to the third embodiment;

FIG. 7 is a refrigerant circuit diagram of a conventional refrigerating cycle system; and

FIG. 8 is a Mollier diagram of a conventional refrigerating cycle system.

erating cycle system.

[0014] FIGS. 1 to 3 show the first embodiment of refrigerating cycle systems according to the present invention. The same components as previously in the above described conventional examples referring to FIG. 7 and FIG. 8 are denoted by the same numerals and characters.

[0015] This refrigerating cycle system uses CO₂ as the refrigerant. As FIG. 1 shows, the refrigerating cycle system sequentially connects a first compressor 1a, a first radiator 2a, an expansion mechanism 3a, a heat absorber 4, and a second compressor 1b using a refrigerant pipe 5. The refrigerating cycle system circulates the CO₂ refrigerant sequentially in the order of the second compressor 1b → the first compressor 1a → the first radiator 2a → the expansion mechanism 3a → the heat absorber 4 → the second compressor 1b as shown by solid-line arrows in FIG. 1, to cool rooms utilizing the heat-absorbing action of the heat absorber 4.

[0016] In the refrigerating cycle system thus constituted, both the second compressor 1b and the expansion mechanism 3a have the constitution as shown in FIG. 2, that is, adopt a scroll-type compression/expansion mechanism.

[0017] The second compressor 1b has a gas inlet 11 at the outer portion and a gas outlet 12 at the center portion, and a rotating scroll 13 is rotated in the arrow direction in FIG. 2 (clockwise to FIG. 2). Thereby the CO₂ refrigerant is sucked from the gas inlet 11, which is compressed between the rotating scroll 13 and the stationary scroll 14, and the compressed CO₂ refrigerant is discharged from the gas outlet 12.

[0018] The expansion mechanism 3a has the inverted constitution to the second compressor 1b. Specifically, the expansion mechanism 3a has a gas outlet 31 at the outer portion and a gas inlet 32 at the inner portion, and a rotating scroll 33 is rotated in the arrow direction in FIG. 2 (counterclockwise to FIG. 2). Thereby the CO₂ refrigerant is sucked from the gas inlet 32, expanded between the rotating scroll 33 and the stationary scroll 34, and discharged from the gas outlet 31.

[0019] The rotating drive shaft of the second compressor 1b is connected to the rotating output shaft of the expansion mechanism 3a with a shaft 6 as FIG. 2 shows, and the driving of the expansion mechanism 3a drives the second compressor 1b.

[0020] Next, the change in the refrigerant of the refrigerating cycle system according to the present invention will be described. First, when the first compressor 1a is operated, the CO₂ refrigerant is compressed, and the pressure thereof is applied through the first radiator 2a to the gas inlet 32 of the expansion mechanism 3a. Thereby, the expansion mechanism 3a is rotated, and the rotation force of the expansion mechanism 3a rotates the second compressor 1b.

[0021] By such operations of the first compressor 1a, the second compressor 1b, and the expansion mecha-

nism 3a, the CO₂ refrigerant is compressed by the second compressor 1b, and further compressed by the first compressor 1a. The refrigerant after two-stage compression is radiated by the first radiator 2a installed outdoors. The pressure of the radiated CO₂ refrigerant is reduced in the expansion mechanism 3a, and the refrigerant absorbs heat in the heat absorber 4 from the air in the room, and is sucked into the second compressor 1b.

[0022] The above-described refrigerating cycle system will be described referring to the Mollier diagram shown in FIG. 3. The CO₂ refrigerant is compressed in the second compressor 1b, for example, from 40 kg/cm² to P1 kg/cm² (A → B1). In the first compressor 1a, the refrigerant is further compressed from P1 kg/cm² to about 100 kg/cm² (B1 → B). Next, it is radiated in the first radiator 2a (B → C), and thereafter, the pressure of the refrigerant is reduced from 100 kg/cm² to 40 kg/cm² along the isentropic line (C → D1). Then the pressure-reduced CO₂ refrigerant is circulated again into the second compressor 1b (D1 → A).

[0023] Here, A → B → C → D shown in FIG. 3 is of a conventional example (an example wherein the refrigerant pressure is changed 40 kg/cm² to 100 kg/cm² by the first compressor 1a alone), and (h) denotes enthalpy. The cooling action of the refrigerating cycle system according to the present invention will be described comparing to the cooling action of the refrigerating cycle system according to a conventional example.

[0024] The power (WA1) of a compressor in the conventional refrigerating cycle system is:

$$WA1 = (hB - hA)$$

[0025] On the other hand, the refrigerating cycle system according to the present invention has a structure wherein the rotating drive shaft of the first compressor 1b is connected to the rotating output shaft of the expansion mechanism 3a with a common shaft 6. As a result, the power generated by the refrigerant-expanding action of the expansion mechanism 3a is utilized for the refrigerant-compressing action of the second compressor 1b. Therefore, the power (WA2) of the compressor 1a is as follows:

$$WA2 = (hB - hB1)$$

Also, the refrigerating effect (WB1) of the conventional refrigerating cycle system is as follows:

$$WB1 = (hA - hD)$$

On the other hand, the refrigerating effect (WB2) of the refrigerating cycle system according to the present invention is as follows:

$$WB2 = (hA - hD1)$$

Furthermore, the cop (coefficient of performance) ($\epsilon\gamma1$) of the conventional refrigerating cycle system is as follows:

$$\epsilon\gamma1 = WB1/WA1$$

The COP ($\epsilon\gamma2$) of the refrigerating cycle system according to the present invention is as follows:

$$\epsilon\gamma2 = WB2/WA2$$

Here, as FIG. 3 shows, since $WA1 > WA2$, and $WB1 < WB2$, each COP is as follows:

$$\epsilon\gamma1 < \epsilon\gamma2$$

[0026] Therefore, the refrigerating cycle system according to the present invention consumes less power than the conventional refrigerating cycle system, and also excels in COP. Since the expansion mechanism 3a of the refrigerating cycle system according to the present invention adiabatically expands the CO₂ refrigerant, the refrigerant pressure changes along the isentropic line, and the refrigerating effect is improved.

[0027] FIG. 4 shows the second embodiment of the refrigerating cycle system. In the drawing, the same components as in the above-described first embodiment are denoted by the same reference numerals and characters, the description thereof will be omitted.

[0028] In the second embodiment, a bypass pipe 7 that bypasses the second compressor 1b is installed in the refrigerant pipe 5 wherein the above-described second compressor 1b is installed. One end of the bypass pipe 7 is connected to the refrigerant pipe 5 connected to the gas inlet 31 of the second compressor 1b, and the other end of the bypass pipe 7 is connected to the refrigerant pipe 5 connected to the gas outlet 32 of the second compressor 1b. A switching valve 8 is installed in the middle of the bypass pipe 7.

[0029] According to this embodiment, the switching valve 8 is opened when the operation of the first compressor 1a is started. Thereby, as the solid-line arrows in FIG. 4 show, the CO₂ refrigerant is sucked into the suction side of the first compressor 1a through the bypass pipe 7, and the pressure in the suction side of the expansion mechanism 3a is elevated. concurrent with the pressure elevation, the expansion mechanism 3a is driven, and the second compressor 1b is also driven. Then, after the expansion mechanism 3a and the second compressor 1b have been driven, the switching valve 8 is closed. Thereby, as dashed-line arrows in FIG. 4 show, the entire CO₂ refrigerant is circulated into the

second compressor 1b, and the operation shifts to the steady operation.

[0030] According to this embodiment, when the operation of the first compressor 1a is started, the suction pressure of the expanding mechanism 3a is rapidly elevated, and shift to the steady operation is smoothly accomplished in a short time.

[0031] FIGS. 5 and 6 show the third embodiment of the refrigerating cycle system. In the drawings, the same components as in the above-described second embodiment are denoted by the same reference numerals and characters, the description thereof will be omitted.

[0032] In the third embodiment, the refrigerant pipe 5 between the first compressor 1a and the second compressor 1b is provided with a second radiator 2b. According to this embodiment, the switching valve 8 is opened when the operation of the first compressor 1a. Thereby, as the solid-line arrows in FIG. 5 show, a CO₂ refrigerant is sucked into the suction side of the first compressor 1a through a bypass pipe 7 and a second radiator 2b, and the pressure in the suction side of the expanding mechanism 3a is elevated, concurrent with the pressure elevation, the expansion mechanism 3a is driven, and the second compressor 1b is also driven. Then, after the expansion mechanism 3a and the second compressor 1b have been driven, the switching valve 8 is closed. Thereby, as dashed-line arrows in FIG. 5 show, the entire CO₂ refrigerant is circulated into the second compressor 1b, and the operation shifts to the steady operation.

[0033] The cooling cycle in such a steady operation will be described referring to the Mollier diagram of FIG. 6. The CO₂ refrigerant is compressed in the second compressor 1b, for example, from 40 kg/cm² to P2 kg/cm² (A → B1). The compressed CO₂ refrigerant is radiated in the second radiator 2b (B1 → C1). In the first compressor 1a, the radiated CO₂ refrigerant is further compressed from P2 kg/cm² to 100 kg/cm² (C1 → B2). Next, it is radiated in the first radiator 2a (B2 → C), and thereafter, in the expanding mechanism 3a the pressure of the refrigerant is reduced from 100 kg/cm² to 40 kg/cm² along the isentropic line (C → D1). Then the pressure-reduced CO₂ refrigerant is circulated again into the second compressor 1b (D1 → A).

[0034] Here, A → B → C → D1 shown in FIG. 6 shows the refrigerant change of the refrigerating cycle system according to the above-described first embodiment. The cooling action of the refrigerating cycle system according to this embodiment will be described below comparing with the cooling action of the refrigerating cycle system according to the above-described first embodiment.

[0035] The power (WA2) of the compressor 1a of the refrigerating cycle system according to the above-described first embodiment is as follows:

$$WA2 = (hB - hB1)$$

The power (WA3) of the compressor 1a of the refrigerating cycle system according to this embodiment is as follows:

$$WA3 = (hB2 - hC1)$$

5

Here, each power WA2 and WA3 is as follows as FIG. 6 shows:

10

$$WA2 > WA3$$

This is because the refrigerant sucked into the first compressor 1a is partly radiated in the second radiator 2b, and the power is reduced by decrease in enthalpy (by increase in the gradient of isentropic line in the first compressor 1a greater than the gradient of isentropic line in the second compressor 1b).

15

[0036] Therefore, in the refrigerating cycle system according to this embodiment, the power of the compressor 1a further decreases, and the refrigerating cycle system excels in energy saving.

20

25

Claims

1. A refrigerating cycle system having a refrigerant pipe (5) for circulating a carbon dioxide refrigerant sequentially to a first compressor (1a), a first radiator (2a), an expansion mechanism (3a), and a heat absorber (4), and discharging heat from said first radiator (2a) in a supercritical state,
wherein a second compressor (1b) is provided in the refrigerant pipe (5) between said heat absorber (4) and said first compressor (1a), and a rotating drive shaft of said second compressor (1b) and a rotating output shaft of said expansion mechanism (3a) are connected to each other.
2. The refrigerating cycle system according to claim 1, provided with a bypass pipe (7) one end of which is connected to the refrigerant pipe (5) connected to the gas inlet (11) of said second compressor (1b), and the other end of which is connected to the refrigerant pipe (5) connected to the gas outlet (12) of said second compressor (1b) to bypass said second compressor (1b); and
said bypass pipe (7) is provided with a switching valve (8).
3. The refrigerating cycle system according to claims 1 or 2, wherein said second compressor (1b) and said expansion mechanism (3a) are composed of a scroll-type compression/expansion mechanism.
4. The refrigerating cycle system according to any of claims 1 to 3, wherein said refrigerant pipe (5) be-

30

35

40

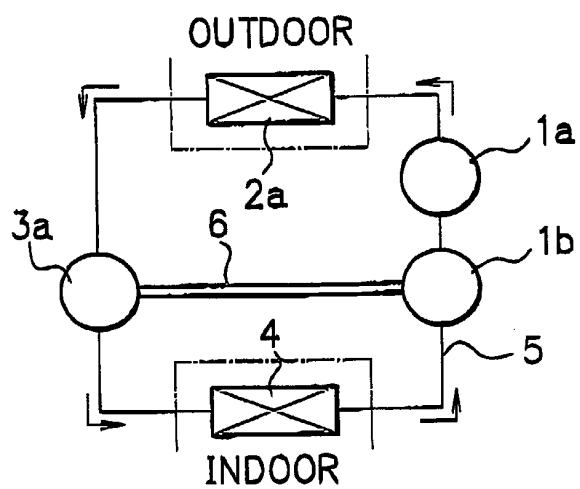
45

50

55

tween said first compressor (1a) and said second compressor (1b) is provided with a second radiator (2b).

F I G. 1



F I G. 2

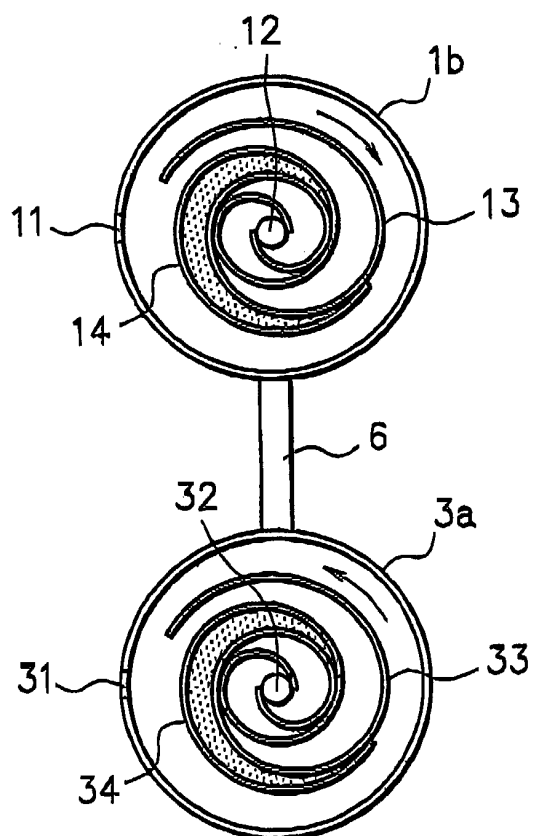


FIG. 3

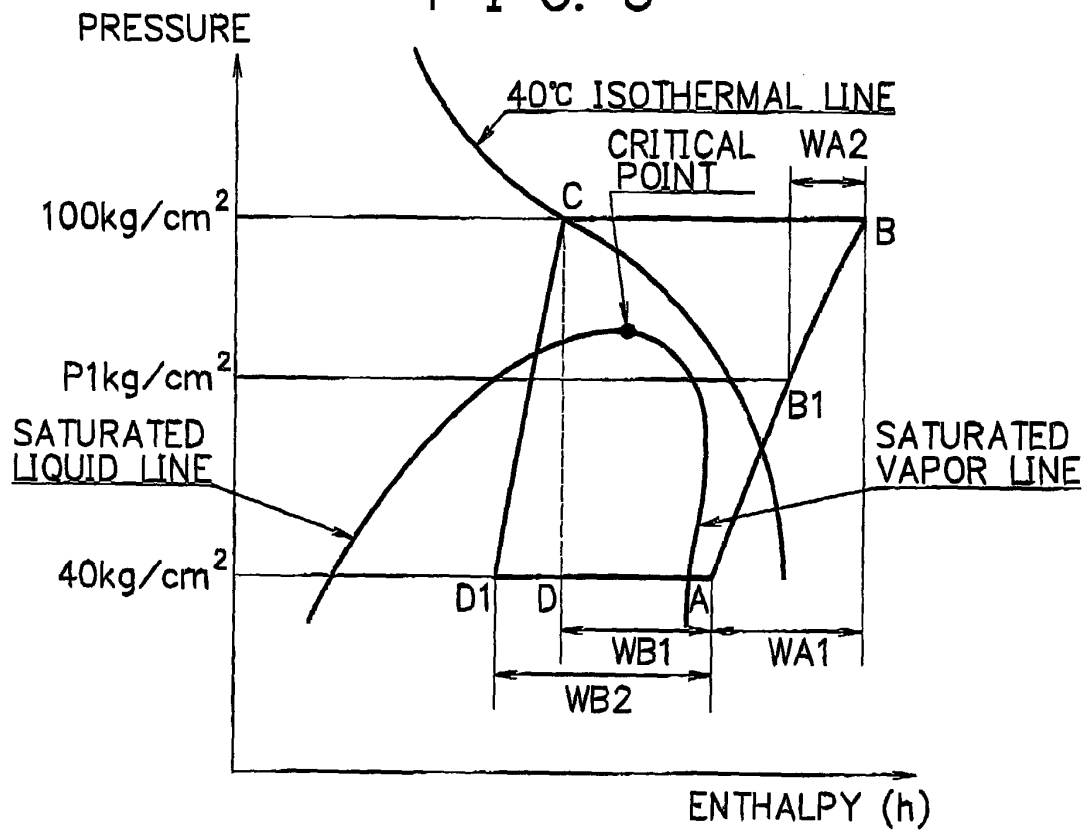


FIG. 4

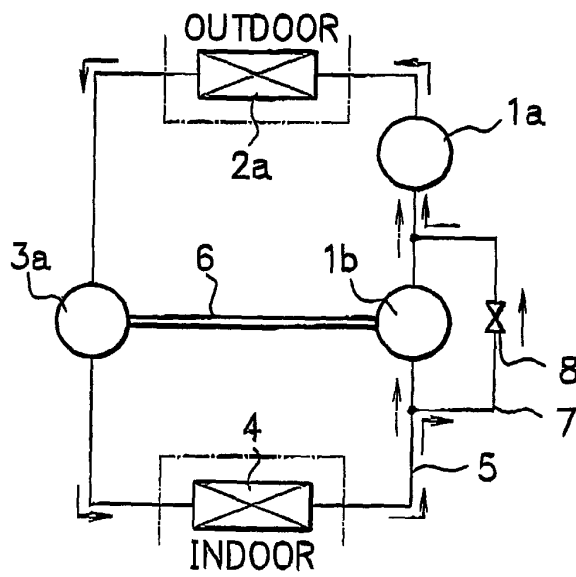


FIG. 5

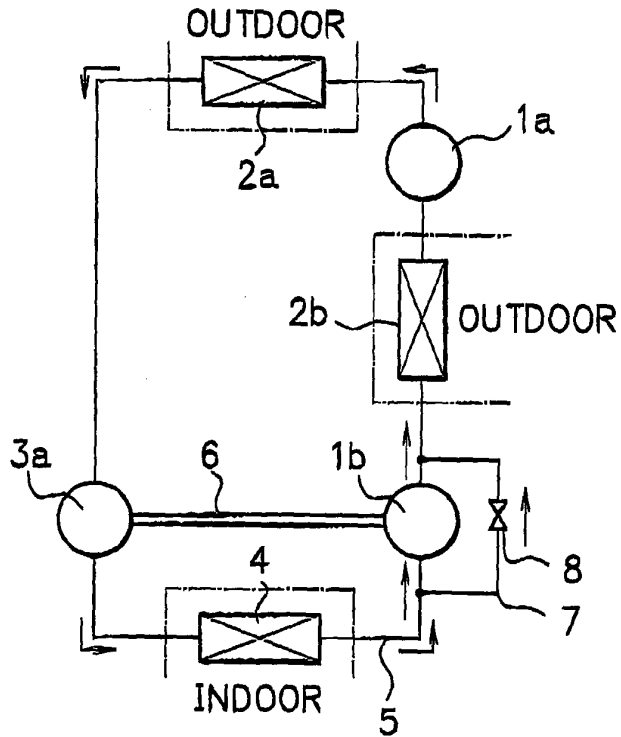


FIG. 6

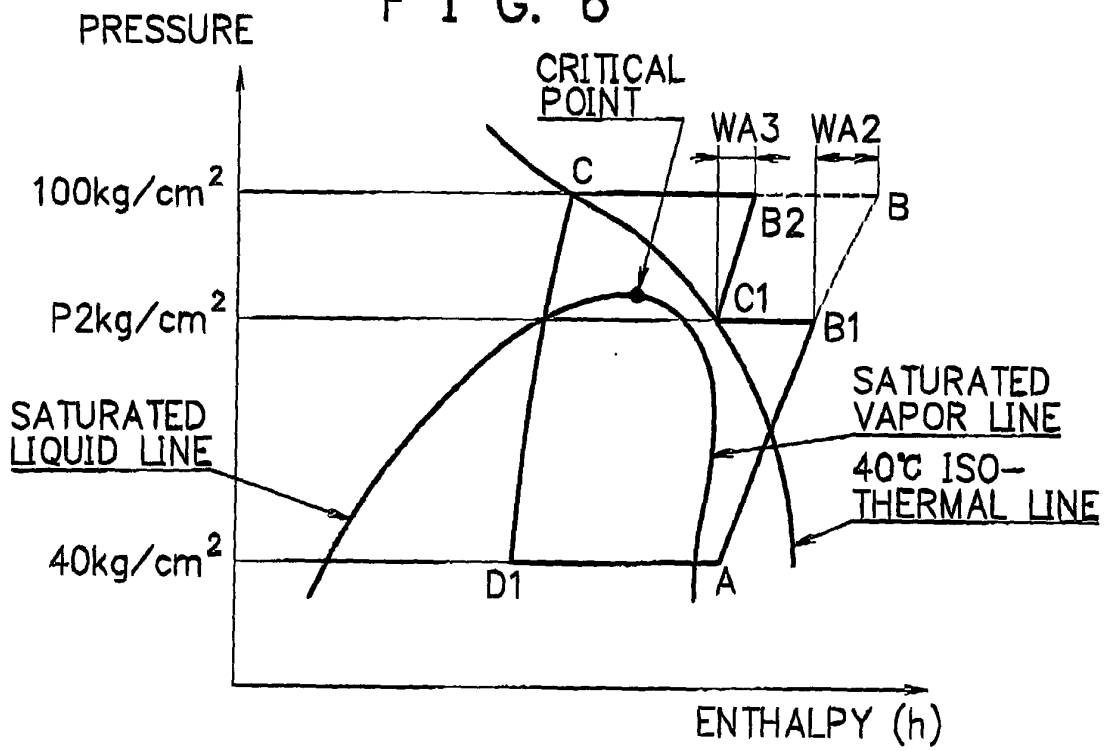


FIG. 7

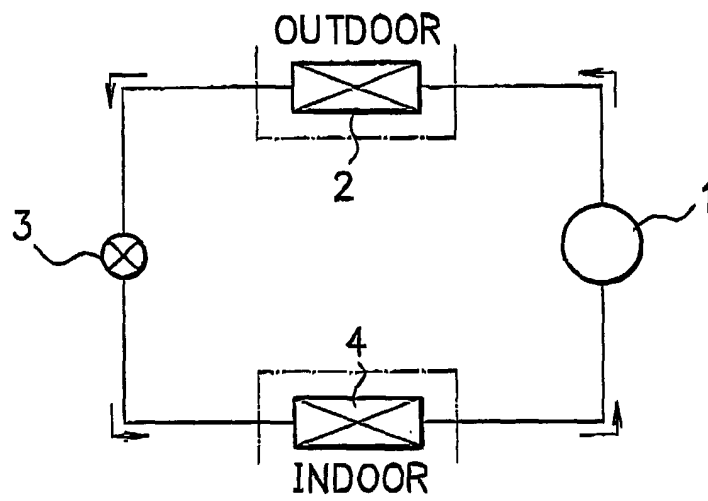
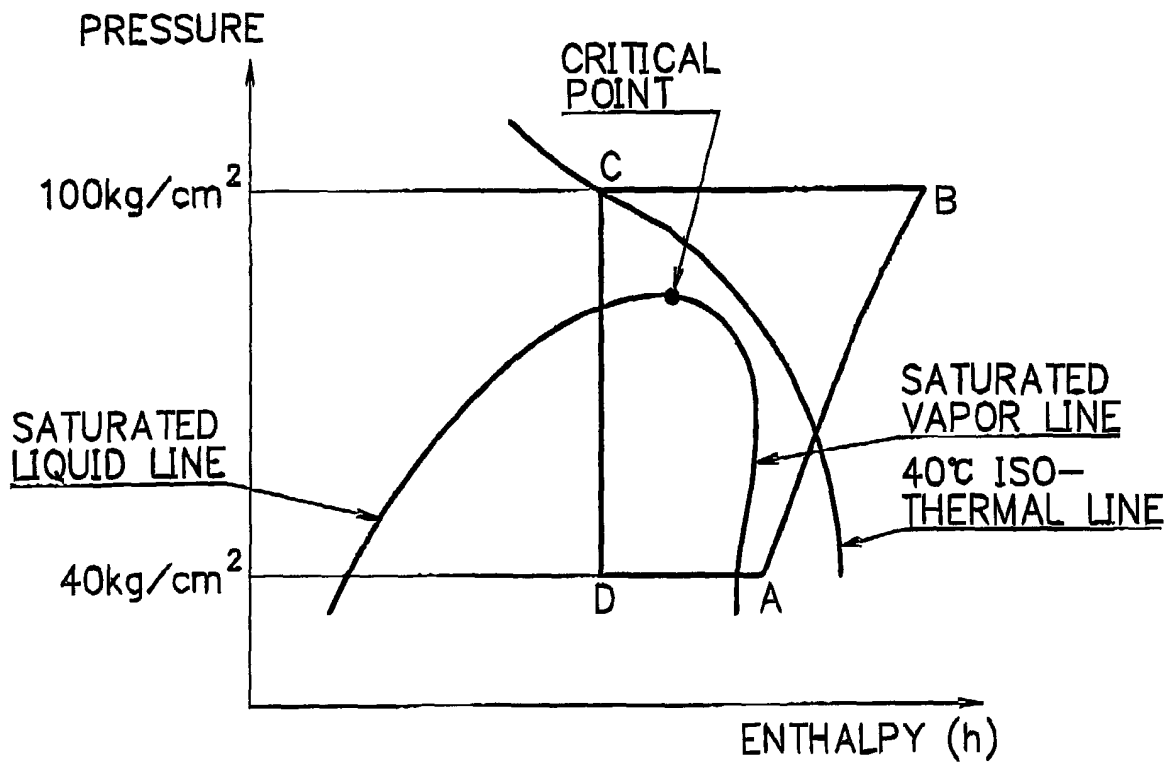


FIG. 8





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 03 25 2306

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	EP 1 046 869 A (SANDEN CORP) 25 October 2000 (2000-10-25) * abstract; claim 1; figures 2,3 *	1	F25B1/10 F25B9/00
Y	* paragraph [0013] - paragraph [0033] *	3,4	
A	* paragraph [0018]; figures 2,3 *	2	

Y	GB 2 152 649 A (COPELAND CORP) 7 August 1985 (1985-08-07) * page 1, line 97 - line 100; figure 1 *	3	

Y	GB 2 180 329 A (MEGATHERM INC) 25 March 1987 (1987-03-25) * page 4, line 48 - page 4, line 89; figure 4 *	4	

A	US 2 494 120 A (FERRO JR BERNARDO J) 10 January 1950 (1950-01-10) * the whole document *	1	

			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			F25B
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 2 July 2003	Examiner Szilagyi, B
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			

EPO FORM 1503 03.02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 03 25 2306

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

02-07-2003

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 1046869	A	25-10-2000	EP 1046869 A1	25-10-2000

GB 2152649	A	07-08-1985	AU 587173 B2	10-08-1989
			AU 3739985 A	18-07-1985
			BR 8500106 A	20-08-1985
			CA 1242086 A1	20-09-1988
			DE 3500800 A1	18-07-1985
			DK 9885 A	12-07-1985
			ES 8602237 A1	01-03-1986
			FR 2557962 A1	12-07-1985
			IT 1212109 B	08-11-1989
			JP 1848448 C	07-06-1994
			JP 5063703 B	13-09-1993
			JP 60159561 A	21-08-1985
			MX 161408 A	21-09-1990
			NZ 210800 A	31-07-1987
			US 4748820 A	07-06-1988
			US 4947655 A	14-08-1990
			US 4594858 A	17-06-1986
			ZA 8500062 A	25-09-1985

GB 2180329	A	25-03-1987	NONE	

US 2494120	A	10-01-1950	NONE	
