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(54) REFRIGERATING CYCLE SYSTEM USING CARBON DIOXIDE AS REFRIGERANT

(76) Inventor: **Masami Negishi**, Isesaki-shi (JP)

Correspondence Address:
BAKER BOTTS LLP
C/O INTELLECTUAL PROPERTY DEPARTMENT
THE WARNER, SUITE 1300
1299 PENNSYLVANIA AVE, NW
WASHINGTON, DC 20004-2400 (US)

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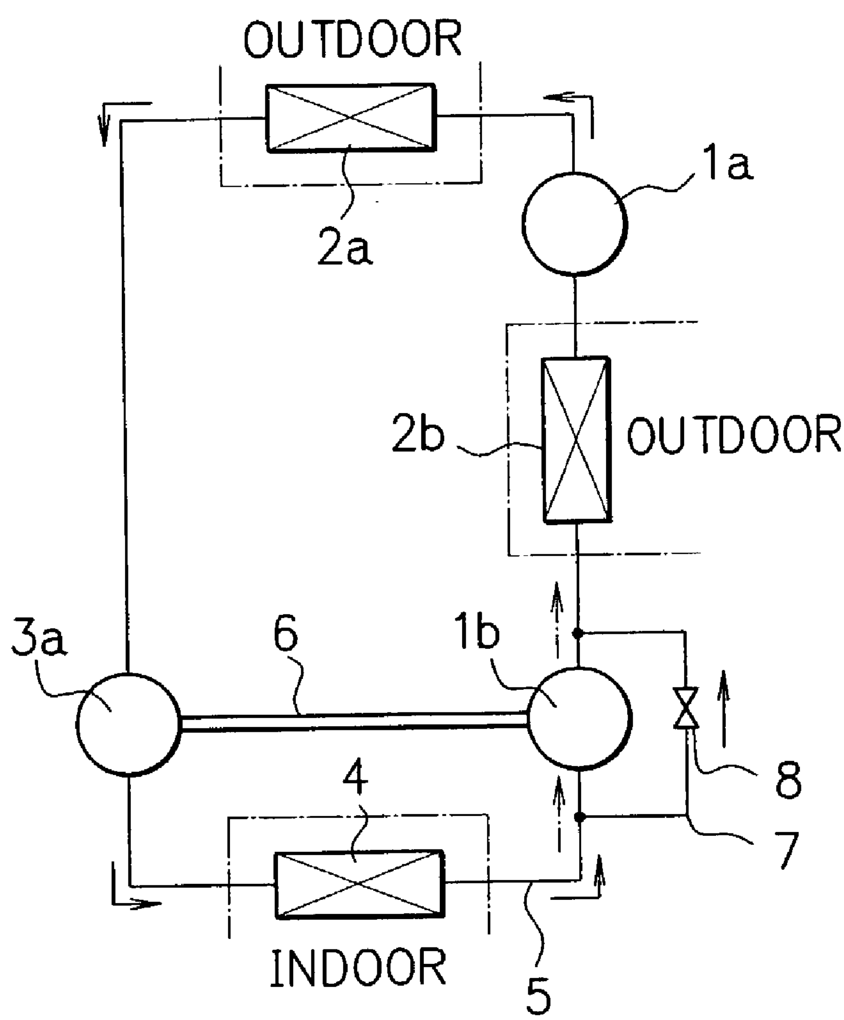
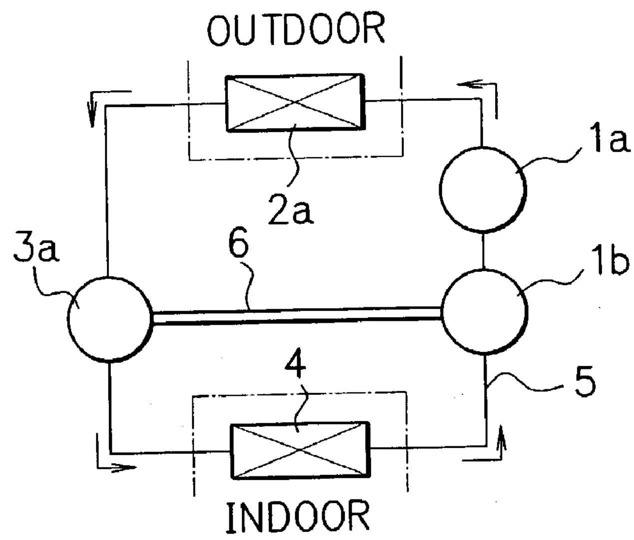
(57) **ABSTRACT**

A refrigerating cycle system of a vapor compression system has a constitution wherein a first compressor, a first radiator, an expansion mechanism, a heat absorber, and a second compressor connected sequentially and circularly. A CO_2 refrigerant is circulated in the sequence of the first compressor→the first radiator→the expansion mechanism→the heat absorber→the second compressor→the first compressor. The rotating drive shaft of the second compressor is connected to the rotating output shaft of the expansion mechanism with a common shaft. Thereby, since the drive force of the second compressor is obtained from the power generated by the refrigerant expanding action of the expansion mechanism, the power of the first compressor consumed for elevating the pressure of the refrigerant to a predetermined pressure can be minimized.



F I G. 1



F I G. 2

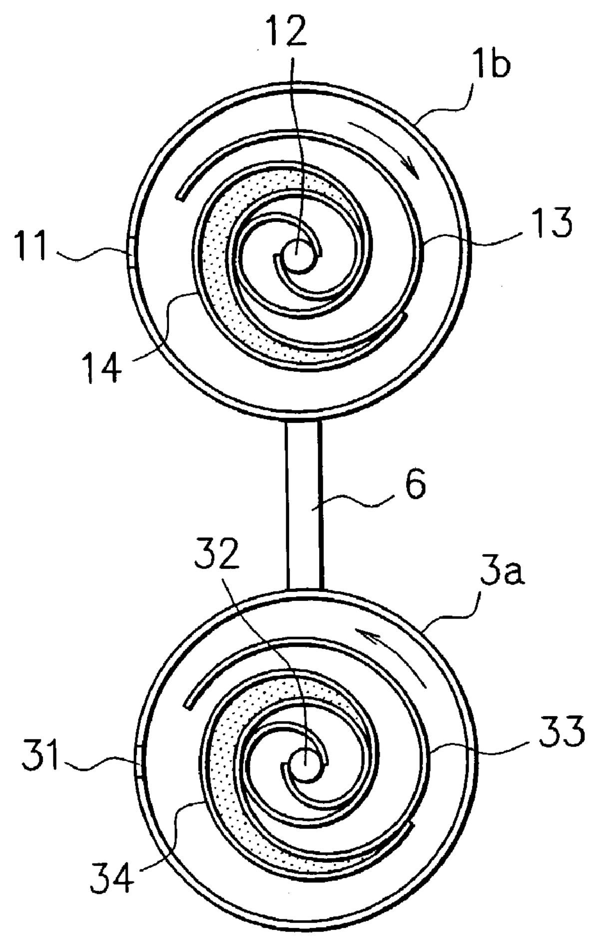


FIG. 3

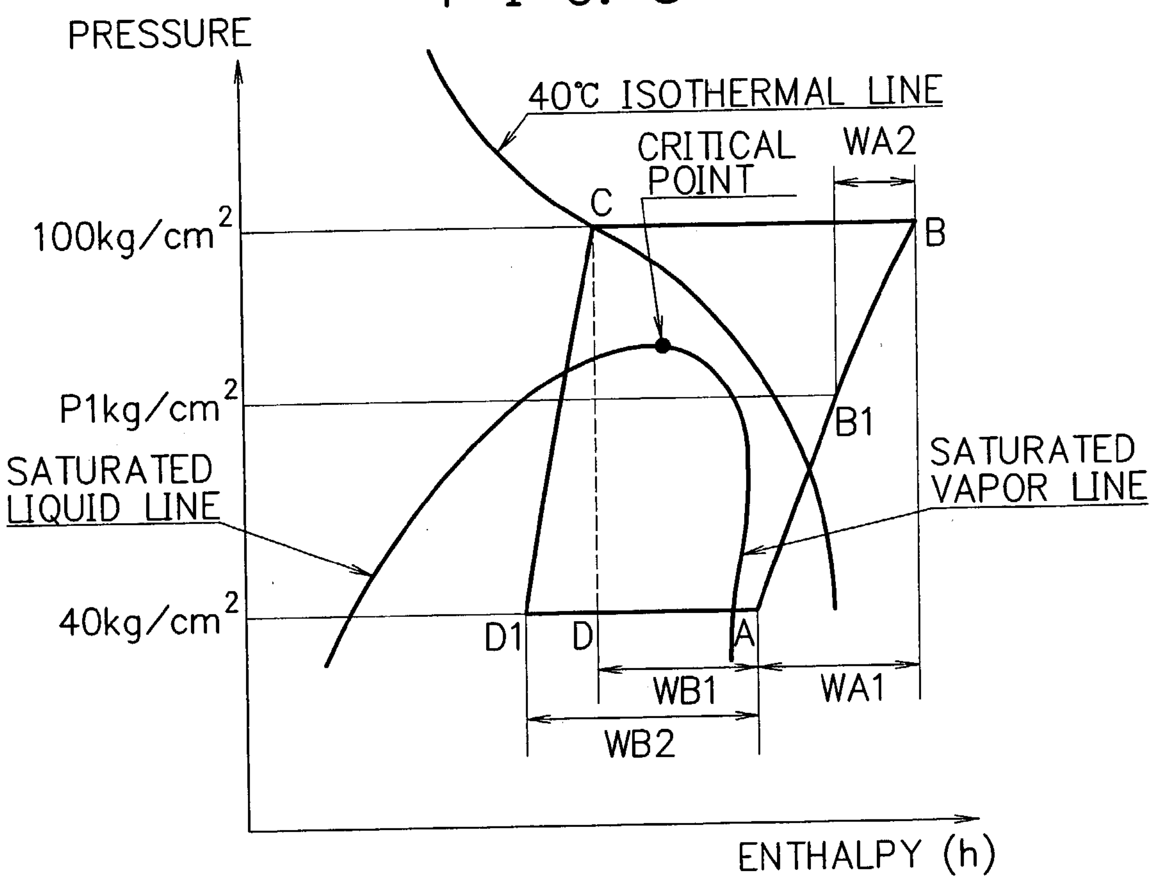

PRESSURE
40℃ ISOTHERMAL LINE
CRITICAL POINT
WA2
C
B
100kg/cm2
P1kg/cm2
B1
SATURATED VAPOR LINE
SATURATED LIQUID LINE
40kg/cm2
D1
D
A
WB1
WA1
WB2
ENTHALPY (h)

FIG. 4

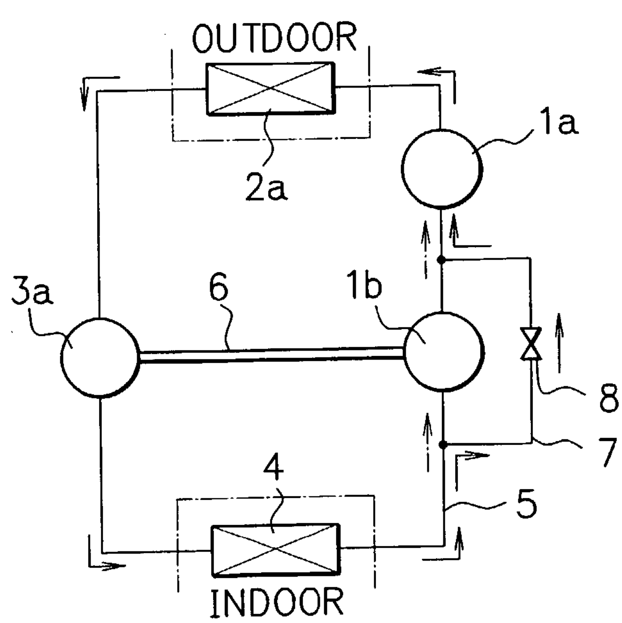

OUTDOOR
1a
2a
3a
6
1b
8
7
4
5
INDOOR

FIG. 5

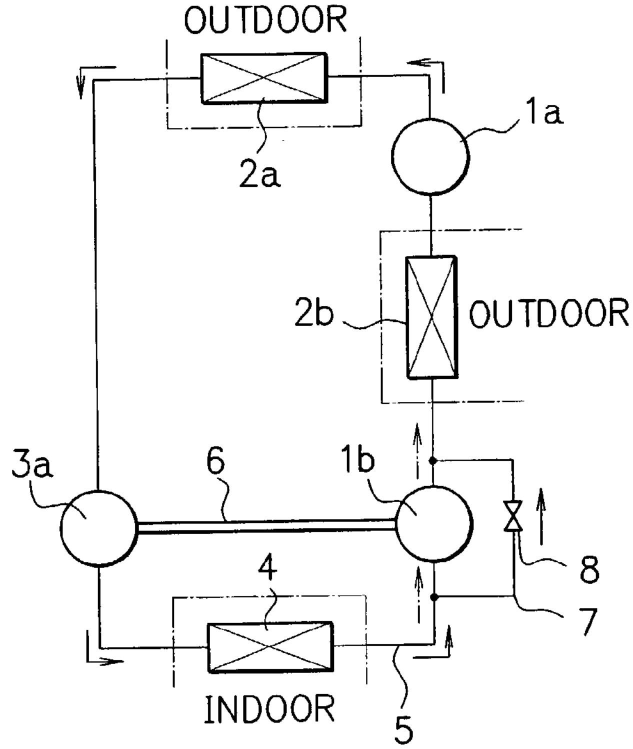

OUTDOOR
1a
2a
2b
OUTDOOR
3a
6
1b
4
8
7
INDOOR
5

FIG. 6

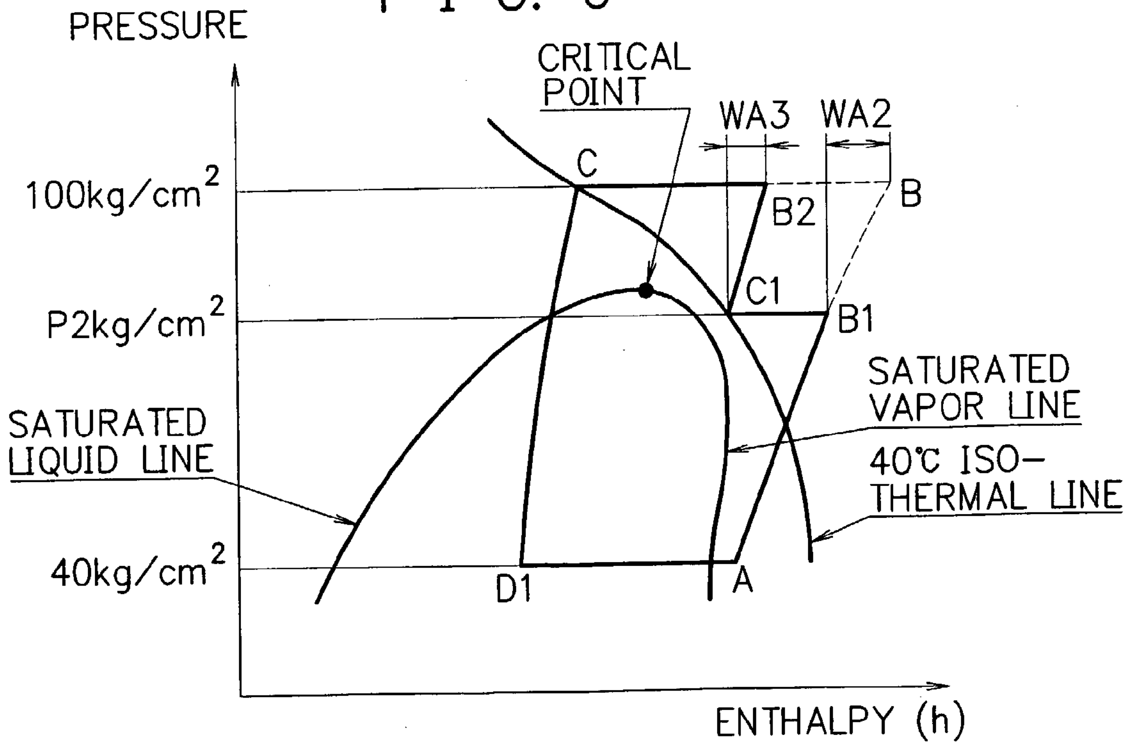

PRESSURE
CRITICAL POINT
WA3
WA2
100kg/cm2
C
B
B2
C1
P2kg/cm2
B1
SATURATED VAPOR LINE
SATURATED LIQUID LINE
40℃ ISO-THERMAL LINE
40kg/cm2
D1
A
ENTHALPY (h)

FIG. 7

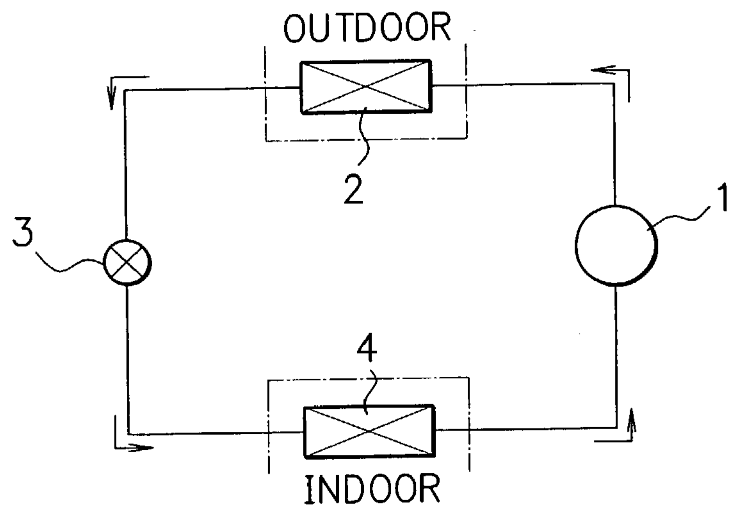
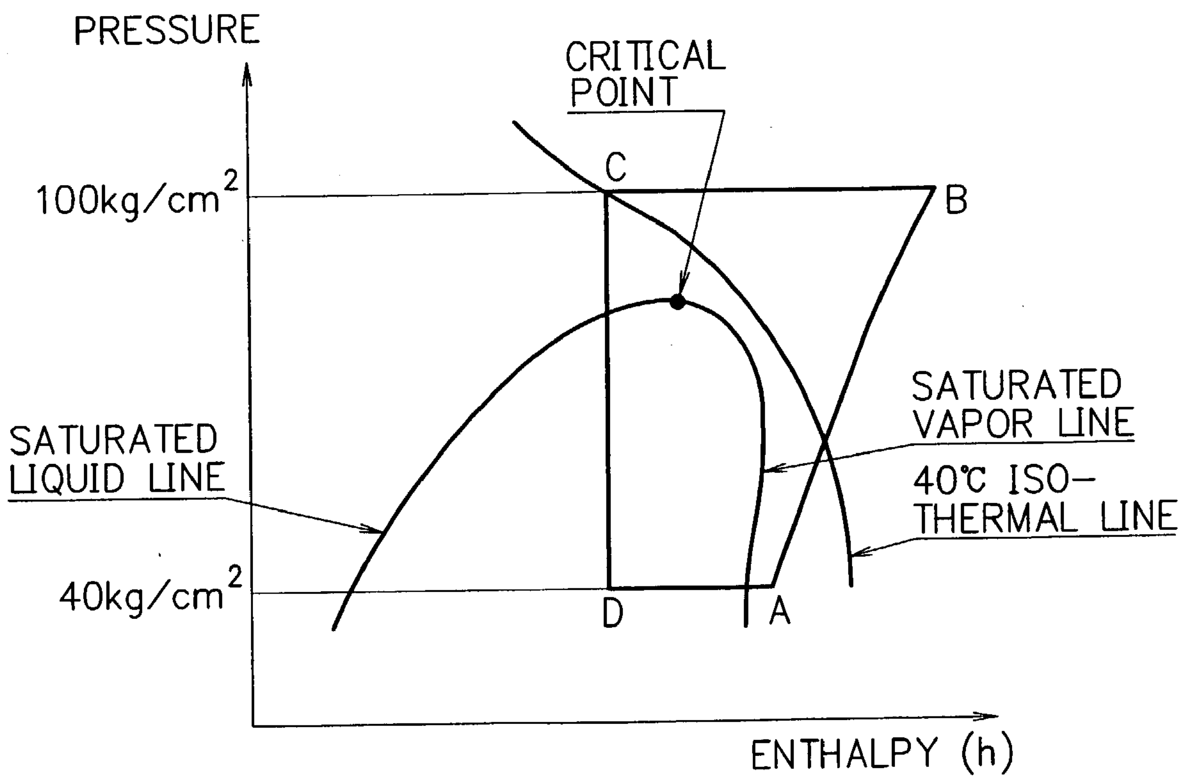

OUTDOOR
2
1
3
4
INDOOR

FIG. 8


PRESSURE
CRITICAL POINT
C
100kg/cm2
B
SATURATED VAPOR LINE
SATURATED LIQUID LINE
40℃ ISO-THERMAL LINE
40kg/cm2
D
A
ENTHALPY (h)

REFRIGERATING CYCLE SYSTEM USING CARBON DIOXIDE AS REFRIGERANT

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a refrigerating cycle system using carbon dioxide as the refrigerant.

[0003] 2. Description of the Related Art

[0004] **FIG. 7** shows a known refrigerating cycle system using carbon dioxide (CO_2) as the refrigerant.

[0005] This refrigerating cycle system has a compressor **1**, a radiator **2**, an expansion valve **3**, and a heat absorber **4**; and circulates a CO_2 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.

[0006] 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 CO_2 refrigerant (refrigerant pressure: 40 kg/cm^2) to a pressure exceeding the critical point of the saturated liquid line and the saturated vapor line, for example, 100 kg/cm^2 (A→B of **FIG. 8**). Next, the compressed CO_2 refrigerant is discharged outdoors with the radiator **2** (B→C of **FIG. 8**). Then, the heat-released CO_2 refrigerant is expanded along the isenthalpic line with the expansion valve **3** to lower the pressure (C→D of **FIG. 8**). The CO_2 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**).

[0007] 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.

[0008] 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.

[0009] 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 CO_2 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.

[0010] 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 the 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.

SUMMARY OF THE INVENTION

[0011] 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.

[0012] 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.

[0013] According to the present invention, a CO_2 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.

[0014] 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.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] **FIG. 1** is a refrigerant circuit diagram of a refrigerating cycle system according to the first embodiment;

[0016] **FIG. 2** is a schematic diagram showing the connecting structure of a second compressor with an expansion mechanism according to the first embodiment;

[0017] **FIG. 3** is a Mollier diagram of a refrigerating cycle system according to the first embodiment;

[0018] **FIG. 4** is a refrigerant circuit diagram of a refrigerating cycle system according to the second embodiment;

[0019] **FIG. 5** is a refrigerant circuit diagram of a refrigerating cycle system according to the third embodiment;

[0020] **FIG. 6** is a Mollier diagram of a refrigerating cycle system according to the third embodiment;

[0021] **FIG. 7** is a refrigerant circuit diagram of a conventional refrigerating cycle system; and

[0022] **FIG. 8** is a Mollier diagram of a conventional refrigerating cycle system.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] 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.

[**0024**] This refrigerating cycle system uses CO_2 as the refrigerant. As **FIG. 1** shows, the refrigerating cycle system sequentially connects a first compressor **1***a*, a first radiator **2***a*, an expansion mechanism **3***a*, a heat absorber **4**, and a second compressor **1***b* using a refrigerant pipe **5**. The refrigerating cycle system circulates the CO_2 refrigerant sequentially in the order of the second compressor **1***b* the first compressor **1***a* the first radiator **2***a*→the expansion mechanism **3***a*→the heat absorber **4**→the second compressor **1***b* as shown by solid-line arrows in **FIG. 1**, to cool rooms utilizing the heat-absorbing action of the heat absorber **4**.

[**0025**] In the refrigerating cycle system thus constituted, both the second compressor **1***b* and the expansion mechanism **3***a* have the constitution as shown in **FIG. 2**, that is, adopt a scroll-type compression/expansion mechanism.

[**0026**] The second compressor **1***b* 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 CO_2 refrigerant is sucked from the gas inlet **11**, which is compressed between the rotating scroll **13** and the stationary scroll **14**, and the compressed CO_2 refrigerant is discharged from the gas outlet **12**.

[**0027**] The expansion mechanism **3***a* has the inverted constitution to the second compressor **1***b*. Specifically, the expansion mechanism **3***a* 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 CO_2 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**.

[**0028**] The rotating drive shaft of the second compressor **1***b* is connected to the rotating output shaft of the expansion mechanism **3***a* with a shaft **6** as **FIG. 2** shows, and the driving of the expansion mechanism **3***a* drives the second compressor **1***b*.

[**0029**] Next, the change in the refrigerant of the refrigerating cycle system according to the present invention will be described. First, when the first compressor **1***a* is operated, the CO_2 refrigerant is compressed, and the pressure thereof is applied through the first radiator **2***a* to the gas inlet **32** of the expansion mechanism **3***a*. Thereby, the expansion mechanism **3***a* is rotated, and the rotation force of the expansion mechanism **3***a* rotates the second compressor **1***b*.

[**0030**] By such operations of the first compressor **1***a,* the second compressor **1***b,* and the expansion mechanism **3***a*, the CO_2 refrigerant is compressed by the second compressor **1***b,* and further compressed by the first compressor **1***a.* The refrigerant after two-stage compression is radiated by the first radiator **2***a* installed outdoors. The pressure of the radiated CO_2 refrigerant is reduced in the expansion mechanism **3***a*, and the refrigerant absorbs heat in the heat absorber **4** from the air in the room, and is sucked into the second compressor **1***b*.

[**0031**] The above-described refrigerating cycle system will be described referring to the Mollier diagram shown in **FIG. 3**. The CO_2 refrigerant is compressed in the second compressor **1***b,* for example, from 40 kg/cm^2 to P1 kg/cm^2 (A→B1). In the first compressor **1***a,* the refrigerant is further compressed from P1 kg/cm^2 to about 100 kg/cm^2 (B1→B). Next, it is radiated in the first radiator **2***a* (B→C), and thereafter, the pressure of the refrigerant is reduced from 100 kg/cm^2 to 40 kg/cm^2 along the isentropic line (C→D1). Then the pressure-reduced CO_2 refrigerant is circulated again into the second compressor **1***b* (D1→A).

[**0032**] Here, A→B→C→D shown in **FIG. 3** is of a conventional example (an example wherein the refrigerant pressure is changed 40 kg/cm^2 to 100 kg/cm^2 by the first compressor **1***a* 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.

[**0033**] The power (WA1) of a compressor in the conventional refrigerating cycle system is:

$$WA1=(hB-hA)$$

[**0034**] 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 **1***b* is connected to the rotating output shaft of the expansion mechanism **3***a* with a common shaft **6**. As a result, the power generated by the refrigerant-expanding action of the expansion mechanism **3***a* is utilized for the refrigerant-compressing action of the second compressor **1***b.* Therefore, the power (WA2) of the compressor **1***a* is as follows:

$$WA2=(hB-hB1)$$

[**0035**] Also, the refrigerating effect (WB1) of the conventional refrigerating cycle system is as follows:

$$WB1=(hA-hD)$$

[**0036**] On the other hand, the refrigerating effect (WB2) of the refrigerating cycle system according to the present invention is as follows:

$$WB2=(hA-hD1)$$

[**0037**] Furthermore, the COP (coefficient of performance) ($\epsilon\gamma1$) of the conventional refrigerating cycle system is as follows:

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

[**0038**] The COP ($\epsilon\gamma2$) of the refrigerating cycle system according to the present invention is as follows:

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

[**0039**] Here, as **FIG. 3** shows, since WA1>WA2, and WB1<WS2, each COP is as follows:

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

[**0040**] 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 **3***a* of the refrigerating cycle system according to the present invention adiabatically expands the CO_2 refrigerant, the refrigerant pressure changes along the isentropic line, and the refrigerating effect is improved.

[**0041**] **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.

[**0042**] In the second embodiment, a bypass pipe **7** that bypasses the second compressor **1***b* is installed in the refrigerant pipe **5** wherein the above-described second compressor **1***b* 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 **1***b,* 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 **1***b.* A switching valve **8** is installed in the middle of the bypass pipe **7**.

[**0043**] According to this embodiment, the switching valve **8** is opened when the operation of the first compressor **1***a* is started. Thereby, as the solid-line arrows in **FIG. 4** show, the CO_2 refrigerant is sucked into the suction side of the first compressor **1***a* through the bypass pipe **7**, and the pressure in the suction side of the expansion mechanism **3***a* is elevated. Concurrent with the pressure elevation, the expansion mechanism **3***a* is driven, and the second compressor **1***b* is also driven. Then, after the expansion mechanism **3***a* and the second compressor **1***b* have been driven, the switching valve **8** is closed. Thereby, as dashed-line arrows in **FIG. 4** show, the entire CO_2 refrigerant is circulated into the second compressor **1***b,* and the operation shifts to the steady operation.

[**0044**] According to this embodiment, when the operation of the first compressor **1***a* is started, the suction pressure of the expanding mechanism **3***a* is rapidly elevated, and shift to the steady operation is smoothly accomplished in a short time.

[**0045**] **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.

[**0046**] In the third embodiment, the refrigerant pipe **5** between the first compressor **1***a* and the second compressor **1***b* is provided with a second radiator **2***b*. According to this embodiment, the switching valve **8** is opened when the operation of the first compressor **1***a*. Thereby, as the solid-line arrows in **FIG. 5** show, a CO_2 refrigerant is sucked into the suction side of the first compressor **1***a* through a bypass pipe **7** and a second radiator **2***b*, and the pressure in the suction side of the expanding mechanism **3***a* is elevated. Concurrent with the pressure elevation, the expansion mechanism **3***a* is driven, and the second compressor **1***b* is also driven. Then, after the expansion mechanism **3***a* and the second compressor **1***b* have been driven, the switching valve **8** is closed. Thereby, as dashed-line arrows in **FIG. 5** show, the entire CO_2 refrigerant is circulated into the second compressor **1***b,* and the operation shifts to the steady operation.

[**0047**] The cooling cycle in such a steady operation will be described referring to the Mollier diagram of **FIG. 6**. The CO_2 refrigerant is compressed in the second compressor **1***b,* for example, from 40 kg/cm^2 to P2 kg/cm^2 (A→B1). The compressed CO_2 refrigerant is radiated in the second radiator **2***b* (B1→C1). In the first compressor **1***a,* the radiated CO_2 refrigerant is further compressed from P2 kg/cm^2 to 100 kg/cm^2 (C1→B2). Next, it is radiated in the first radiator **2***a* (B2→C), and thereafter, in the expanding mechanism **3***a* the pressure of the refrigerant is reduced from 100 kg/cm^2 to 40 kg/cm^2 along the isentropic line (C→D1). Then the pressure-reduced CO_2 refrigerant is circulated again into the second compressor **1***b* (D1→A).

[**0048**] 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.

[**0049**] The power (WA2) of the compressor **1***a* of the refrigerating cycle system according to the above-described first embodiment is as follows:

$$WA2=(hB-hB1)$$

[**0050**] The power (WA3) of the compressor **1***a* of the refrigerating cycle system according to this embodiment is as follows:

$$WA3=(hB2-hC1)$$

[**0051**] Here, each power WA2 and WA3 is as follows as **FIG. 6** shows:

$$WA2>WA3$$

[**0052**] This is because the refrigerant sucked into the first compressor **1***a* is partly radiated in the second radiator **2***b*, and the power is reduced by decrease in enthalpy (by increase in the gradient of isentropic line in the first compressor **1***a* greater than the gradient of isentropic line in the second compressor **1***b*).

[**0053**] Therefore, in the refrigerating cycle system according to this embodiment, the power of the compressor **1***a* further decreases, and the refrigerating cycle system excels in energy saving.

What is claimed is:

1. 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 said first radiator in a supercritical state,

wherein a second compressor is provided in the refrigerant pipe between said heat absorber and said first compressor, and a rotating drive shaft of said second compressor and a rotating output shaft of said expansion mechanism are connected to each other.

2. The refrigerating cycle system according to claim 1, provided with a bypass pipe one end of which is connected to the refrigerant pipe connected to the gas inlet of said second compressor, and the other end of which is connected to the refrigerant pipe connected to the gas outlet of said second compressor to bypass said second compressor; and

said bypass pipe is provided with a switching valve.

3. The refrigerating cycle system according to claim 1, wherein said second compressor and said expansion mechanism are composed of a scroll-type compression/expansion mechanism.

4. The refrigerating cycle system according to claim 2, wherein said second compressor and said expansion mechanism are composed of a scroll-type compression/expansion mechanism.

5. The refrigerating cycle system according to claim 1, wherein said refrigerant pipe between said first compressor and said second compressor is provided with a second radiator.

6. The refrigerating cycle system according to claim 2, wherein said refrigerant pipe between said first compressor and said second compressor is provided with a second radiator.

7. The refrigerating cycle system according to claim 3, wherein said refrigerant pipe between said first compressor and said second compressor is provided with a second radiator.

8. The refrigerating cycle system according to claim 4, wherein said refrigerant pipe between said first compressor and said second compressor is provided with a second radiator.

* * * * *