

Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration system, typically an air refrigeration system, which achieves cooling by the sensible heat of a circulating gaseous refrigerant. More particularly, the invention relates to a closed-cycle gas refrigeration system that allows adjustment of refrigerant gas pressure in a compressor inlet-side refrigerant gas passage.

BACKGROUND ART

[0002] Air refrigeration systems with air as the working refrigerant have been known, wherein air is compressed to high pressure and high temperature by a compressor and cooled by a cooler that uses a cooling water and a cold energy recovery heat exchanger, after which the air is expanded to low pressure and low temperature by an expander driven by the same drive shaft as that of the compressor, to achieve cooling by the sensible heat of this low-temperature, low-pressure air. Such air refrigeration systems have the advantage of environmental friendliness as they do not use refrigerants such as CFC or ammonia.

[0003] These types of air refrigeration systems can be classified into open-cycle air refrigeration systems (hereinafter "open-cycle system") that include an open end to the atmosphere in an air refrigerant circulation system, and closed-cycle air refrigeration systems (hereinafter "closed-cycle system") that have an air refrigerant circulation system closed to the atmosphere. An open-cycle system releases low-temperature air from an expander outlet, for example, into a refrigerator to cool the objects to be cooled with this low-temperature air, and returns the air that has served to refrigerate back to a compressor inlet-side air refrigerant passage connected to a compressor inlet port. The pressure of air refrigerant in the compressor inlet-side air refrigerant passage is therefore maintained always at the atmospheric level. A closed-cycle air refrigeration system, on the other hand, has an air refrigerant circulation system that is closed to the atmosphere, and is configured to exchange heat via brine, i.e., heat is exchanged between low-temperature air on the outlet side of an expander and brine, and the objects to be cooled are cooled with the cooled brine. Therefore, the air refrigerant pressure on the inlet side of the compressor varies depending on the operating condition and is not constant.

[0004] In a closed-cycle air refrigeration system, if it starts operating at an atmospheric pressure, the air refrigerant in the air refrigerant circulation system is gradually cooled down, and with a decrease in volume, the air pressure inside the air refrigerant circulation system lowers gradually, eventually to a negative level on the inlet side of the compressor. When this occurs, the compression performance of the compressor or cooling per-

formance of the expander may drop suddenly, or the system may malfunction. For this reason, an open-cycle system and a closed-cycle system cannot be implemented by a machine with the same design specifications (such as pressure), and separate machines having different design specifications are required, which causes an increase in cost.

[0005] If the air refrigerant pressure on the compressor inlet side of the closed-cycle system is adjustable, the pressure can be made equal to the atmospheric level on the compressor inlet side, which will resolve the problem of the drop in cooling performance mentioned above. Also, a single machine can serve both as a closed-cycle system and an open-cycle system with the same pressure capacity, without a worry that the cooling performance may drop when the machine is used as the closed-cycle system.

[0006] Patent Document 1, for example, discloses a technique of making air refrigerant pressure adjustable on the compressor inlet side.

The system of Patent Document 1 is an open-cycle type, but includes means of preventing the passage from clogging and of adjusting pressure, whereby, in the event of an abnormal drop in the compressor inlet pressure, dry air is supplied to the refrigerant passage, and when the compressor inlet pressure rises to the atmospheric level or above, part of the air refrigerant is released to the outside.

The system disclosed in Patent Document 1 is an open-cycle type, in which low-temperature air from the outlet side of the expander is released into the refrigerator. Although it is not a closed-cycle system, this technique allows the compressor inlet pressure to stay more or less at the atmospheric level, whereby the object of using a single machine with the same pressure capacity both as a closed-cycle system and an open-cycle system can be achieved.

However, as this system includes a dry air introducing unit and an air release passage on the inlet side of the compressor for the adjustment of pressure, the pressure of incoming air and the pressure of outgoing air tend to counterbalance each other, because of which smooth pressure control may often be difficult.

Patent Document 2, for example, discloses a technique of introducing dry air having a dew point of about -30°C from a refrigerant gas replenishing system via an introducing path into a compressor inlet path, which forms part of a refrigerant gas circulation path in a closed-cycle refrigeration system.

[0007]

Patent Document 1: Japanese Patent Application Laid-open No. 2004-317081

Patent Document 2: Japanese Patent Application Laid-open No. H10-47829

[0008] The system of Patent Document 2 is a closed-cycle type (see paragraph [0019]) wherein dry air

having a dew point of about -30°C is introduced into the compressor inlet path, after which the refrigerant gas circulation path is filled with gas to a level of about $1\text{ kg/cm}^2\text{G}$, for example, before the compressor is started up. This is, however, applied to a specific type of refrigeration system, as stated in paragraph [0008], where one operation in which a refrigerant is cooled with the refrigerant gas and another operation in which objects to be cooled are refrigerated with the circulating refrigerant are performed at the same time or in different time periods. Disclosed is only the introducing of dry air before the compressor is started up, and there is no mention of adjusting pressure on the compressor inlet side.

DISCLOSURE OF THE INVENTION

[0009] In view of the problems in the conventional techniques, an object of the present invention is to realize a closed-cycle gas refrigeration system that uses air or nitrogen as the working refrigerant, has a simple and low-cost configuration, and allows adjustment of the pressure on the compressor inlet side.

[0010] To achieve the above object, a closed-cycle gas refrigeration system of the present invention includes a compressor and an expander coupled to a single output shaft of a driving device, a cooler that cools refrigerant gas on an outlet side of the compressor, a brine cooler that cools brine cooling an object to be cooled with refrigerant gas made of air or nitrogen gas, and a cold energy recovery heat exchanger that further cools the refrigerant gas cooled by the cooler with the refrigerant gas returning from the brine cooler. The system further includes a sealed refrigerant gas supply/discharge system formed by an expansion tank hermetically containing refrigerant gas having a pressure of at least an atmospheric pressure and a gauge pressure of lower than 0.2 MPa that is outside of an applicable pressure range specified by the High Pressure Gas Safety Act in Japan, a compressor inlet-side connecting passage connecting the expansion tank and a compressor inlet-side refrigerant gas passage, and a compressor outlet-side connecting passage connecting the expansion tank and a compressor outlet-side refrigerant gas passage; and a pressure sensor detecting a pressure of refrigerant gas flowing in the compressor inlet-side refrigerant gas passage. The system is configured such that refrigerant gas is replenished from the expansion tank to the compressor inlet-side refrigerant gas passage, and discharged from the compressor outlet-side refrigerant gas passage to the expansion tank while the pressure sensor detects the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage, such that the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage is maintained within a preset range.

[0011] In the system of the present invention, even though the system is a closed-cycle type having the sealed refrigerant gas supply/discharge system without any open end that leads to the outside, refrigerant gas

can be reliably replenished from the expansion tank to the compressor inlet-side refrigerant gas passage, and discharged from the compressor outlet-side refrigerant gas passage into the expansion tank, by using a pressure difference between the outlet side and the inlet side of the compressor.

Since the refrigerant gas is replenished and discharged via the expansion tank in a closed circulation loop, the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage can be adjusted, while the closed circulation loop is maintained without any unnecessary release of refrigerant gas to the atmosphere. Thereby, the pressure inside the expansion tank can be maintained lower than 0.2 MPa (gauge), which is outside of the applicable pressure range specified by the High Pressure Gas Safety Act in Japan.

As a result, the closed-cycle system can be used also as an open-cycle system having equivalent design specifications (such as pressure), whereby a cost reduction can be achieved.

[0012] The refrigerant gas is not dissipated to the outside. Therefore, there will be no loss of refrigerant gas, and as no external air mixes into the refrigerant gas passages, no moisture contained in the external gas mixes in the refrigerant gas. Accordingly, with dry air or nitrogen having a lower dew point than the operating temperature of the refrigeration system in the expansion tank, the system can be operated always at a temperature higher than the dew point temperature of the refrigerant gas, so that no dehumidification system is required, and the problem of increased pressure loss in the refrigerant gas passages due to freezing of water component contained in the refrigerant gas will not occur. Also, with the use of the sealed refrigerant gas supply/discharge system, the loss of refrigerant gas can be reduced.

[0013] With the refrigerant gas pressure in the expansion tank being maintained higher than that in the compressor inlet-side refrigerant gas passage and lower than a gauge pressure of 0.2 MPa , which is lower than the refrigerant gas pressure in the compressor outlet-side refrigerant gas passage and is outside of the applicable pressure range specified by the High Pressure Gas Safety Act in Japan, the closed-cycle system can be configured at low cost even though the system has design specifications equivalent to those of an open-cycle system, and also the refrigerant gas can be supplied from the expansion tank to the compressor inlet-side refrigerant gas passage, and discharged from the compressor outlet-side refrigerant gas passage to the expansion tank, smoothly.

[0014] In the present invention, the system may preferably further include a first open/close valve provided in the compressor inlet-side connecting passage, a second open/close valve provided in the compressor outlet-side connecting passage, and a controller receiving a detection signal from the pressure sensor and thereby controlling the first open/close valve and the second open/close valve, such that the refrigerant gas pressure in the com-

pressor inlet-side refrigerant gas passage is maintained within the preset range.

[0015] In this configuration, when the pressure detected by the pressure sensor becomes lower than the preset range during the operation of the system, the first open/close valve is opened to supply refrigerant gas to the compressor inlet-side refrigerant gas passage, while, when the pressure detected by the pressure sensor becomes higher than the preset range, the second open/close valve is opened to recover excess refrigerant gas from the refrigerant gas passage into the expansion tank. Thereby, the refrigerant gas pressure in the refrigerant gas passage can be precisely maintained within the preset range.

[0016] In the system of the present invention, preferably, the expansion tank may include an expandable hollow member in which gas is hermetically contained in an expandable, hollow hermetic membrane, this expandable hollow member being expanded and contracted in accordance with the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage, such that the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage is maintained within the preset range. Thereby, when the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage becomes lower than the preset range, the extendable hollow member expands automatically and supplies refrigerant gas to the compressor inlet-side refrigerant gas passage. Conversely, when the refrigerant gas pressure in the compressor inlet-side becomes higher than the preset range, the expandable hollow member automatically contracts, as it is pressed by the surrounding air refrigerant, so that refrigerant gas is recovered from the compressor inlet-side refrigerant gas passage.

[0017] With this configuration, there is no need to provide a pressure reducing valve or an open/close valve in the compressor inlet-side refrigerant gas passage, and the refrigerant gas pressure in the refrigerant gas passage can be maintained within the preset range without requiring complex control of valve operation, etc. The refrigerant gas pressure on the inlet side of the compressor can be automatically determined by presetting the pressure level of gas in the expandable hollow member in accordance with the size of the expansion tank.

[0018] An operating method according to the present invention using the above-described system of the present invention includes the steps of detecting the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage with the pressure sensor; supplying the refrigerant gas to the compressor inlet-side refrigerant gas passage from the expansion tank when the refrigerant gas pressure becomes lower than the preset range such that the refrigerant gas pressure falls back into the preset range; and discharging the refrigerant gas from the compressor outlet-side refrigerant gas passage to the expansion tank when the refrigerant gas pressure becomes higher than the preset range such that the refrigerant gas pressure falls back into the preset range.

[0019] With the method of the present invention, as the refrigerant gas travels between the sealed refrigerant gas supply/discharge system and the closed-cycle refrigerant gas passages via the expansion tank, the refrigerant gas pressure in the compressor inlet side can be adjusted. Thereby, the pressure inside the expansion tank can be maintained lower than 0.2 MPa (gauge), which is outside of the applicable pressure range specified by the High Pressure Gas Safety Act in Japan. There is no loss of refrigerant gas as the gas is not released to the atmosphere (outside), and no external air mixes into the refrigerant gas passages. With dry gas sealed in the expansion tank, the system can be operated always at a dew point temperature or higher of the refrigerant gas, as no moisture in the external gas mixes in the refrigerant gas. Therefore, no dehumidification system is required. Also, there will be no loss of refrigerant gas as the system uses the sealed refrigerant gas supply/discharge system.

[0020] According to the present invention, the refrigerant gas pressure in the expansion tank is maintained higher than the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage and lower than that in the compressor outlet-side refrigerant gas passage (lower than 0.2 MPa (gauge)), whereby the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage can be adjusted smoothly. A dehumidification system need not be installed, and refrigerant gas can be smoothly supplied to and discharged from the refrigerant gas passages. Moreover, even though the system is a closed-cycle type, it can be used also as an open-cycle system having equivalent design specifications (such as pressure). Also, as the pressure in the expansion tank can be maintained lower than 0.2 MPa (gauge) that is outside of the applicable pressure range specified by the High Pressure Gas Safety Act in Japan, the system can be designed at low cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

FIG. 1 is a system diagram of a closed-cycle air refrigeration system according to a first embodiment, in which the present invention is applied to an air refrigeration system; and

FIG. 2 is a system diagram of a closed-cycle air refrigeration system according to a second embodiment, in which the present invention is applied to an air refrigeration system.

BEST MODE FOR CARRYING OUT THE INVENTION

[0022] The illustrated embodiments of the present invention will be hereinafter described in detail. It should be noted that, unless otherwise particularly specified, the sizes, materials, shapes, and relative arrangement or the like of constituent components described in these embodiments are not intended to limit the scope of this in-

vention.

(Embodiment 1)

[0023] A first embodiment in which the present invention is applied to an air refrigeration system will be described with reference to FIG. 1. The closed-cycle air refrigeration system 10A according to this embodiment shown in FIG. 1 includes air refrigerant passages 12a to 12f for air refrigerant to circulate, and a compression/expansion unit 14, a water cooled heat exchanger 16, a heat recovery heat exchanger 18, and a brine cooler 20 arranged in these air refrigerant passages 12a to 12f. The compression/expansion unit 14 includes a compressor 22, a motor 24, and an expander 26. The compressor 22 and the expander 26 are coupled to a rotating shaft 24a of the motor 24 to rotate coaxially.

[0024] To the outlet port of the compressor 22 is connected a compressor outlet-side air refrigerant passage 12b, which is connected to the entrance of a high-temperature passage of the water cooled heat exchanger 16. The exit of the high-temperature passage is connected to an air refrigerant passage 12c, and the other end of the air refrigerant passage 12c is connected to the entrance of a high-temperature passage of the heat recovery heat exchanger 18. The exit of the high-temperature passage is connected to an air refrigerant passage 12d, and the other end of the air refrigerant passage 12d is connected to the entrance of the expander 26.

[0025] The exit of the expander 26 is connected to an air refrigerant passage 12e, and the other end of the air refrigerant passage 12e is connected to the entrance of the brine cooler 20. An air refrigerant passage 12f is connected to the exit of the brine cooler 20, and the other end of the air refrigerant passage 12f is connected to the entrance of a low-temperature passage of the heat recovery heat exchanger 18. The exit of the low-temperature passage is connected to a compressor inlet-side air refrigerant passage 12a, and the other end of the compressor inlet-side air refrigerant passage 12a is connected to the inlet port of the compressor 22.

[0026] A cooling water circulation passage 28 is connected to the entrance and exit of the low-temperature passage of the water cooled heat exchanger 16. A cooling tower 30, a pump 32, and a flow control valve 34 are arranged in the cooling water circulation passage 28. Cooling water is cooled at the cooling tower 30, and circulated in the direction of the arrows by the pump 32. Water such as well water or industrial water is replenished as required to the cooling water circulation passage 28.

A brine circulation passage 36 is arranged inside the brine cooler 20. The brine circulation passage 36 is connected to heat exchanging pipes 38 arranged inside a refrigerator 40.

[0027] Further provided is a sealed expansion tank 51 containing air refrigerant at a pressure of at least the atmospheric level and having no open port to the outside.

The expansion tank 51 communicates with the compressor inlet-side air refrigerant passage 12a via a compressor inlet-side connecting (replenishing) passage 52, and with the compressor outlet-side air refrigerant passage 12b via a compressor outlet-side connecting (recovering) passage 54. A pressure reducing valve 56 and a solenoid 58 are provided in the compressor inlet-side connecting (replenishing) passage 52, while a solenoid 60 is provided in the compressor outlet-side connecting (recovering) passage 54. The expansion tank 51 is filled with dry air or nitrogen that has a lower dew point than the operating temperature condition of the refrigeration system. The inside pressure the expansion tank 51 is set higher than that of the air refrigerant in the compressor inlet-side air refrigerant passage 12a and lower than that of the air refrigerant in the compressor outlet-side air refrigerant passage 12b.

[0028] A pressure sensor 62 that detects the pressure of the air refrigerant is provided in the compressor inlet-side air refrigerant passage 12a. A controller 64 receives a detection signal from the pressure sensor 62 and controls the solenoids 58 and 60 to open and close. The expansion tank 51, compressor inlet-side connecting passage 52, compressor outlet-side connecting passage 54, and their associated devices constitute a sealed air refrigerant supply/discharge system 50.

[0029] In this configuration, air refrigerant is compressed by the compressor 22 and discharged at high temperature and high pressure. The high-temperature, high-pressure air refrigerant is cooled primarily by the cooling water in the water cooled heat exchanger 16. The primary cooled air refrigerant is cooled secondarily by air refrigerant that has returned from the brine cooler 20 at the heat recovery heat exchanger 18. The secondary cooled air refrigerant is expanded by the expander 26 and turns into a very low-temperature, low-pressure air refrigerant.

[0030] The low-temperature, low-pressure air refrigerant is supplied to the brine cooler 20 via the refrigerant gas passage 12e, where it exchanges heat with the brine circulating in the brine circulation passage 36 to cool the brine. The brine thus cooled is sent to the heat exchanging pipes 38 inside the refrigerator 40 to cool the atmosphere inside the refrigerator 40 to, for example, -50°C to -100°C . Thus the object to be cooled such as food stored in the refrigerator 40 is refrigerated. The air refrigerant, after having served to cool the brine in the brine cooler 20, travels through the air refrigerant passage 12f, and reaches the heat recovery heat exchanger 18. There in the heat recovery heat exchanger 18 it exchanges heat with the air refrigerant to be sent to the expander 26 and cools the same, after which it is sent to the inlet port of the compressor 22 via the compressor inlet-side air refrigerant passage 12a.

[0031] Once the closed-cycle air refrigeration system 10A starts operating, the air refrigerant in the air refrigerant passages 12d to 12f is cooled gradually, and at the same time reduced in volume. With a decrease in volume,

the density of the air refrigerant increases. The pressure of the air refrigerant in the air refrigerant passages 12a, 12e, and 12f gradually reduces. In the compressor inlet-side air refrigerant passage 12a, the pressure turns negative, which is lower than the preset range. Therefore, when the pressure sensor 62 detects this, the controller 64 opens the solenoid 58. Thereupon, the air refrigerant sealed in the expansion tank 51 is supplied to the compressor inlet-side air refrigerant passage 12a via the compressor inlet-side connecting (replenishing) passage 52 to return the pressure of the air refrigerant in the compressor inlet-side air refrigerant passage 12a to fall back into the preset range.

[0032] A pressure rise of air refrigerant in the compressor inlet-side air refrigerant passage 12a due to, for example, an increase in ambient temperature of the refrigeration system may render the system unable to start operation. Therefore, when the pressure sensor 62 detects that the air refrigerant pressure has exceeded a preset range, the controller 64 opens the solenoid 60. Thereupon, the air refrigerant in the compressor outlet-side air refrigerant passage 12b is returned to the expansion tank 51 via the compressor outlet-side connecting (recovering) passage 54 to return the pressure of the air refrigerant in the compressor inlet-side air refrigerant passage 12a to fall back into the preset range.

[0033] According to this embodiment, the air refrigerant pressure in the compressor inlet-side air refrigerant passage 12a of the closed-cycle air refrigeration system 10A can be adjusted to stay within a preset range, so that the machine can be used also as an open-cycle air refrigeration system. This means that a single air refrigeration machine can serve as a closed-cycle system and an open-cycle system, and moreover, since the pressure inside the expansion tank 51 can be maintained lower than 0.2 MPa (gauge), which is outside of the applicable pressure range specified by the High Pressure Gas Safety Act in Japan, the cost can be reduced.

[0034] Since air refrigerant travels between the sealed air refrigerant supply/discharge system 50 and the compressor inlet-side air refrigerant passage 12a, there is no loss in air refrigerant, and no external air mixes in the refrigerant gas. As no moisture contained in the external air mixes in the refrigerant gas, the system can be operated always at a dew point temperature or higher of the refrigerant gas. Therefore, no dehumidification system is required. Also, as the air refrigerant is not discharged to the outside, there is no loss of it.

[0035] As the air refrigerant is supplied from the expansion tank 51 to the compressor inlet-side air refrigerant passage 12a at low pressure, and the air refrigerant in the compressor outlet-side air refrigerant passage 12b is discharged therefrom to the low-pressure expansion tank 51 via the compressor outlet-side connecting (recovering) passage 54, air refrigerant can be supplied and discharged smoothly to and from these air refrigerant passages.

The pressure sensor 62 detects the pressure of the air

refrigerant in the compressor inlet-side air refrigerant passage 12a and the controller 64 controls the solenoids 58 and 60 to open and close so that the pressure stays within the preset range. The air refrigerant pressure in the compressor inlet-side air refrigerant passage 12a is thus maintained precisely within the preset range.

[0036] While air is used as the refrigerant gas in this embodiment, nitrogen gas may be used instead of air. In this case, nitrogen gas is sealed in the expansion tank 51. The controller 64 may also control the opening degree of the flow control valve 34 to regulate the flow amount of cooling water flowing in the cooling water circulation passage 28 for the purpose of adjusting the cooling performance of the water cooled heat exchanger 16.

(Embodiment 2)

[0037] Next, a second embodiment in which the present invention is applied to an air refrigeration system will be described with reference to FIG. 2. A closed-cycle air refrigeration system 10B of this embodiment includes an expandable hollow member 74 that contains gas g in an expandable hollow hermetic membrane and is arranged inside an expansion tank 72 forming a sealed air refrigerant supply/discharge system 70. The hermetic membrane may be made of rubber, for example, and the gas g sealed inside the expandable hollow member 74 may be air or nitrogen.

[0038] The sealed air refrigerant supply/discharge system 70 in this embodiment does not include the pressure reducing valve 56 and the solenoid 58 of the first embodiment in the inlet-side connecting passage 52. The controller 64 opens and closes the solenoid 60 in accordance with a detection signal received from the pressure sensor 62. The structure is otherwise the same as that of the previously described first embodiment.

[0039] In this embodiment, when the air refrigerant pressure in the compressor inlet-side air refrigerant passage 12a drops, the hollow hermetic membrane 72 expands automatically and supplies air refrigerant to the compressor inlet-side air refrigerant passage 12a via the compressor inlet-side connecting (replenishing) passage 52. Conversely, when the air refrigerant pressure in the compressor inlet-side air refrigerant passage 12a rises, the expandable hollow member 74 automatically contracts, as it is pressed by the surrounding air refrigerant, so that air refrigerant is recovered from the compressor inlet-side air refrigerant passage 12a.

[0040] If the air refrigerant pressure in the compressor inlet-side air refrigerant passage 12a is still higher than the preset range even with the expansion and contraction of the expandable hollow member 74, the controller 64 opens the solenoid 60 to recover air refrigerant back to the expandable hollow member 74 through the compressor outlet-side connecting (recovering) passage 54, so that the air refrigerant pressure in the compressor inlet-side air refrigerant passage 12a falls back into the preset range.

[0041] With this configuration, similarly to the first embodiment, the air refrigerant pressure in the compressor inlet-side air refrigerant passage 12a is adjustable, and in addition, there is no need to provide a pressure reducing valve or an open/close valve in the compressor inlet-side air refrigerant passage 12a. There is thus the advantage of lower cost as the sealed air refrigerant supply/discharge system 70 does not require complex control for operation of these valves. The air refrigerant pressure in the compressor inlet-side air refrigerant passage 12a can be automatically determined by presetting the pressure level of gas in the expandable hollow member 74 in accordance with the size of the expansion tank 72.

INDUSTRIAL APPLICABILITY

[0042] According to the present invention, the refrigerant gas pressure in an expansion tank is maintained lower than 0.2 MPa (gauge), which is higher than the refrigerant gas pressure in a compressor inlet-side refrigerant gas passage and lower than that in a compressor outlet-side refrigerant gas passage, whereby a low-cost closed-cycle gas refrigeration system that allows adjustment of refrigerant gas pressure in the compressor inlet-side refrigerant gas passage can be realized.

Claims

1. A closed-cycle gas refrigeration system, comprising: a compressor and an expander coupled to a single output shaft of a driving device; a cooler cooling refrigerant gas on an outlet side of the compressor; a brine cooler cooling brine that cools an object to be cooled with refrigerant gas made of air or nitrogen gas; and a cold energy recovery heat exchanger further cooling the refrigerant gas cooled by the cooler with the refrigerant gas returning from the brine cooler, the system further comprising:
 - a sealed refrigerant gas supply/discharge system formed by an expansion tank hermetically containing refrigerant gas having a pressure of at least an atmospheric pressure and a gauge pressure of lower than 0.2 MPa that is outside of an applicable pressure range specified by the High Pressure Gas Safety Act in Japan, a compressor inlet-side connecting passage connecting the expansion tank and a compressor inlet-side refrigerant gas passage, and a compressor outlet-side connecting passage connecting the expansion tank and a compressor outlet-side refrigerant gas passage; and
 - a pressure sensor detecting a pressure of refrigerant gas flowing in the compressor inlet-side refrigerant gas passage, wherein refrigerant gas is supplied from the expansion

tank to the compressor inlet-side refrigerant gas passage via the compressor inlet-side connecting passage, and discharged from the compressor outlet-side refrigerant gas passage to the expansion tank via the compressor outlet-side connecting passage while the pressure sensor detects the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage, such that the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage is maintained within a preset range.

2. The closed-cycle gas refrigeration system according to claim 1, further comprising: a first open/close valve provided in the compressor inlet-side connecting passage; a second open/close valve provided in the compressor outlet-side connecting passage; and a controller receiving a detection signal from the pressure sensor and thereby controlling the first open/close valve and the second open/close valve, such that the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage is maintained within the preset range.
3. The closed-cycle gas refrigeration system according to claim 1, wherein the expansion tank includes an expandable hollow member in which gas is hermetically contained in an expandable, hollow hermetic membrane, and the expandable hollow member is expanded and contracted in accordance with the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage, such that the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage is maintained within the preset range.
4. A method of operating the closed-cycle gas refrigeration system according to claim 1, comprising the steps of:
 - detecting the refrigerant gas pressure in the compressor inlet-side refrigerant gas passage with the pressure sensor;
 - supplying the refrigerant gas to the compressor inlet-side refrigerant gas passage from the expansion tank via the compressor inlet-side connecting passage when the refrigerant gas pressure becomes lower than the preset range such that the refrigerant gas pressure falls back into the preset range; and
 - discharging the refrigerant gas from the compressor outlet-side refrigerant gas passage to the expansion tank via the compressor outlet-side connecting passage when the refrigerant gas pressure becomes higher than the preset range such that the refrigerant gas pressure falls back into the preset range.

Fig. 1

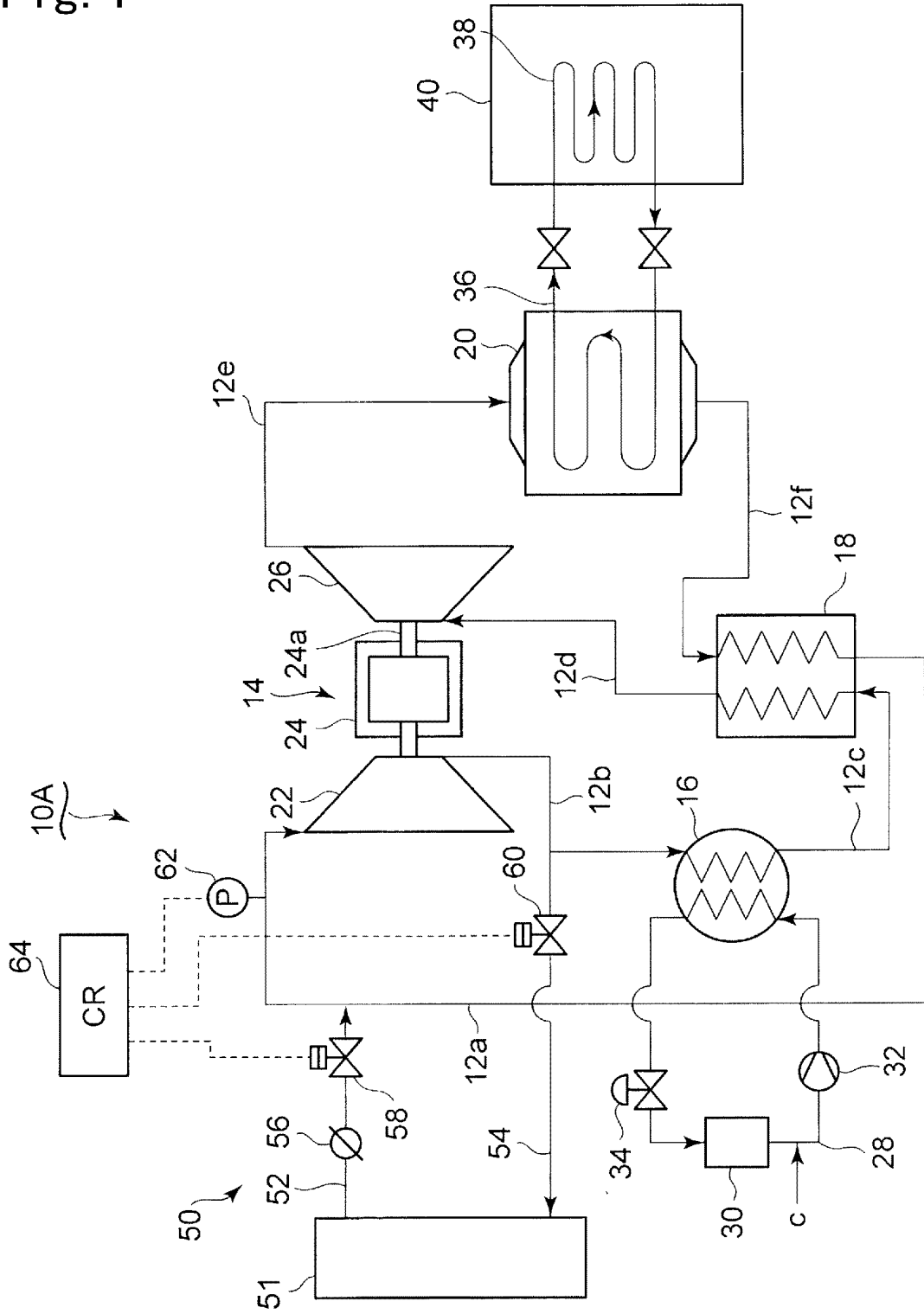
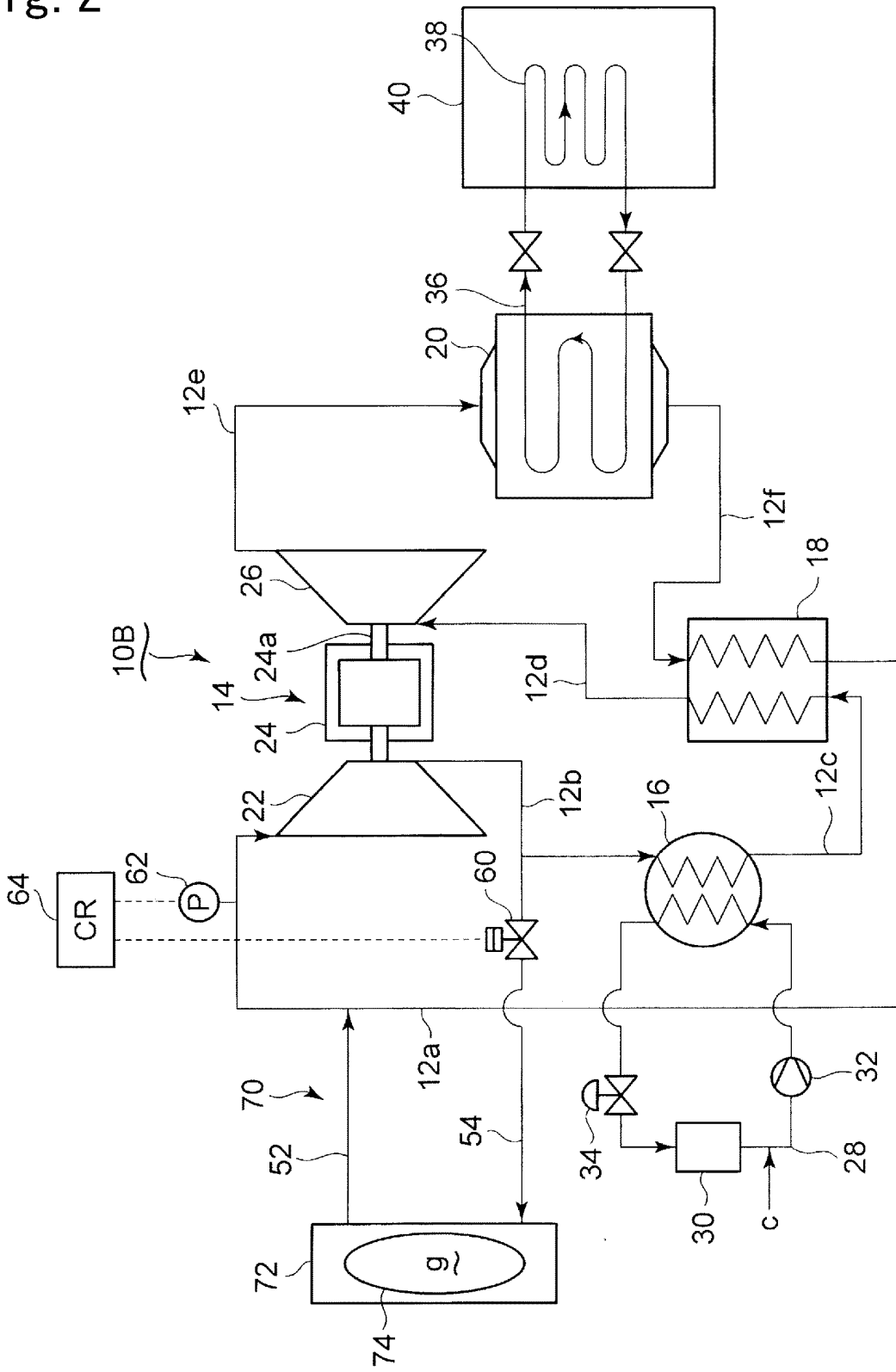


Fig. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/071259

A. CLASSIFICATION OF SUBJECT MATTER

F25B9/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B9/00Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012
Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2008-249254 A (Mitsubishi Heavy Industries, Ltd.), 16 October 2008 (16.10.2008), paragraphs [0035] to [0055]; fig. 2 to 5 (Family: none)	1-4
Y	JP 2003-194459 A (Kobe Steel, Ltd.), 09 July 2003 (09.07.2003), paragraphs [0027] to [0030]; fig. 5 (Family: none)	1-4
Y	JP 63-315866 A (Nippondenso Co., Ltd.), 23 December 1988 (23.12.1988), page 4, lower right column, line 10 to page 6, upper left column, line 15; fig. 5, 7 (Family: none)	1-4

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
06 November, 2012 (06.11.12)Date of mailing of the international search report
20 November, 2012 (20.11.12)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/071259

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2004-69259 A (Rokko Engineering Co., Ltd.), 04 March 2004 (04.03.2004), paragraph [0038] & WO 2004/015340 A1	3

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REFERENCES CITED IN THE DESCRIPTION

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