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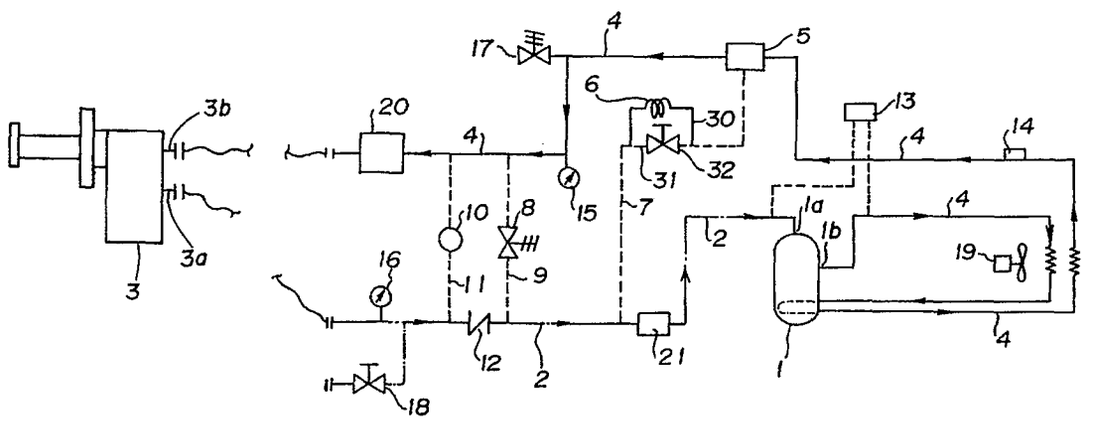
(54) Helium gas compressing apparatus.

(57) The helium gas compressing apparatus of this invention is constructed in such a manner that the oil separator (5) in the high-pressure gas passage (4) is connected to the low-pressure gas passage (2); that the oil return path having the first (30) and second (31) branch paths is provided between the high- and low-pressure gas passages; that the capillary tube (6) is installed in one of the two branch paths; and that the adjust valve (32) is installed in the other branch path to adjust the pressure difference between the supply gas in the high-pressure gas passage (4) and the return gas in the low-pressure gas passage (2). Because of this construction, the adjust valve (32) can be manipulated from outside to make fine adjustments on the pressure difference or change it to a desired value with ease even during operation of the apparatus, thereby adjusting the refrigerating capability of the helium refrigerating machine and the power consumption of the helium gas compressing apparatus.

FIG. 1



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HELIUM GAS COMPRESSING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a helium gas compressing apparatus used in a helium refrigerating machine and more particularly to a helium gas compressing apparatus which is capable of adjusting a pressure difference between a supply gas to the helium refrigerating machine and a return gas therefrom.

Description of the Prior Art

A helium gas compressing apparatus generally has a compressor 1 for compressing helium gas. The compressor 1 has its low-pressure suction side 1a connected to a low-pressure discharge side 3a of a helium refrigerating machine 3 via a low-pressure gas passage 2 while a high-pressure delivery side 1b of the compressor 1 is connected to a high-pressure supply side 3b of the helium refrigerating machine 3 through a high-pressure gas passage 4.

In the high-pressure gas passage 4 is installed an oil separator 5, which is connected to the low-pressure gas passage 2 via an oil return path 7.

Further, between the low-pressure gas passage 2 and the high-pressure gas passage 4 are provided two other paths, one path 9 including a pressure retaining valve 8 and the other path 11 including a solenoid valve 10. The pressure retaining valve 8 is intended to determine the pressure difference (or braking pressure) between the pressure (high pressure) in the high-pressure gas passage 4 and that (low pressure) in the low-pressure gas passage 2. That is, the pressure difference is determined by a preset spring pressure of a spring installed in the pressure retaining valve 8. A part of the high pressure in the high-pressure gas passage 4 flows into the low-pressure gas passage 2 through the path 9 incorporating the pressure retaining valve 8 to keep this pressure difference constant.

The path 11 in which the solenoid valve 10 is installed works as follows. Immediately after the helium gas compressing apparatus stops, the solenoid valve 10 is switched from a closed to an open state to increase the pressure at the low-pressure discharge side 3a of the helium refrigerating machine 3 so that oil in the oil separator 5 and in the compressor 1 will not flow back to the helium refrigerating machine 3 through the low-pressure gas passage 2. The oil backflow is also prevented by a check valve 12.

A pressure switch 13 monitors the pressures in the low-pressure suction side la and the high-pressure delivery side 1b of the compressor 1. A thermostat 14 monitors the temperature of a gas in the high-pressure gas passage 4. Pressure gauges 15, 16 monitor the pressures in the high-pressure gas passage 4 and the low-pressure gas passage 2, respectively. A safety valve 17 is designed to release excess gas from the high-pressure gas passage 4 in times of emergency.

In the above-mentioned helium gas compressing apparatus, the helium gas is supplied into the low-pressure gas passage 2 through a charge valve 18.

Next, we will explain about the operation of the helium gas compressing apparatus of the above configuration.

With this helium gas compressing apparatus, the helium gas in the form of oil mist compressed by the compressor 1 to a high pressure is supplied from the high-pressure delivery side 1b of the compressor 1 into the high-pressure gas passage 4 and then cooled by a cooling fan 19 down to a normal temperature. The cooled gas now passes through the compressor 1 to cool the oil therein and is then cooled again by the fan to the normal temperature on its way to the oil separator 5, which is installed in the high-pressure gas passage 4.

In the oil separator 5, the high-pressure helium gas in the form of oil mist is separated into high-pressure helium gas and oil. The high-pressure helium gas thus extracted by the oil separator 5 is fed through the high-pressure gas passage 4 to an oil adsorber 20 where the gas is further removed of residual oil contained therein, before being supplied to the high-pressure supply side 3b of the helium refrigerating machine 3. (The high-pressure helium gas supplied to the refrigerating machine 3 is hereafter referred to as a supply gas.)

The supply gas fed to the helium refrigerating machine 3 is returned from, the low-pressure discharge side 3a of the refrigerating machine 3 into the low-pressure gas passage 2. (The helium gas returned to the low-pressure gas passage 2 is hereafter referred to as a return gas.) The return gas flows through the check valve 12 and a strainer 21 to the low-pressure suction side 1a of the compressor 1 where it is compressed again into a high-pressure helium gas in the form of oil mist.

The oil separated by the oil separator 5 is passed through a capillary tube 6 to meter or restrict the oil flow to a predetermined amount, which is then fed to the low-pressure gas passage 2, for which the oil flows through the strainer 21 to the low-pressure suction side 1a of the compressor

1 and into the compressor 1.

The pressure retaining valve 8 that determines the pressure difference (braking pressure) between the supply gas in the high-pressure gas passage 4 and the return gas in the low-pressure gas passage 2 operates to allow a part of the high-pressure gas in the high-pressure gas passage 4 to flow into the low-pressure gas passage 2 so that the pressure difference determined based on the spring pressure of the spring installed in the pressure retaining valve 8 is maintained.

With the conventional helium gas compressing apparatus mentioned above, however, the pressure retaining valve 8, which determines the pressure difference (braking pressure) between the supply gas in the high-pressure gas passage 4 and the return gas in the low-pressure gas passage 2, is operated by means of the spring pressure of the preset spring installed therein, and it does not have a means to adjust the pressure difference. Hence the pressure difference is fixed and it is structurally impossible to change the preset pressure difference from outside.

Thus, the following problem arises with the conventional helium gas compressing apparatus of the above construction. In cannot meet such user demands as making in-service adjustments on the pressure difference in the helium gas compressing apparatus according to power consumption of the apparatus and to specifications involving the refrigerating capability of the helium refrigerating machine. Both the power consumption and the refrigerating capability depend on the magnitude of the pressure difference. Because of the inability to make fine adjustments on the pressure difference, a single apparatus cannot meet varying specifications and power consumptions. In other words, two or more helium gas compressing apparatuses are required to accommodate such demands.

With a gas-driven helium refrigerating machine, in particular, vibrations and impacts occur depending on the magnitude of the pressure difference. It has therefore been an urgent task to develop a helium gas compressing apparatus capable of making fine adjustment on the pressure difference to alleviate the vibrations and impacts produced during operation.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a helium gas compressing apparatus capable of performing adjustment on the pressure difference.

It is another object of the present invention to provide a helium gas compressing apparatus with a control valve to accelerate a refrigerating period from operation start to a predetermined cooling temperature.

It is further object of the present invention to provide a helium gas compressing apparatus with an automatic control valve in order to rapidly cool a refrigerating machine to a predetermined temperature in a short time, and automatically control an operating condition to prevent excessive cooling and reduce vibrations, noise and operating power.

To achieve the above objectives, the helium gas compressing apparatus of this invention comprises: a compressor for compressing a helium gas; a low-pressure gas passage connecting a low-pressure suction side of the compressor and a low-pressure discharge side of a helium refrigerating machine; a high-pressure gas passage connecting a high-pressure delivery side of the compressor and a high-pressure supply side of the helium refrigerating machine; an oil separator installed in the high-pressure gas passage; a pressure retaining valve installed in a path between the high-pressure gas passage and the low-pressure gas passage to determine a pressure difference between the low- and high-pressure gas passages; an oil return path connecting the oil separator and the low-pressure gas passage, said oil return path having a first branch path and a second branch path; a capillary tube installed in one of the two branch paths of the oil return path; and an adjust valve installed in the other branch path of the oil return path to adjust the pressure difference between a supply gas in the high-pressure gas passage and a return gas in the low-pressure gas passage.

This invention further comprises open-close control valve connected in series with the adjust valve.

In this invention according to the above construction, the adjust valve comprises automatic adjust valve controlled by a programmed controller.

In the helium gas compressing apparatus according to this invention, the oil separated by the oil separator 5 installed in the high-pressure gas passage 4 and a part of the supply gas in the high-pressure gas passage 4 are led into the low-pressure gas passage 2 through a capillary tube 6 and an adjust valve 32 that are installed in a first branch path 30 and a second branch path 31, respectively, the first and second branch paths 30, 31 forming an oil return path 7. The capillary tube 6, adjust valve 32 and pressure retaining valve 8 work in combination to determine the pressure difference between the supply gas in the high-pressure gas passage 4 and the return gas in the low-pressure gas passage 2, with the pressure difference being adjusted by the opening of the adjust valve 32.

In the helium gas compressing apparatus with the above mentioned open-close control valve, immediately after the apparatus is started it is possible to cool the refrigerating machine rapidly at the

maximum pressure difference with only the pressure retaining valve in operation by closing the open-close control valve connected in series with the adjust valve. When the temperature has lowered to a specified cooling temperature, the open-close control valve is fully opened to bring the preset adjust valve into operation, thus allowing the pressure difference to be promptly changed to the minimum required valve.

In the helium gas compressing apparatus with the above mentioned automatic adjust valve, immediately after the apparatus is started a sensor detects that the cooling section of the helium refrigerating machine has not reached the predetermined cooling temperature. According to the detection signal of this sensor, the programmed controller controls the automatic adjust valve to the fully closed state, rapidly cooling the refrigerating machine at the maximum pressure difference with only the pressure retaining valve in operation. When the sensor detects that the temperature of the cooling section of the helium refrigerating machine has reached the specified temperature, the programmed controller, according to the detection signal from the sensor, opens the automatic adjust valve to the preset opening. This combined operation of the automatic adjust valve and the pressure retaining valve enables an immediate change of the pressure difference in the helium gas compressing apparatus to the minimum required value.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram showing a helium gas compressing apparatus of this invention;

Figure 2 is a schematic diagram showing a conventional helium gas compressing apparatus;

Figure 3 is a table showing the power consumption of a helium gas compressing apparatus and the specifications of a helium refrigerating machine, both the power consumption and specifications being dependent of the pressure difference;

Figure 4 is a schematic diagram showing one embodiment of a helium gas compressing apparatus with open-close control valve; and

Figure 5 is a schematic diagram showing another embodiment of a helium gas compressing apparatus with automatic adjust valve.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

One preferred embodiment of a helium gas compressing apparatus according to this invention will be described in detail by referring to Figure 1.

In the figure, like reference numerals are assigned to components that are identical to those of the conventional apparatus, and their description are omitted.

In the helium gas compressing apparatus of this invention, a compressor 1 for compressing a helium gas, as shown in Figure 1, is connected with one end of a low-pressure gas passage 2 and with one end of a high-pressure gas passage 4 in which an oil separator 5 is installed. The other ends of these passages 2, 4 are connected to a helium refrigerating machine 3. connected between the two passages 2, 4 are a path 9 in which a pressure retaining valve 8 is installed and a path 11 in which a solenoid valve 10 is installed. The above construction is the same as the conventional apparatus and its detailed description omitted. Now, a configuration characteristic of this invention will be explained below.

In this helium gas compressing apparatus, the oil separator 5 and the low-pressure gas passage 2 are interconnected through an oil return path 7, which has a first branch path 30 and a second branch path 31. The first branch path 30 contains a capillary tube 6 while the second branch path 31 has an adjust valve 32. The adjust valve 32 is intended to adjust the pressure difference between the supply gas in the high-pressure gas passage 4 and the return gas in the low-pressure gas passage 2.

Next, how the construction characteristic of this invention works will be described.

The oil separated by the oil separator 5 arranged in the high-pressure gas passage 4 and a part of the supply gas are fed to the low-pressure gas passage 2 via the oil return path 7, which is made up of the two passages ---the first and second branch paths 30, 31 that have the capillary tube 6 and the adjust valve 31, respectively. This reduces the pressure in the high-pressure gas passage 4 and increases the pressure in the low-pressure gas passage 2 until the pressure difference between the two passages settles to a specific value, as shown in Figure 3, which depends on the opening of the adjust valve 32.

When the adjust valve 32 is fully closed, only a specified amount of oil is supplied to the low-pressure gas passage 2 through the capillary tube 6 in the first branch path 30 of the oil return path 7.

With the adjust valve 32 fully closed, the pressure difference is determined by the pressure retaining valve 8 and the capillary tube 6. Figure 3 shows the pressure differences that become smaller as the adjust valve 32 is gradually opened from the fully closed state.

In the helium gas compressing apparatus mentioned above, the oil separator in the high-pressure gas passage 4 is connected to the low-pressure gas passage 2; the oil return path 7 which consists of the first and second branch paths 30, 31 is connected between the high- and low-pressure

passages 2, 4; the capillary tube 6 is installed in the first branch path 30; and the adjust valve 32 is installed in the second branch path 31 to adjust the pressure difference between the supply gas in the high-pressure gas passage 4 and the return gas in the low-pressure gas passage 2. Because of this configuration, the adjust valve 32 can be manipulated from outside to a desired opening so that the pressure difference between the supply gas in the high-pressure gas passage 4 and the return gas in the low-pressure gas passage 2 can be adjusted according to the opening of the adjust valve 32. This allows an operator to make fine adjustments from outside on the pressure difference or change it to a desired value with ease even during operation of the apparatus, thereby adjusting the refrigerating capability of the helium refrigerating machine and the power consumption of the helium gas compressing apparatus, both of which depend on the magnitude of the pressure difference.

When applied to a gas-driven helium refrigerating machine, the helium gas compressing apparatus of this invention is able to minimize impacts and vibrations produced in the refrigerating machine, by slightly changing the pressure difference to reduce the operating power of the refrigerating machine.

While this embodiment has the adjust valve installed in the second branch path, it is possible to arrange the adjust valve in the first branch path and the capillary tube in the second branch path. The adjust valve may also be installed in a branch of the path, connected between the high- and low-pressure gas passages, that has the pressure retaining valve or in a branch of the path having the solenoid valve.

Another embodiments will be described by referring to Figures 4 and 5. In Figure 4, the oil return path 7 is provided with a solenoid valve 34 (open-close control valve) connected in series with the adjust valve 32 and in parallel with the capillary tube 6. The solenoid valve 34 is driven by an output signal from a timer or a temperature sensor that monitors the temperature of the cooling section of the refrigerating machine. (The timer and the temperature sensor are not shown.)

With the helium gas compressing apparatus according to this invention, immediately after the apparatus is started the helium refrigerating machine 3 can be quickly cooled at the maximum pressure difference with only the pressure retaining valve 8 in operation by closing the solenoid valve 34 serially connected with the adjust valve 32. When a specified cooling temperature is reached, the solenoid valve 34 is fully opened automatically by an output from the timer or the temperature sensor to activate the preset adjust valve. This combined operation of the pressure retaining valve 8 and the adjust valve 32 can cause an immediate change in the pressure difference to a minimum required value.

Therefore, it is not necessary to manually open the adjust valve 32 during operation each time the helium gas compressing apparatus is activated. The adjust valve 32, which is preset to an optimum opening, is maintained at that opening at all times, so that it is possible to realize the optimum pressure difference as soon as the refrigerating machine 3 reaches the specified temperature. This in turn prevents excessive cooling of the refrigerating machine 3 below that temperature and reduces vibrations, noise and operating power, significantly improving the operability of the helium gas compressing apparatus.

While in the above embodiment the capillary tube 6 is installed in the bypass path 30, and the adjust valve 32 and the solenoid valve 34 are installed in the oil return path 7, the same result can also be obtained if the capillary tube 6 is put in the oil return path 7, and the adjust valve 32 and the solenoid valve 34 are arranged in the bypass path 30.

Although the above embodiment has the adjust valve 32 and the solenoid valve 34 connected in parallel with the capillary tube 6, it is possible to form a bypass path in the gas return path 9 and put both of them 32, 34 in the bypass path in parallel with the pressure retaining valve 8. Or the gas return path 11 may be provided with a bypass path, in which the adjust valve 32 and the solenoid valve 34 are installed so that they are connected in parallel with the solenoid valve 10.

In Figure 5, an oil separator 5 is connected to a low-pressure gas passage 2 via an oil return path 7 having a parallel bypass path 30. A capillary tube 6 is installed in the bypass path 30, and a needle valve 32 (automatic adjust valve) which is driven by a step-motor 34 and connected in parallel with the capillary tube 6 is arranged in the oil return path 7. The cooling section of the helium gas refrigerating machine 3 is fitted with a sensor 36 that detects the temperature of the cooling section. A detection signal output from the sensor 36 is fed to a controller 38 which, according to the detection signal and a program ROM 40, controls by way of the step-motor 34 the opening of the needle valve 32.

In the helium gas compressing apparatus of the above construction, immediately after the apparatus is started the sensor 36 detects that the cooling section of the helium refrigerating machine 3 has not reached the predetermined cooling temperature. Based on the detection signal of the sensor 36, the controller 38 controls the step-motor 34 to fully close the needle valve 32. As a result, the helium gas compressing apparatus can rapidly cool the helium refrigerating machine 3 at the

maximum pressure difference with only the pressure retaining valve 8 in operation. Then, when the sensor 36 detects that the cooling section of the helium refrigerating machine 3 has lowered to the predetermined cooling temperature, the controller 38, according to the detection signal of the sensor 36, controls the step-motor 34 to open the needle valve 32 to a specified opening, which was preset in ROM. The combined operation of the needle valve 32 and the pressure retaining valve 8 now enables the pressure difference to be immediately changed to the minimum required value.

With this embodiment, since the needle valve 32 can automatically be operated by the controller 38, there is no need to manually operate the adjust valve 32 during operation each time the apparatus is energized as with the conventional apparatus. Further, by storing the desired opening of the needle valve 32 in the ROM beforehand, it is always possible to instantly open the needle valve 32 to the optimum degree, allowing the pressure difference to be immediately set to the optimum value as soon as the helium refrigerating machine 3 has reached the specified temperature. This in turn prevents excessive cooling of the helium refrigerating machine 3 below that temperature and also reduces vibrations, noise and operating power, substantially improving the operability of the helium gas compressing apparatus.

While in the above embodiment the capillary tube 6 is provided in the bypass path 30 and the needle valve 32 driven by the step-motor 34 is installed in the oil return path 7, the same result can also be obtained if the capillary tube 6 is arranged in the oil return path 7 and the needle valve 32 in the bypass path 30.

Furthermore, although in the above embodiment the needle valve 32 driven by the step-motor 34 is provided in parallel with the capillary tube 6, it is possible to form a bypass path in the gas return path 9 and arrange the needle valve 32 in the bypass path in parallel with the pressure retaining valve 8 or to form a bypass path in the gas return path 11 and install it in that bypass path in parallel with the solenoid valve 10.

As mentioned above, the helium gas compressing apparatus of this invention is constructed in such a manner that the oil separator in the high-pressure gas passage is connected to the low-pressure gas passage; that the oil return path having the first and second branch paths is provided between the high- and low-pressure gas passages; that the capillary tube is installed in one of the two branch paths; and that the adjust valve is installed in the other branch path to adjust the pressure difference between the supply gas in the high-pressure gas passage and the return gas in the low-pressure gas passage. Because of this construction, the adjust valve can be manipulated form outside to make fine adjustments on the pressure difference or change it to a desired value with each even during operation of the apparatus, thereby adjusting the refrigerating capability of the helium refrigerating machine and the power consumption of the helium gas compressing apparatus. This in turn makes it possible for a wide range of refrigerating capability and power consumption.

Especially when applied to a gas-driven helium refrigerating machine, the helium gas compressing apparatus of this invention can meet the requirements for reducing impacts and vibrations produced in the refrigerating machine, by slightly adjusting the pressure difference to reduce the operating power of the refrigerating machine. The apparatus therefore has the advantage of an expanded range of capability.

Furthermore, this invention has the following advantages. Immediately after the start of the apparatus, the pressure difference is set to the maximum to cool the refrigerating machine to a predetermined temperature in the shortest possible time. Once the refrigerating machine has been cooled to the predetermined temperature, the pressure difference is immediately changed to the minimum required value to prevent excessive cooling below that temperature and also reduce vibrations, noise and operating power. This results in a substantial improvement in the operability of the helium gas compressing apparatus.

Claims

1. A helium gas compressing apparatus comprising:
a compressor for compressing a helium gas;
a low-pressure gas passage connecting a low-pressure suction side of the compressor and a low-pressure discharge side of a helium refrigerating machine;
a high-pressure gas passage connecting a high-pressure delivery side of the compressor and a high-pressure supply side of the helium refrigerating machine;
an oil separator installed in the high-pressure gas passage;
a pressure retaining valve installed in a path between the high-pressure gas passage and the low-pressure gas passage to determine a pressure difference between the low-pressure gas passage and high-pressure gas passage;
an oil return path connecting the oil separator and the low-pressure gas passage;
a capillary tube installed in the oil return path; and
an adjust valve installed in a path between the high-pressure gas passage and low-pressure gas passage to adjust the pressure difference between

a supply gas in the high-pressure gas passage and a return gas in the low-pressure gas passage.

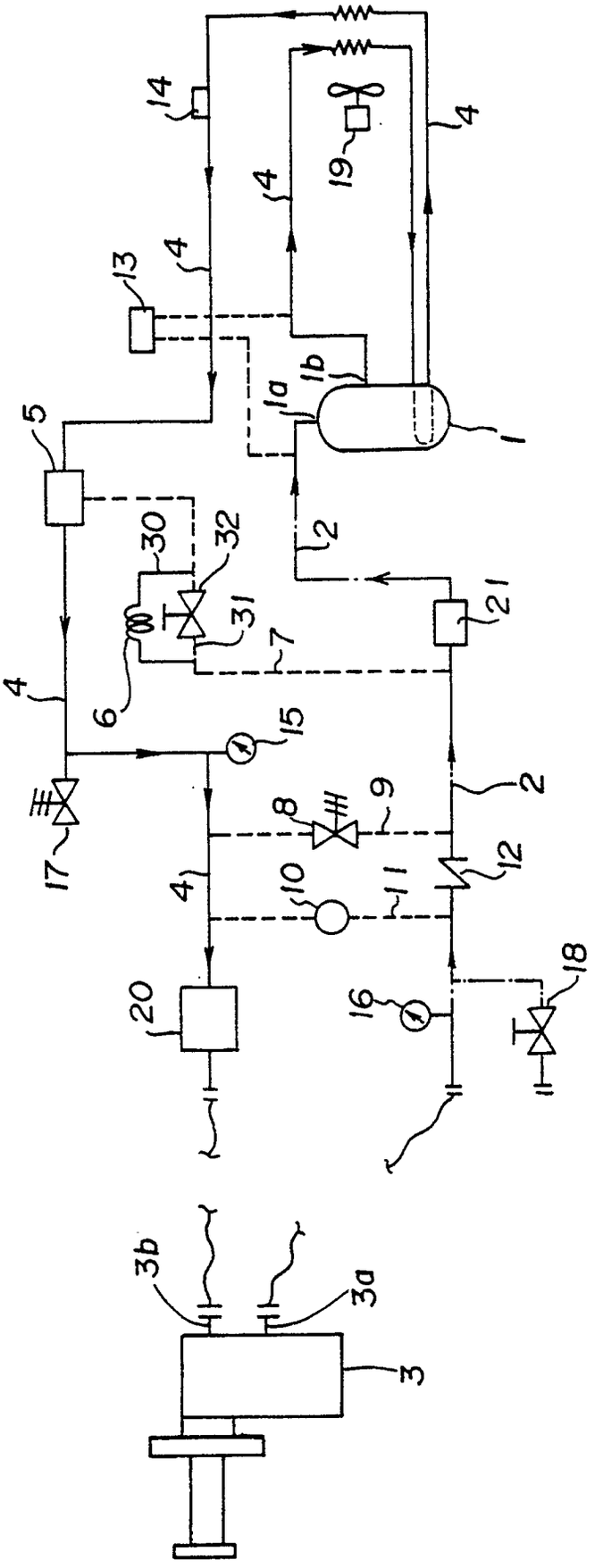
2. The helium gas compressing apparatus in accordance with claim 1, wherein said adjust valve is installed in a branch path disposed in parallel with the path in which said capillary is installed.

3. The helium gas compressing apparatus in accordance with claim 1, wherein said adjust valve is installed in a branch path disposed in parallel with the path in which said pressure retaining valve is installed.

4. The helium gas compressing apparatus in accordance with claim 1, further comprising an open-close control valve disposed in series with said adjust valve.

5. The helium gas compressing apparatus in accordance with claim 1, wherein said adjust valve comprises an automatic control adjust valve, and said apparatus further comprising sensor means for detecting a temperature of a cooling section of said helium refrigerating machine, and control means for controlling said automatic control adjust valve in response to a signal detected by said sensor means.

FIG. 1


14
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13
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1b
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32
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3b
3a
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FIG.2
PRIOR ART

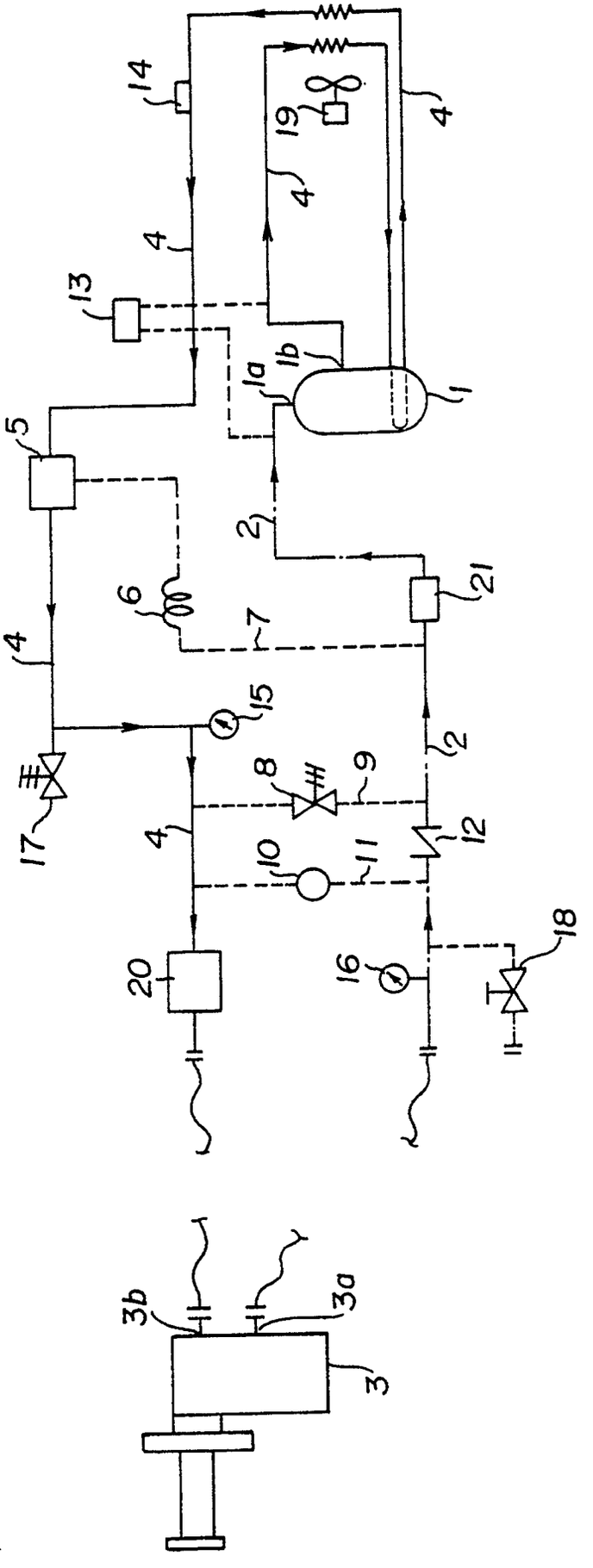

FIG.3

PRESSURE / OPENING OF ADJUST VALVE	EXAMPLES OF PRESSURE ADJUSTMENT [kg/cm²G]			CHARACTERISTICS DEPENDING ON PRESSURE DIFFERENCE		POWER CONSUMPTION DEPENDING ON PRESSURE DIFFERENCE
	SUPPLY GAS PRESSURE	RETURN GAS PRESSURE	PRESSURE DIFFERENCE	REFRIGERATNG CAPABILITY	IMPACTS AND VIBRATIONS	
FULL CLOSE	17.0	4.0	13.0	HIGH	HIGH	HIGH
↓	16.5	5.0	11.5	↓	↓	↓
↓	16.0	6.0	10.0	↓	↓	↓
OPEN	↓	↓	↓	LOW	LOW	LOW

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FIG.4

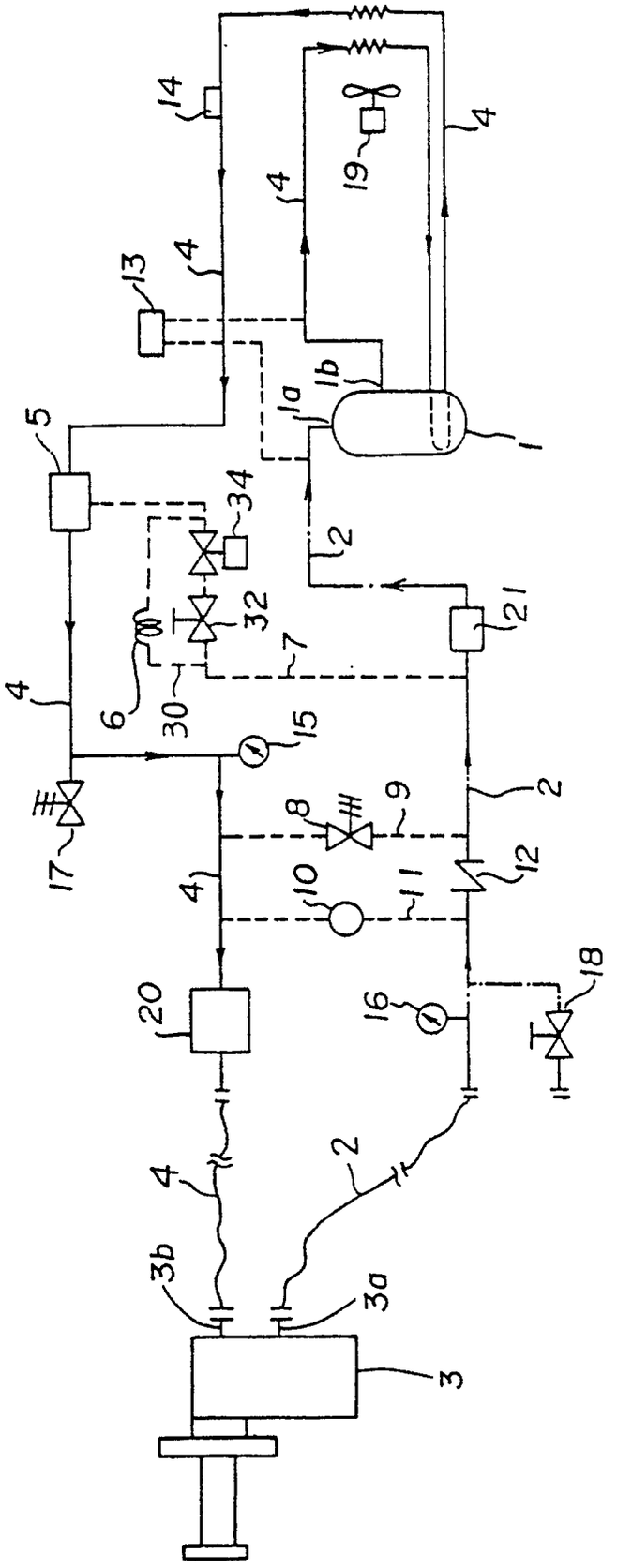
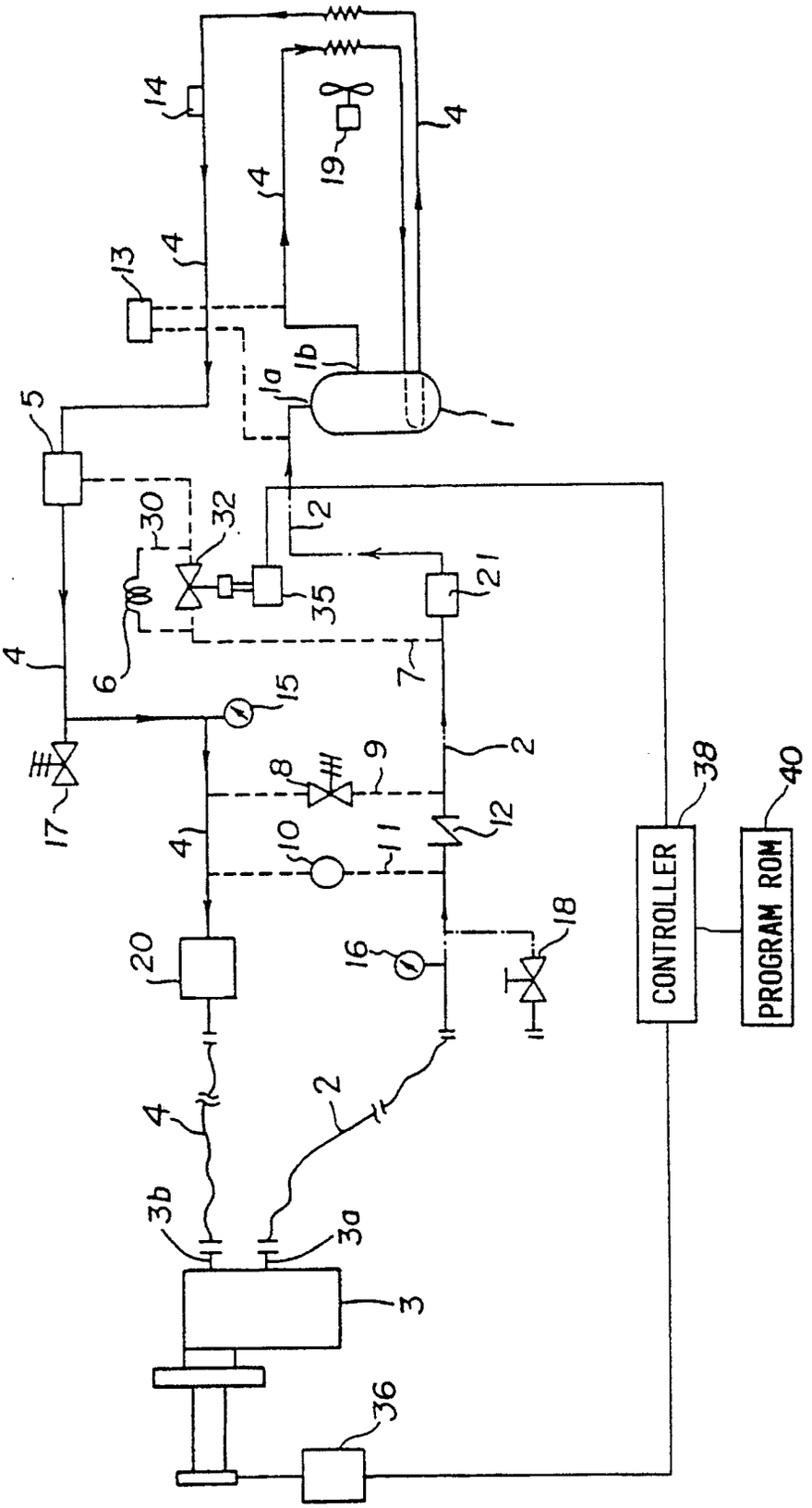


FIG. 5



European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 12 0714

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.5)
Y	DE-A-3 028 217 (KERNFORSCHUNGSZENTRUM KARLSRUHE) * Whole document *	1,3	F 17 C 5/06 F 17 C 13/02 F 25 B 9/00 F 25 B 41/04
Y	US-A-4 718 442 (NICOLL) * Column 1, line 1 - column 2, line 9; column 2, line 34 - column 3, line 6; figure 1 *	1,3	
A	US-A-4 462 219 (IWATA) * Whole document *	1,5	
A,P	US-A-4 949 546 (KLUSMIER et al.) * Column 2, lines 22-57; figure 1 *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

F 17 C
F 25 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11-03-1991	STEVNSBORG N.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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