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(54) **RECIPROCATING COMPRESSOR**

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F04B 25/00 (2006.01)

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CPC ***F04B 25/02*** (2013.01); ***F04B 25/005*** (2013.01); *F05D 2210/12* (2013.01); *F05D 2270/02* (2013.01)

(58) **Field of Classification Search**
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USPC 417/321
See application file for complete search history.

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(57) **ABSTRACT**

Provided is a reciprocating compressor including a third-stage compression unit, a fifth-stage compression unit, a drive unit, a discharge mechanism, a pressure sensor, and a discharge control unit. The discharge mechanism is capable of discharging hydrogen gas from a second connection pipe that allows hydrogen gas to flow to be suctioned into the third-stage compression unit. The discharge control unit controls the discharge mechanism to discharge the hydrogen gas from the second connection pipe when pressure of the hydrogen gas detected by the pressure sensor is higher than a set value preset.

6 Claims, 9 Drawing Sheets

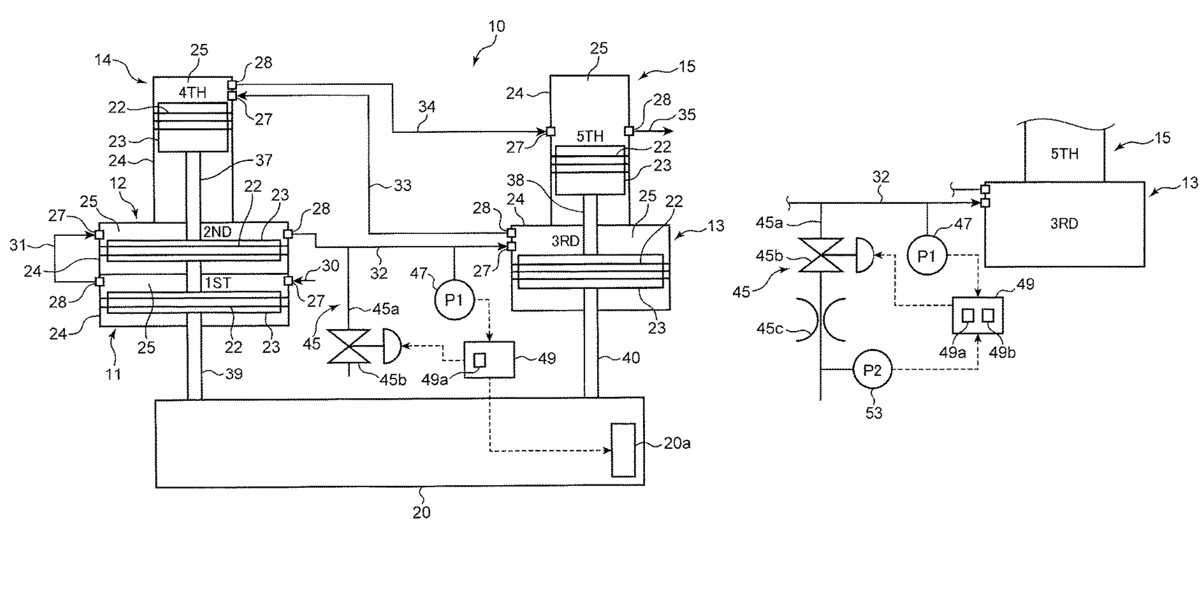

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FIG.1

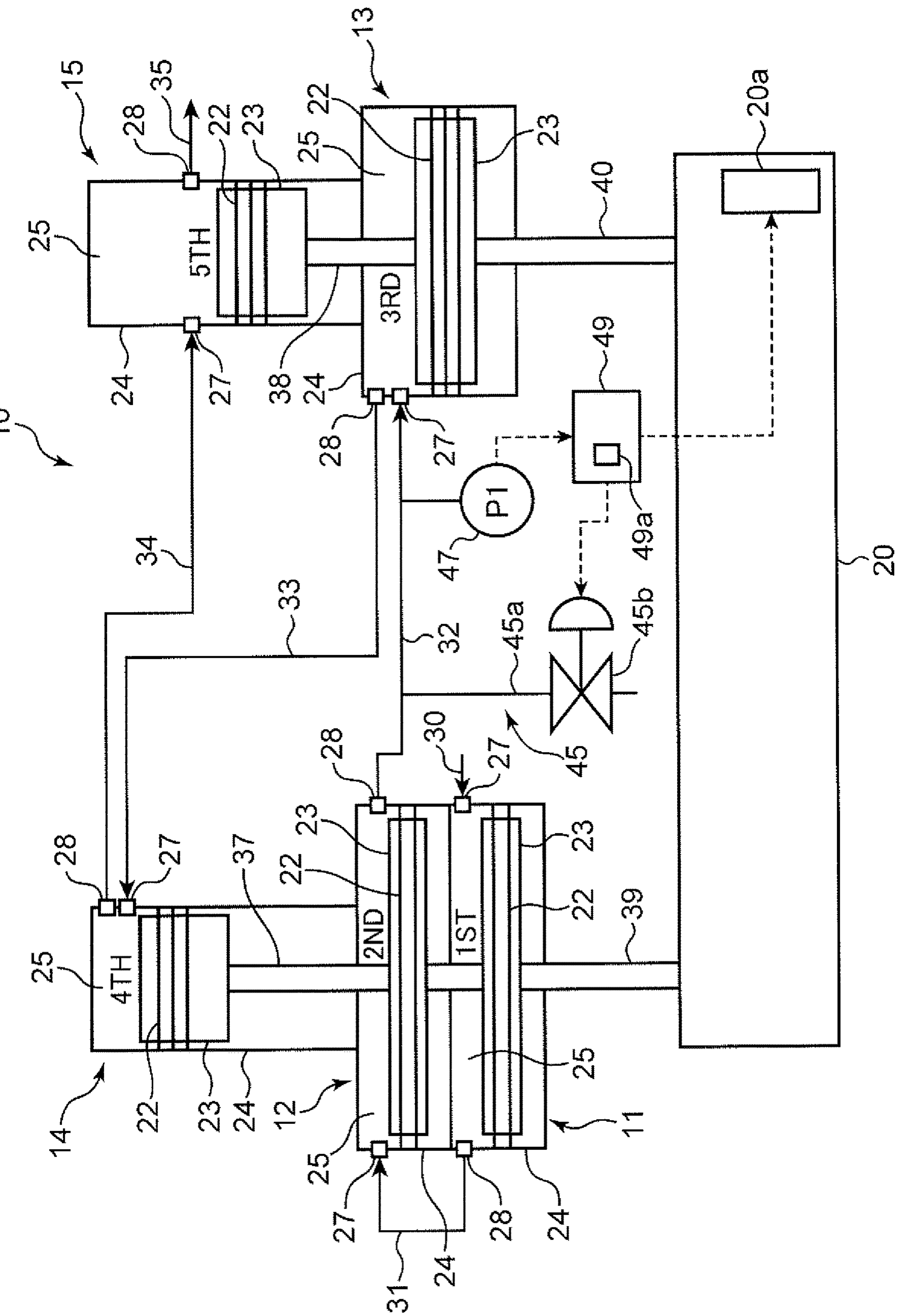
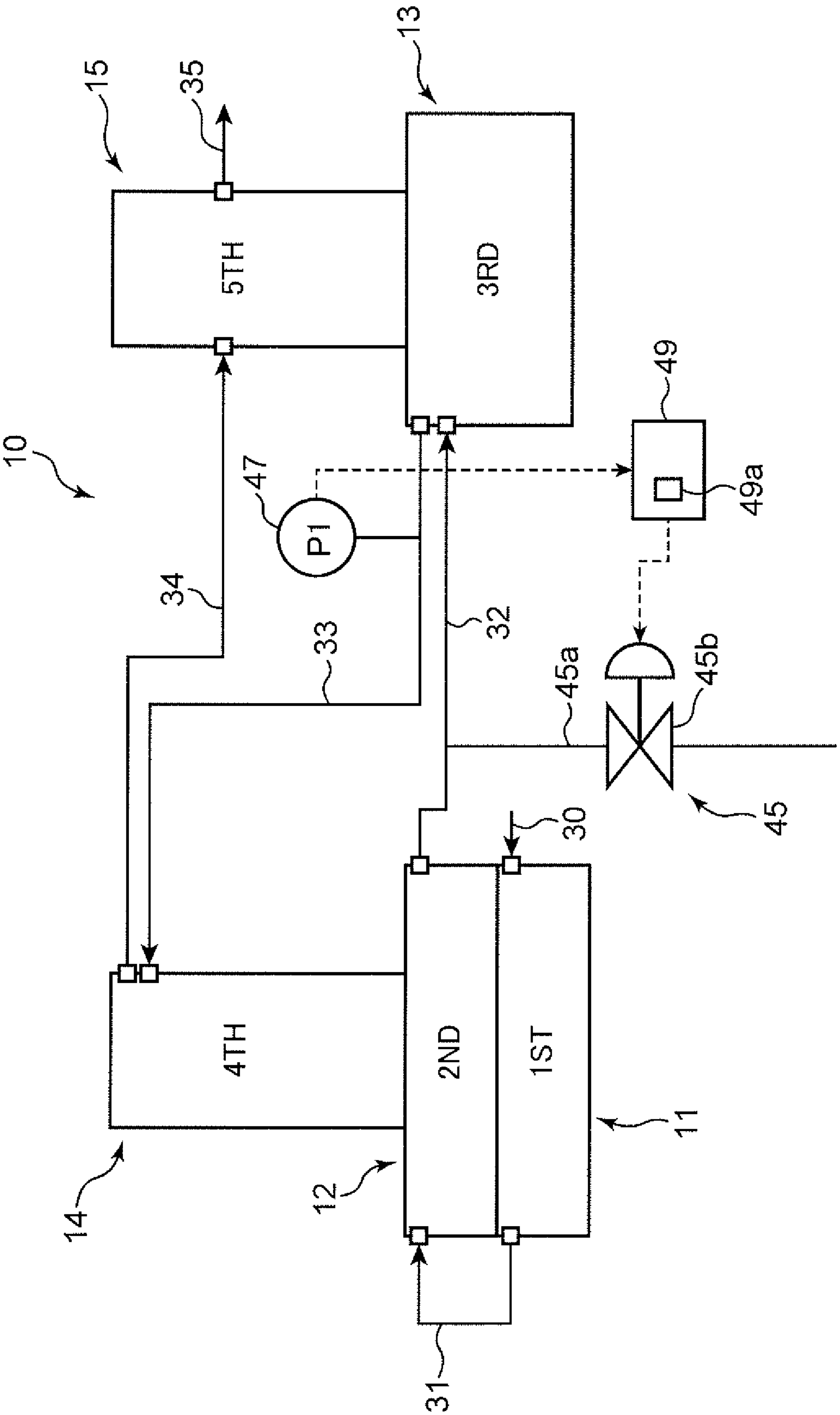
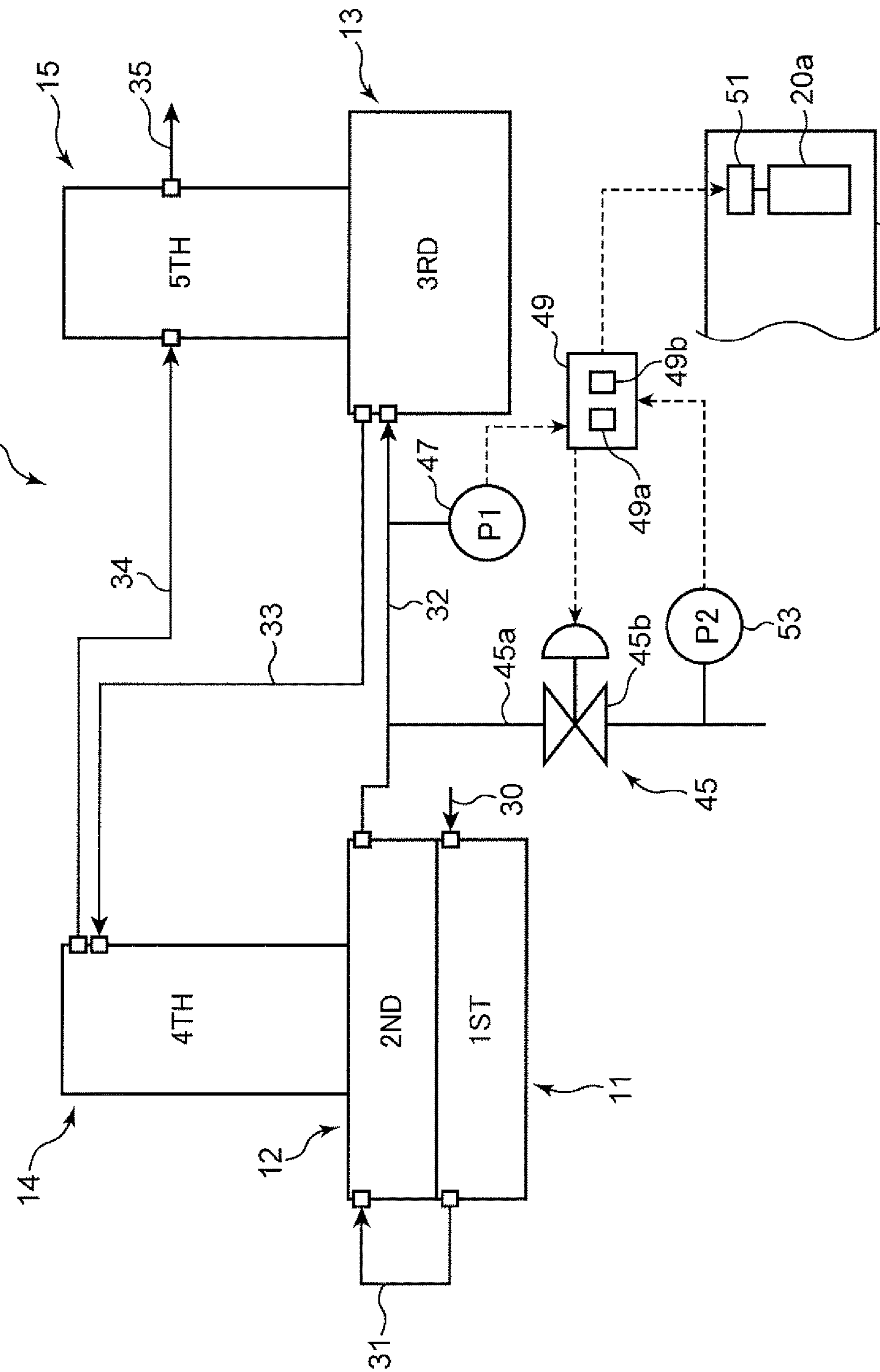

10
11
12
13
14
15
20
20a
22
23
24
25
27
28
30
31
32
33
34
35
37
38
39
40
45
45a
45b
47
49
49a
P1
1ST
2ND
3RD
4TH
5TH

FIG.2



15
35
13
5TH
3RD
49
10
47
P1
49a
34
33
32
45a
45b
45
30
4TH
2ND
1ST
11
14
12
31

FIG.3


10
11
12
13
14
15
1ST
2ND
3RD
4TH
5TH
20
20a
30
31
32
33
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35
45
45a
45b
47
P1
49
49a
49b
51
53
P2

FIG.4

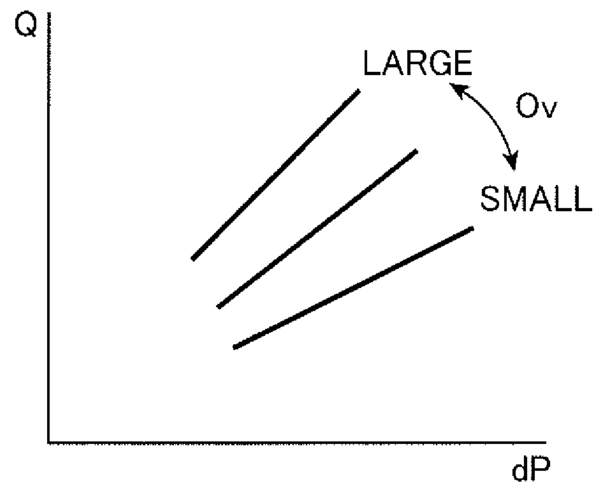

Q
LARGE
Ov
SMALL
dP

FIG.5

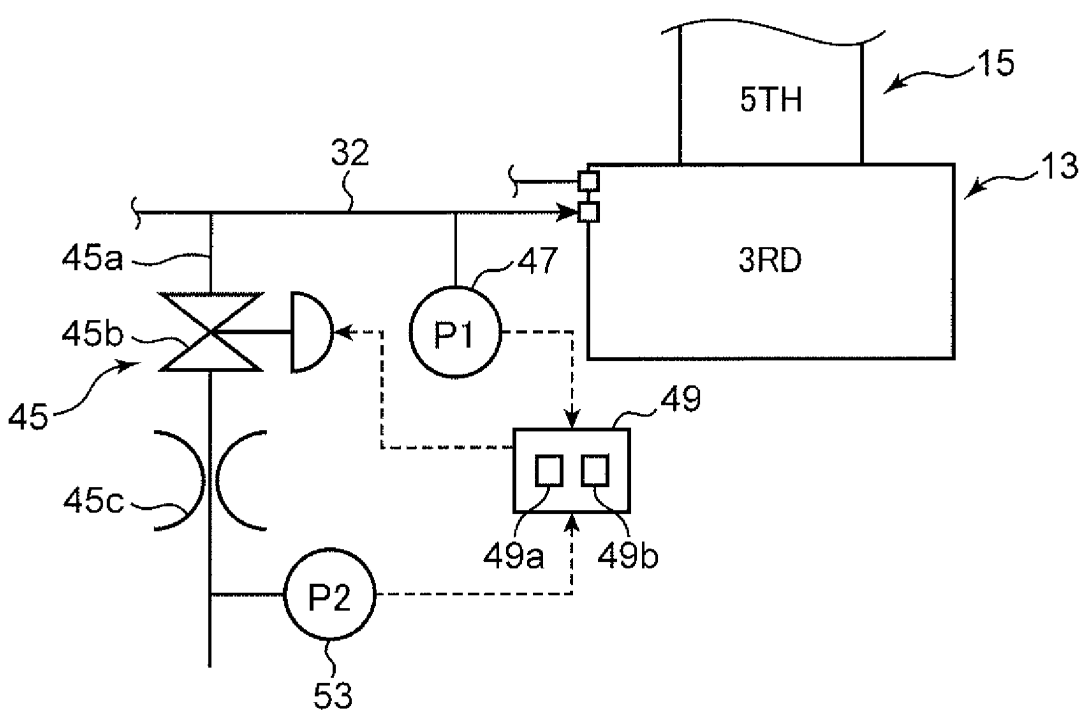

15
5TH
13
32
3RD
45a
47
45b
P1
45
49
45c
49a
49b
P2
53

FIG.6

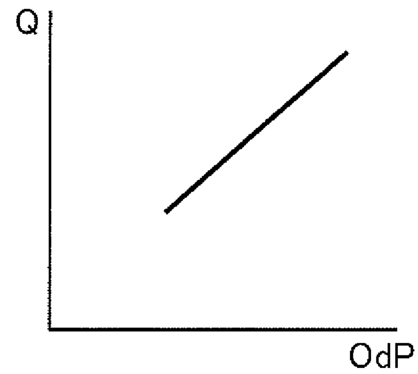

Q
OdP

FIG.7

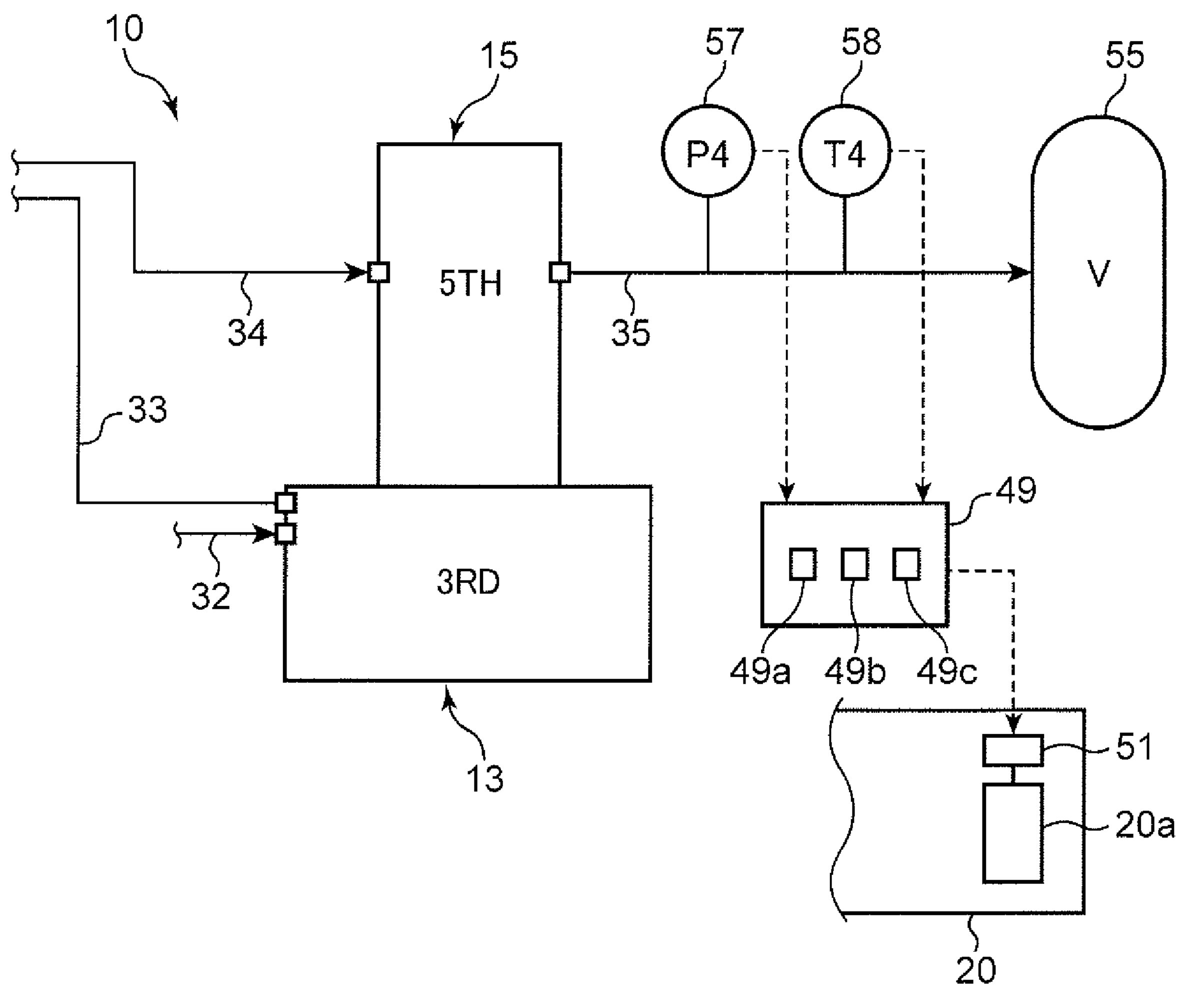

10
15
57
58
55
P4
T4
5TH
V
34
35
33
49
32
3RD
49a
49b
49c
51
20a
13
20

FIG.8

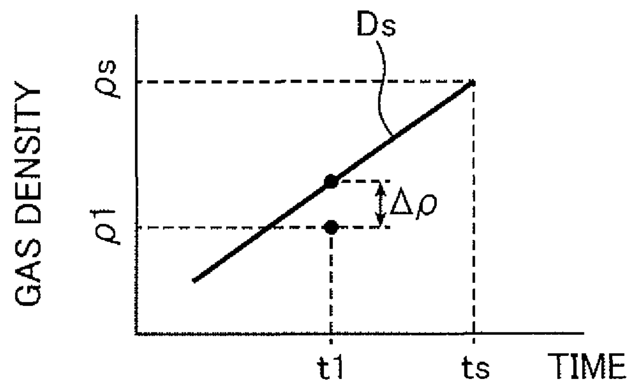
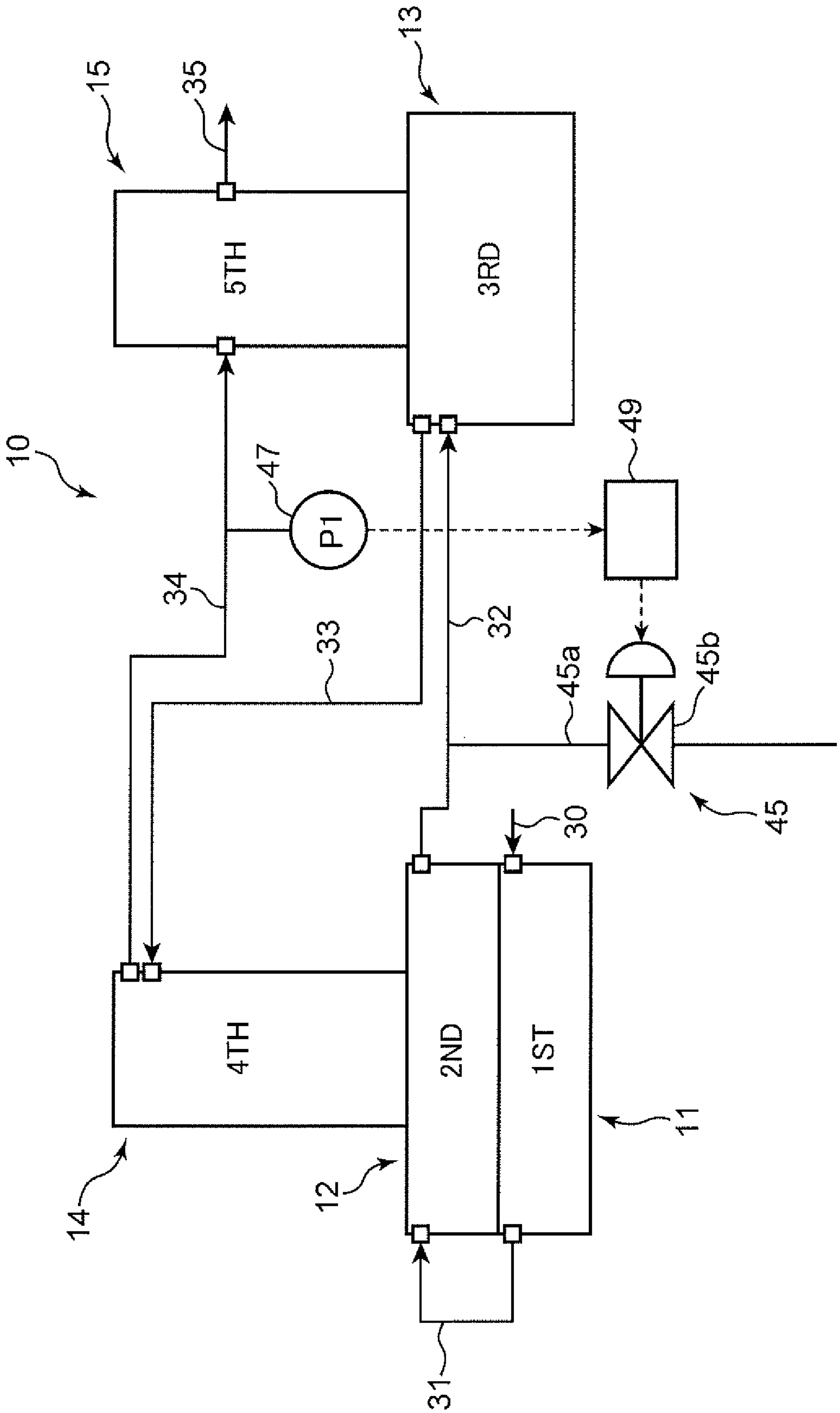
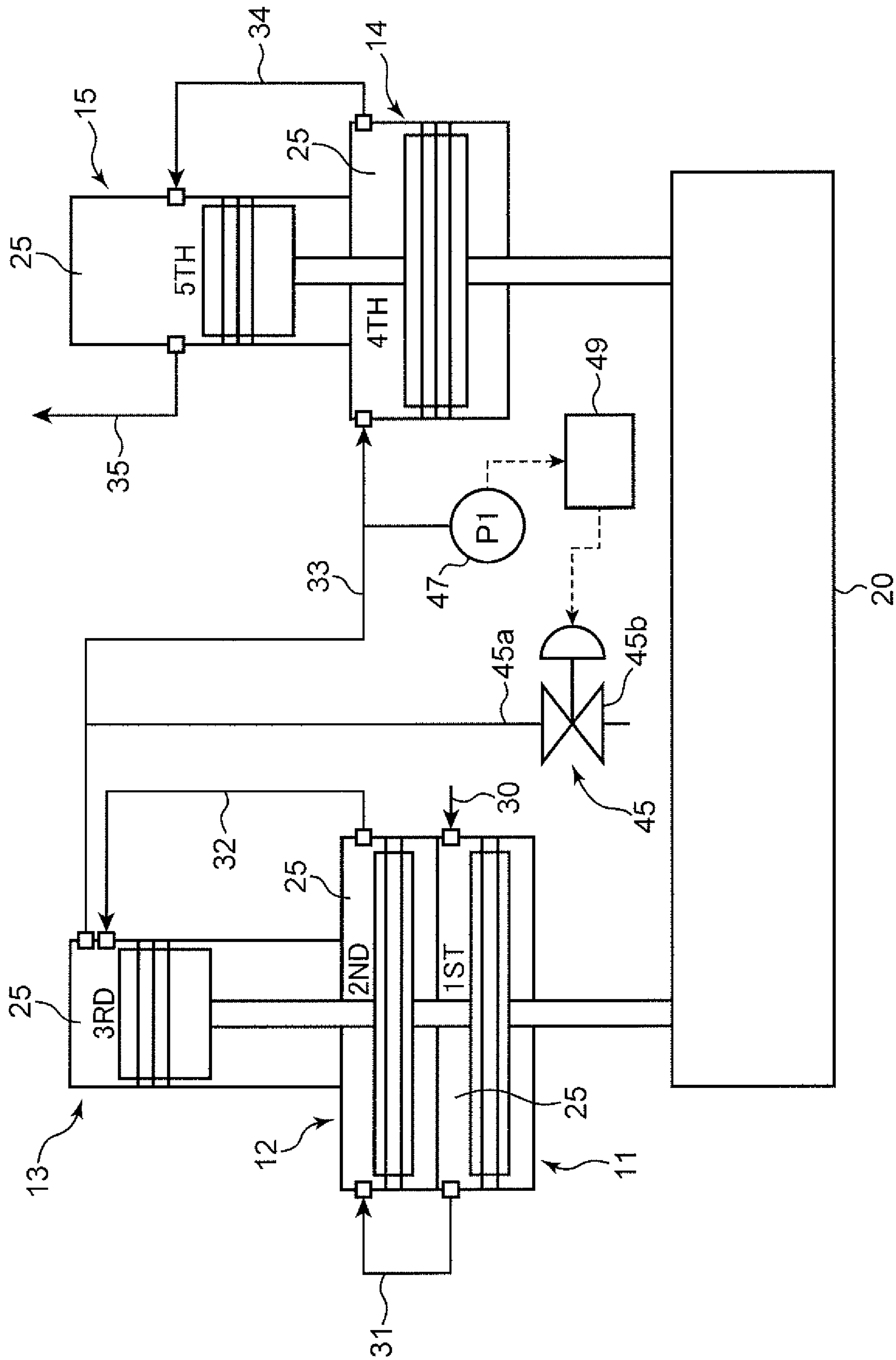


FIG.9



10
11
1ST
12
2ND
13
3RD
14
4TH
15
5TH
30
31
32
33
34
35
45
45a
45b
47
P1
49

FIG.10


34
14
15
25
25
5TH
4TH
25
49
35
P1
33
47
45a
45b
20
30
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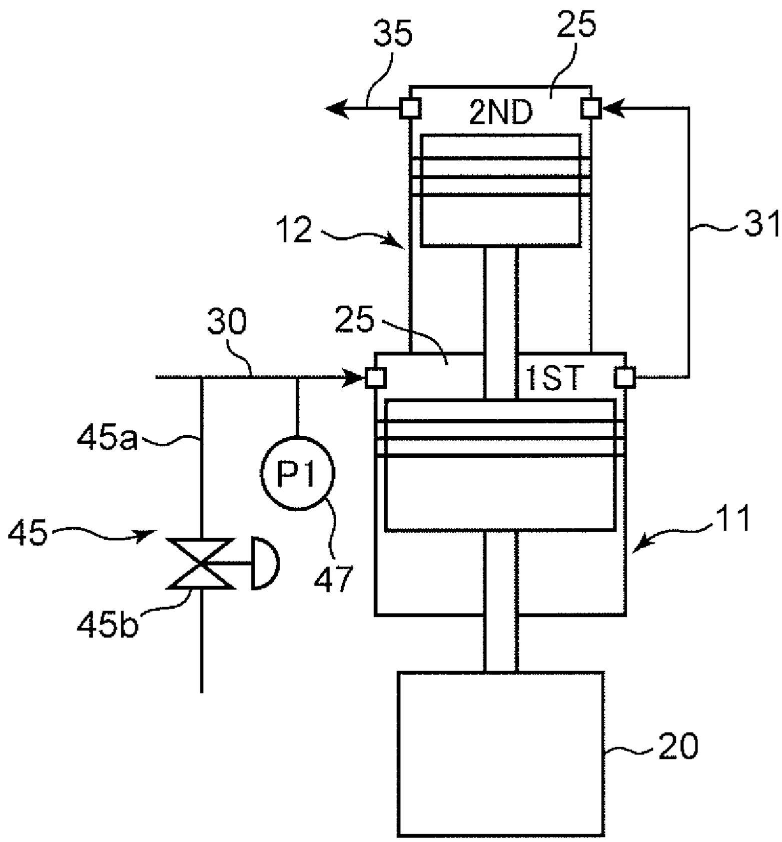
3RD
2ND
1ST
25
25
13
12
11
31

FIG.11



RECIPROCATING COMPRESSOR

FIELD OF THE INVENTION

The present invention relates to a reciprocating compressor.

BACKGROUND ART

As disclosed in JP 2018-17145 A, a reciprocating compressor that compresses hydrogen gas and includes compression units at multiple stages has been conventionally known. The compressor disclosed in JP 2018-17145 A includes compression units at five stages, and each of the compression units includes a piston to which a piston ring is attached and a cylinder that houses the piston. The compression units at first to third stages are connected to each other to foam a so-called tandem type, and the compression units at fourth and fifth stages are also connected to each other to form a tandem type. The pistons of the compression units at the first to fifth stages are driven by a common drive source.

This configuration may cause the compression unit at the first stage to increase in discharge pressure (suction pressure of the second compression unit) when gas leaks from the compression chamber at the second stage due to wear of the piston ring in the compression unit at the second stage, for example. This is because the gas leaked from a compression chamber in the compression unit at the second stage flows into a compression chamber of the compression unit at the first stage.

When a leakage of hydrogen gas from the compression chamber increases, a discharge rate from the compression chamber becomes insufficient, and when suction pressure of the compression unit at a leakage destination (or discharge pressure at a stage immediately before the leakage destination) increases, operation becomes difficult. This case may cause difficulty in continuing the operation, such as that the drive source needs to be stopped.

SUMMARY OF THE INVENTION

It is an object of the present invention to prevent excessive increase in suction pressure of a compression unit on a low-pressure side (discharge pressure of a compression unit at a stage immediately before the compression unit on the low-pressure side) even when hydrogen gas leaks from the compression unit to the compression unit on the low-pressure side.

A reciprocating compressor according to an aspect of the present invention for compressing hydrogen gas, includes: a low-pressure stage compression unit that includes a low-pressure stage piston, a low-pressure stage cylinder that houses the low-pressure stage piston, and a piston ring group attached to the low-pressure stage piston to compress the hydrogen gas; a high-pressure stage compression unit that includes a high-pressure stage piston connected to the low-pressure stage piston, a high-pressure stage cylinder that houses the high-pressure stage piston and is connected to the low-pressure stage cylinder, and a piston ring group attached to the high-pressure stage piston to compress the hydrogen gas after being compressed by the low-pressure stage compression unit; a drive unit for driving the high-pressure stage compression unit and the low-pressure stage compression unit; a discharge mechanism that allows the hydrogen gas to be discharged from a suction-side flow path that allows hydrogen gas to flow to be suctioned into the low-pressure stage compression unit; a pressure sensor for detecting a pressure of the hydrogen gas suctioned into the low-pressure stage compression unit or a pressure of the hydrogen gas discharged from the low-pressure stage compression unit; and a discharge control unit for controlling the discharge mechanism to discharge the hydrogen gas from the suction-side flow path when the pressure of the hydrogen gas detected by the pressure sensor is higher than a set value preset.

A reciprocating compressor according to another aspect of the present invention for compressing hydrogen gas, includes: a low-pressure stage compression unit that includes a low-pressure stage piston, a low-pressure stage cylinder that houses the low-pressure stage piston, and a piston ring group attached to the low-pressure stage piston to compress the hydrogen gas; an intermediate-stage compression unit for compressing the hydrogen gas discharged from the low-pressure stage compression unit; a high-pressure stage compression unit that includes a high-pressure stage piston connected to the low-pressure stage piston, a high-pressure stage cylinder that houses the high-pressure stage piston and is connected to the low-pressure stage cylinder, and a piston ring group attached to the high-pressure stage piston to compress the hydrogen gas discharged from the intermediate-stage compression unit; a drive unit for driving the low-pressure stage compression unit, the intermediate-stage compression unit, and the high-pressure stage compression unit; a discharge mechanism that allows the hydrogen gas to be discharged from a suction-side flow path that allows the hydrogen gas to flow to be suctioned into the low-pressure stage compression unit; a pressure sensor for detecting a pressure of the hydrogen gas suctioned into the low-pressure stage compression unit, a pressure of the hydrogen gas discharged from the low-pressure stage compression unit and suctioned into the intermediate-stage compression unit, or a pressure of the hydrogen gas discharged from the intermediate-stage compression unit and suctioned into the high-pressure stage compression unit; and a discharge control unit for controlling the discharge mechanism to discharge the hydrogen gas from the suction-side flow path when the pressure of the hydrogen gas detected by the pressure sensor is higher than a set value preset.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram schematically illustrating a configuration of a reciprocating compressor according to a first embodiment;

FIG. **2** is a diagram schematically illustrating a configuration of a reciprocating compressor according to a modification of the first embodiment;

FIG. **3** is a diagram schematically illustrating a configuration of a reciprocating compressor according to a second embodiment;

FIG. **4** is a diagram schematically illustrating flow rate characteristics data on a discharge valve stored in a controller;

FIG. **5** is a diagram partially and schematically illustrating a reciprocating compressor according to a modification of the second embodiment;

FIG. **6** is a diagram schematically illustrating flow rate characteristics data on an orifice stored in a controller;

FIG. **7** is a diagram partially and schematically illustrating a reciprocating compressor according to a third embodiment;

FIG. **8** is a diagram schematically illustrating a relationship between time and gas density stored in a controller;

FIG. **9** is a diagram schematically illustrating a configuration of a reciprocating compressor according to a fourth embodiment;

FIG. **10** is a diagram schematically illustrating a configuration of a reciprocating compressor according to another embodiment; and

FIG. **11** is a diagram schematically illustrating a configuration of a reciprocating compressor according to yet another embodiment.

DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments will be described in detail with reference to the drawings.

First Embodiment

As illustrated in FIG. **1**, a reciprocating compressor **10** according to a first embodiment is for compressing hydrogen gas, and is configured as a multistage compressor including compression units **11** to **15** at multiple stages (five stages in an example of the drawing). The reciprocating compressor **10** may be provided in a hydrogen station for filling a tank of a fuel cell vehicle or the like using high-pressure hydrogen gas, for example.

The reciprocating compressor **10** includes a first-stage compression unit **11**, a second-stage compression unit **12**, a third-stage compression unit **13**, a fourth-stage compression unit **14**, a fifth-stage compression unit **15**, and a drive unit **20** that drives these compression units **11** to **15**. The hydrogen gas compressed in the first-stage compression unit **11** is introduced into the second-stage compression unit **12** and further compressed. The hydrogen gas is further sequentially compressed by the third-stage to fifth-stage compression units **13** to **15**. Each of the compression units **11** to **15** includes a piston **23** to which a piston ring group **22** is attached, and a cylinder **24** that houses the piston **23**, and is constituted of a reciprocating compression mechanism including a space close to a distal end of the piston **23** in the cylinder **24**, the space functioning as a compression chamber **25**.

The cylinder **24** of each of the compression units **11** to **15** is provided with a suction valve **27** and a discharge valve **28** at respective positions facing the corresponding compression chamber **25**. The first-stage compression unit **11** includes the suction valve **27** connected to a suction pipe **30**, and the discharge valve **28** connected to one end of a first connection pipe **31**. Thus, hydrogen gas is suctioned into the compression chamber **25** of the first-stage compression unit **11** through the suction pipe **30**. The first connection pipe **31** is connected at the other end to the suction valve **27** of the second-stage compression unit **12**. Thus, the hydrogen gas compressed by the first-stage compression unit **11** is suctioned into the compression chamber **25** of the second-stage compression unit **12** through the first connection pipe **31**. The second-stage compression unit **12** includes the discharge valve **28** connected to one end of a second connection pipe **32**, and the second connection pipe **32** is connected at the other end to the suction valve **27** of the third-stage compression unit **13**. Thus, the hydrogen gas compressed by the second-stage compression unit **12** is suctioned into the compression chamber **25** of the third-stage compression unit **13** through the second connection pipe **32**. The third-stage compression unit **13** includes the discharge valve **28** connected to one end of a third connection pipe **33**, and the third connection pipe **33** is connected at the other end to the suction valve **27** of the fourth-stage compression unit **14**. Thus, the hydrogen gas compressed by the third-stage compression unit **13** is suctioned into the compression chamber **25** of the fourth-stage compression unit **14** through the third connection pipe **33**. The fourth-stage compression unit **14** includes the discharge valve **28** connected to one end of a fourth connection pipe **34**, and the fourth connection pipe **34** is connected at the other end to the suction valve **27** of the fifth-stage compression unit **15**. Thus, the hydrogen gas compressed by the fourth-stage compression unit **14** is suctioned into the compression chamber **25** of the fifth-stage compression unit **15** through the fourth connection pipe **34**. The fifth-stage compression unit **15** includes the discharge valve **28** connected to a supply pipe **35**. Thus, the hydrogen gas compressed by the fifth-stage compression unit **15** is discharged through the supply pipe **35**.

The first-stage compression unit **11**, the second-stage compression unit **12**, and the fourth-stage compression unit **14** are connected to each other to form a so-called tandem compression mechanism. That is, the pistons **23** of the respective compression units **11**, **12**, and **14** are connected to each other by a connecting rod **37**. The cylinders **24** of the respective compression units **11**, **12**, and **14** are connected to each other and integrated. Thus, when the hydrogen gas may leak from the compression chamber **25** of the fourth-stage compression unit **14**, the leaked gas may flow into the compression chamber **25** of the second-stage compression unit **12**.

The third-stage compression unit **13** and the fifth-stage compression unit **15** are connected to each other to form a so-called tandem compression mechanism. That is, the pistons **23** of the respective compression units **13** and **15** are connected to each other by a connecting rod **38**. The cylinders **24** of the respective compression units **13** and **15** are connected to each other and integrated. Thus, when the hydrogen gas may leak from the compression chamber **25** of the fifth-stage compression unit **15**, the leaked gas may flow into the compression chamber **25** of the third-stage compression unit **13**.

The piston **23** of the first-stage compression unit **11** is connected to a first crank mechanism (not illustrated) of the drive unit **20** by a drive rod **39**, and the piston **23** of the third-stage compression unit **13** is connected to a second crank mechanism (not illustrated) of the drive unit **20** by another drive rod **40**. The first crank mechanism and the second crank mechanism are driven by a motor **20*a*** provided in the drive unit **20**. Thus, the drive unit **20** collectively drives the pistons **23** of the respective first-stage to fifth-stage compression units **11** to **15**. At this time, the pistons **23** move in the same cycle.

The second connection pipe **32** through which the hydrogen gas suctioned into the third-stage compression unit **13** flows is provided with a discharge mechanism **45** capable of discharging the hydrogen gas from the inside of the second connection pipe **32**. The discharge mechanism **45** includes a gas discharge path **45*a*** connected to the second connection pipe **32** and a discharge valve **45*b*** located on the gas discharge path **45*a***. The discharge valve **45*b*** includes an on-off valve that switches opening and closing of the gas discharge path **45*a***.

The discharge valve **45*b*** may be directly attached to the second connection pipe **32** while branching from the second connection pipe **32**. This case allows the gas discharge path **45*a*** to be eliminated. The discharge mechanism **45** may be constituted of a three-way valve provided on the second connection pipe **32**. This case allows the three-way valve to be configured to be switchable between a state in which hydrogen gas can be discharged from the second connection pipe **32** and a state in which hydrogen gas is not discharged from the second connection pipe **32**.

The second connection pipe **32** is provided with a pressure sensor **47** for detecting pressure of hydrogen gas flowing through the second connection pipe **32**. That is, when the third-stage compression unit **13** is regarded as a low-pressure stage compression unit, the fifth-stage compression unit **15** serves as a high-pressure stage compression unit, and the fourth-stage compression unit **14** serves as an intermediate-pressure stage compression unit. At this time, the piston **23** and the cylinder **24** of the third-stage compression unit **13** function as a low-pressure stage piston and a low-pressure stage cylinder, respectively, the piston **23** and the cylinder **24** of the fourth-stage compression unit **14** function as an intermediate-pressure stage piston and an intermediate-pressure stage cylinder, respectively, and the piston **23** and the cylinder of the fifth-stage compression unit **15** function as a high-pressure stage piston and a high-pressure stage cylinder, respectively. The second connection pipe **32** functions as a suction-side flow path through which the hydrogen gas suctioned into the low-pressure stage compression unit flows. The pressure sensor **47** detects pressure of the hydrogen gas suctioned into the low-pressure stage compression unit.

The pressure sensor **47** outputs a signal indicating the detected pressure. This signal is received by a controller **49**. The controller **49** is constituted of a microcomputer including a CPU that performs arithmetic processing, a ROM that stores a processing program, data, and the like, and a RAM that temporarily stores data. The controller **49** exerts a predetermined function by executing the processing program. This function includes a function of a discharge control unit **49***a*.

The discharge control unit **49***a* is configured to control the discharge valve **45***b* to discharge the hydrogen gas from the second connection pipe **32** when pressure of the hydrogen gas detected by the pressure sensor **47** is higher than a set value preset. This set value is higher than a pressure value in the second connection pipe **32** when the suction valve **27** of the third-stage compression unit **13** is opened in a normal state.

That is, when differential pressure between pressure in the second connection pipe **32** and pressure in the compression chamber **25** of the third-stage compression unit **13** reaches a set pressure value, the suction valve **27** is opened. Thus, increase in pressure in the second connection pipe **32** to more than a normal pressure value causes pressure in the compression chamber **25** of the third-stage compression unit **13** to be higher than a normal pressure value. Assumed examples of this case include a case where leaked gas from the fifth-stage compression unit **15** flows into the compression chamber **25** of the third-stage compression unit **13** due to wear or the like of the piston ring group **22** of the fifth-stage compression unit **15**, so that the pressure in the compression chamber **25** of the third-stage compression unit **13** increases to more than the normal pressure value. Thus, when the pressure sensor **47** detects that the pressure in the second connection pipe **32** is higher than the set value, the discharge mechanism **45** discharges the hydrogen gas in the second connection pipe **32** to prevent suction pressure of the third-stage compression unit **13** from excessively increasing.

Here, operation of the reciprocating compressor **10** will be described. The reciprocating compressor **10** according to the first embodiment causes the drive unit **20** to be driven when the controller **49** receives a command from the outside. When the drive unit **20** is driven, the discharge valve **45***b* of the discharge mechanism **45** is normally closed. The drive unit **20** is driven to compress the hydrogen gas in each of the compression units **11** to **15**. The hydrogen gas is suctioned into the first-stage compression unit **11** through the suction pipe **30** and compressed, and then sequentially compressed in the second-stage compression unit **12** to the fifth-stage compression unit **15**, and discharged through the supply pipe **35**.

At this time, the pressure sensor **47** detects the pressure of the hydrogen gas in the second connection pipe **32**. The detection value of the pressure sensor **47** is normally to be lower than the set value. Thus, the discharge valve **45***b* is closed. However, when leaked gas from the fifth-stage compression unit **15** flows into the compression chamber **25** of the third-stage compression unit **13** to increase pressure in the second connection pipe **32** to higher than the set value, the detection value of the pressure sensor **47** becomes higher than the set value. The controller **49** accordingly opens the discharge valve **45***b*. As a result, the hydrogen gas is discharged from the second connection pipe **32** to reduce the amount of hydrogen gas suctioned into the third-stage compression unit **13**, and thus preventing excessive increase in suction pressure of the third-stage compression unit **13**.

As described above, the present embodiment may cause the hydrogen gas suctioned into the third-stage compression unit **13** or the hydrogen gas discharged from the third-stage compression unit **13** to have pressure higher than the set value when the hydrogen gas leaks from the fifth-stage compression unit **15** to the third-stage compression unit **13**. In this case, the discharge mechanism **45** discharges the hydrogen gas from the second connection pipe **32**. This configuration enables preventing an excessive increase in suction pressure of the third-stage compression unit **13** or discharge pressure of the third-stage compression unit **13** even when hydrogen gas leaks from the fifth-stage compression unit **15** to the third-stage compression unit **13**. Thus, difficulty in operating the compressor **10** can be suppressed.

The first embodiment allows the pressure sensor **47** to be provided in the second connection pipe **32**. Alternatively, the pressure sensor **47** may be provided in the third connection pipe **33** as illustrated in FIG. **2**. That is, the pressure sensor **47** may be configured to detect pressure of hydrogen gas discharged from a low-pressure stage compression unit or hydrogen gas suctioned into an intermediate-stage compression unit. In other words, gas discharge may be controlled by detecting pressure of hydrogen gas suctioned into a compression unit at a subsequent stage (compression unit at a next stage) of a compression unit into which the leaked gas flows.

When the leaked gas from the fifth-stage compression unit **15** flows into the compression chamber **25** of the third-stage compression unit **13** due to wear or the like of the piston ring group **22** of the fifth-stage compression unit **15**, gas pressure increases in the third connection pipe **33** through which the discharged gas from the third-stage compression unit **13** flows. Thus, even when the pressure sensor **47** is provided in the third connection pipe **33**, the pressure sensor **47** can detect gas leakage from the fifth-stage compression unit **15** to the third-stage compression unit **13**.

The first embodiment enables addressing gas leakage from the fifth-stage compression unit **15** to the third-stage compression unit **13** by providing the pressure sensor **47** in the second connection pipe **32**. Alternatively or additionally, the pressure sensor **47** may be provided in the first connection pipe **31**, and the discharge mechanism **45** may discharge hydrogen gas from the first connection pipe **31** to enable addressing gas leakage from the fourth-stage compression unit **14** (high-pressure stage compression unit) to the second-stage compression unit **12** (low-pressure stage compression unit).

Second Embodiment

FIG. **3** illustrates a second embodiment. Here, the same components as those of the first embodiment are denoted by the same reference numerals, and a detailed description thereof will not be described.

The second embodiment allows a motor **20***a* to increase in rotational speed when a discharge mechanism **45** discharges hydrogen gas, thereby compensating for the amount of gas corresponding to the discharge. Hereinafter, the second embodiment will be specifically described.

A reciprocating compressor **10** is provided with an inverter **51** capable of adjusting the rotational speed of the motor **20***a* of a drive unit **20**, and the inverter **51** adjusts the rotational speed of the motor **20***a*.

A discharge valve **45***b* is constituted of a valve capable of adjusting a valve opening. Thus, when an opening of the discharge valve **45***b* is adjusted, a gas discharge rate with the discharge mechanism **45** is changed. The opening of the discharge valve **45***b* is adjusted by a discharge control unit **49***a* in accordance with a magnitude of differential pressure dP between pressure on a primary side and pressure on a secondary side of the discharge valve **45***b* (differential pressure between a detection value P**1** of a pressure sensor **47** and a detection value P**2** of an auxiliary pressure sensor **53** described later).

The auxiliary pressure sensor **53** is provided in a gas discharge path **45***a* while being located downstream of the discharge valve **45***b* and detects gas pressure downstream of the discharge valve **45***b*.

The controller **49** stores flow rate characteristics data on the discharge valve **45***b*. This flow rate characteristics data defines a relationship among the differential pressure dP between pressure on the primary side and pressure on the secondary side of the discharge valve **45***b* (differential pressure between the detection value P**1** of the pressure sensor **47** and the detection value P**2** of the auxiliary pressure sensor **53**), a valve opening Ov of the discharge valve **45***b*, and a discharge flow rate Q. Although the flow rate characteristics of the discharge valve **45***b* indicates that the discharge flow rate Q increases as the differential pressure dP between the detection values P**1** and P**2** increases as illustrated in FIG. **4**, for example, a degree of increase in the discharge flow rate Q increases as the valve opening Ov of the discharge valve **45***b* increases.

The controller **49** also stores rotational characteristics data that indicates a relationship between rotational speed of the motor **20***a* and a discharge flow rate of hydrogen gas from the second-stage compression unit **12**. Thus, when throughput of gas is increased, the controller **49** can derive an increase in the motor rotational speed in accordance with the increase of the throughput. The controller **49** may store rotational characteristic data that indicates a relationship between rotational speed of the motor **20***a* and a discharge flow rate of hydrogen gas from at least one of the first-stage to fifth-stage compression units **11** to **15**.

The controller **49** includes a function of a rotational speed control unit **49***b* that controls the inverter **51**. When the discharge valve **45***b* of the discharge mechanism **45** is opened to a predetermined opening in response to a command of the discharge control unit **49***a*, hydrogen gas is discharged from the second connection pipe **32**. Thus, the rotational speed control unit **49***b* performs control to increase the rotational speed of the motor **20***a* to add the amount of gas compression corresponding to a discharge rate of the hydrogen gas to the amount of normal compression. More specifically, the rotational speed control unit **49***b* derives the discharge flow rate Q using the detection value P**1** of the pressure sensor **47**, the detection value P**2** of the auxiliary pressure sensor **53**, and the flow rate characteristics of the discharge valve **45***b* stored in the controller **49**. Specifically, the differential pressure dP is calculated from the detection values P**1** and P**2**, and the discharge flow rate Q is derived based on the calculated differential pressure dP and the current valve opening Ov stored in the controller **49**. The current valve opening Ov stored in the controller **49** is based on the data sent from the discharge valve **45***b*. Then, the rotational speed control unit **49***b* derives how much the rotational speed needs to be increased using the rotation characteristics data, and controls the inverter **51** to increase the rotational speed of the motor **20***a* by the derived rotational speed. The rotational speed control unit **49***b* may increase the rotational speed in compensation for the amount of hydrogen gas (or a gas flow rate thereof) smaller than a discharge rate thereof (or a flow rate thereof), instead of compensating for the amount of hydrogen gas (or a flow rate thereof) equal to the discharge rate thereof (or the flow rate thereof). In this case, a half or more of the amount of hydrogen gas (or a flow rate thereof) discharged may be compensated, for example.

Thus, the present embodiment allows the motor **20***a* to increase its rotational speed when the hydrogen gas is discharged, thereby increasing a discharge rate of the hydrogen gas by the third-stage compression unit **13** to the fifth-stage compression unit **15**. This configuration enables compensating for the hydrogen gas discharged by the discharge mechanism **45**, and thus enables suppressing a decrease in throughput of hydrogen gas with the reciprocating compressor **10**. Although the discharge rate of the hydrogen gas with the third-stage compression unit **13** increases by increasing the rotational speed of the motor **20***a* because a leakage from the fifth-stage compression unit **15** is constant, an increase in discharge pressure of the third-stage compression unit **13** can be suppressed.

The present embodiment allows the detection value P**1** of the pressure sensor **47** to be used when the amount of compensation of hydrogen gas is derived. Thus, a discharge rate of hydrogen gas with the discharge mechanism **45** can be derived while the pressure sensor **47** for detecting gas pressure in the second connection pipe **32** (a suction-side flow path of the third-stage compression unit **13**) is used.

Although the second embodiment allows the discharge valve **45***b* to be constituted of a valve capable of adjusting its opening, the present embodiment is not limited thereto. For example, the discharge mechanism **45** may include the discharge valve **45***b* formed of an on-off valve and located in the gas discharge path **45***a*, and an orifice **45***c* located downstream of the discharge valve **45***b* in the gas discharge path **45***a*, as illustrated in FIG. **5**. This case allows the controller **49** to store flow rate characteristics data on the orifice **45***c*. As illustrated in FIG. **6**, the flow rate characteristics data defines a relationship between differential pressure (differential pressure between the primary side and the secondary side) OdP in the orifice **45***c* and the discharge flow rate Q. The flow rate characteristics data shows flow rate characteristics of the orifice **45***c*, in which the discharge flow rate Q increases as the differential pressure OdP at the orifice **45***c* increases.

The rotational speed control unit **49**b derives the discharge flow rate Q using the detection value P**1** of the pressure sensor **47**, the detection value P**2** of the auxiliary pressure sensor **53**, and the flow rate characteristics of the orifice **45**c stored in the controller **49**. Then, the rotational speed control unit **49**b derives how much the rotational speed needs to be increased using the rotation characteristics data, and controls the inverter **51** to increase the rotational speed of the motor **20**a by the derived rotational speed.

Although other configurations, operations, and effects are not described, the description of the first embodiment can be applied to the second embodiment.

Third Embodiment

FIG. **7** illustrates a third embodiment. Here, the same components as those of the first and second embodiments are denoted by the same reference numerals, and a detailed description thereof will not be described.

A reciprocating compressor **10** according to the third embodiment allows an accumulator **55** including a tank to serve as a demander of hydrogen gas discharged from the compressor **10**. The reciprocating compressor **10** in this case is configured to adjust a discharge rate of hydrogen gas to allow the accumulator **55** to store a predetermined amount of hydrogen gas within a predetermined time.

As illustrated in FIG. **7**, a supply pipe **35** is connected to the accumulator **55**. The supply pipe **35** is provided with a demand side pressure sensor **57** for detecting pressure of hydrogen gas in the supply pipe **35** (pressure of the hydrogen gas after being discharged from the compressor **10**) and a demand side temperature sensor **58** for detecting temperature of the hydrogen gas in the supply pipe **35** (temperature of the hydrogen gas after being discharged from the compressor **10**). The supply pipe **35** is a demander connection flow path that connects the reciprocating compressor **10** and the accumulator **55** to each other. The demand side pressure sensor **57** may be located in the accumulator **55**. The demand side temperature sensor **58** also may be located in the accumulator **55**.

The present embodiment requires the predetermined amount of hydrogen gas to be stored in the accumulator **55** within the predetermined time, so that the controller **49** includes a function of an estimation unit **49**c that estimates a density variation of hydrogen gas per unit time in the accumulator **55**. That is, the estimation unit **49**c derives the density of the hydrogen gas stored in the accumulator **55** with a gas state equation to which detection values are applied, the detection values including pressure detected by the demand side pressure sensor **57** as pressure of the hydrogen gas, temperature detected by the demand side temperature sensor **58** as temperature of the hydrogen gas, and a tank capacity of the accumulator **55** as a volume of the hydrogen gas. Then, the estimation unit **49**c derives repetition density from the detection values repeatedly detected by the demand side pressure sensor **57** and the demand side temperature sensor **58**, and estimates the density variation per unit time of the hydrogen gas accumulated in the accumulator **55**.

The accumulator **55** is required to store hydrogen gas under predetermined pressure within the predetermined time, so that the amount of hydrogen gas discharged needs to be compensated when a part of the hydrogen gas is discharged by the discharge mechanism **45**. Thus, a rotational speed control unit **49**b is configured to increase rotational speed of the motor **20**a in compensation for the amount (or a flow rate) of the hydrogen gas, corresponding to a difference between the density variation per unit time of the hydrogen gas accumulated in the accumulator **55** on an assumption that there is no leakage of hydrogen gas from a high-pressure stage compression unit to a low-pressure stage compression unit and the density variation per unit time of the hydrogen gas estimated by the estimation unit **49**c.

For example, the controller **49** stores data Ds indicating a time transition of density ρ (on an assumption that there is no leakage of hydrogen gas from the high-pressure stage compression unit to the low-pressure stage compression unit) so that hydrogen gas at a predetermined density ρs can be stored within a predetermined time is as illustrated in FIG. **8**. Then, gas density ρ**1** at a certain time t**1** is derived from the density variation per unit time of the hydrogen gas estimated by the estimation unit **49**c. Then, the controller **49** derives a difference $\Delta\rho$ between the data Ds at the time t**1** and the derived gas density ρ**1**, and the rotational speed control unit **49**b performs control of increasing the rotational speed of the motor **20**a in compensation for the difference $\Delta\rho$. This configuration enables the accumulator **55** to store the hydrogen gas under the predetermined pressure within the predetermined time even when the hydrogen gas is discharged by the discharge mechanism **45**.

Thus, the present embodiment enables preventing time for accumulating the hydrogen gas in the accumulator **55** from increasing to more than assumed time even when the hydrogen gas leaks from the high-pressure stage compression unit to the low-pressure stage compression unit.

Although other configurations, operations, and effects are not described, the description of the first and second embodiments can be applied to the third embodiment.

Fourth Embodiment

FIG. **9** illustrates a fourth embodiment. Here, the same components as those of the first to third embodiments are denoted by the same reference numerals, and a detailed description thereof will not be described.

The fourth embodiment is different from the first embodiment in that a pressure sensor **47** is located in a fourth connection pipe **34**. When a third-stage compression unit **13** is regarded as a low-pressure stage compression unit, a fifth-stage compression unit **15** serves as a high-pressure stage compression unit. Then, a fourth-stage compression unit **14** functions as an intermediate-stage compression unit that compresses hydrogen gas discharged from the low-pressure stage compression unit. Thus, the pressure sensor **47** is provided in the fourth connection pipe **34**, and is configured to detect pressure of the hydrogen gas discharged from the intermediate-stage compression unit and suctioned into the high-pressure stage compression unit. That is, when the hydrogen gas leaks from the fifth-stage compression unit **15** to the third-stage compression unit **13**, pressure of gas discharged from the third-stage compression unit **13** is also higher than an assumed value. In this case, pressure of the gas suctioned into the fourth-stage compression unit **14** and pressure of the gas discharged from the fourth-stage compression unit **14** are each also higher than an assumed value. Thus, even when the pressure sensor **47** is located in the fourth connection pipe **34**, a gas leakage from the fifth-stage compression unit **15** to the third-stage compression unit **13** can be detected. When the pressure of the hydrogen gas detected by the pressure sensor **47** is higher than a preset set value, the discharge mechanism **45** discharges the hydrogen gas from a second connection pipe **32** (a pipe connected to a suction valve of the low-pressure stage compression unit).

Although other configurations, operations, and effects are not described, the description of the first to third embodiments can be applied to the fourth embodiment.

Other Embodiments

It should be understood that the embodiments disclosed herein are illustrative in all respects and are not restrictive. The present invention is not limited to the above embodiments, and various modifications, improvements, and the like can be made without departing from the gist of the present invention. For example, although the first-stage compression unit **11**, the second-stage compression unit **12**, and the fourth-stage compression unit **14** are of a tandem type, and the third-stage compression unit **13** and the fifth-stage compression unit **15** are of a tandem type, in the above embodiments, the present embodiment is not limited thereto. For example, the first-stage compression unit **11**, the second-stage compression unit **12**, and the third-stage compression unit **13** may be of a tandem type, and the fourth-stage compression unit **14** and the fifth-stage compression unit **15** may be of a tandem type, as illustrated in FIG. **10**. In this case, leaked gas from the fifth-stage compression unit **15** (high-pressure stage compression unit) flows into the fourth-stage compression unit **14** (low-pressure stage compression unit), and thus the pressure sensor **47** may be provided in the third connection pipe **33** (pipe connected to the suction valve of the low-pressure stage compression unit), for example. The discharge mechanism **45** in this case may be configured to discharge the hydrogen gas from the third connection pipe **33**. Then, leaked gas from the third-stage compression unit **13** (high-pressure stage compression unit) flows into the second-stage compression unit **12** (low-pressure stage compression unit), and thus the pressure sensor **47** may be provided in the first connection pipe **31** (pipe connected to the suction valve of the low-pressure stage compression unit), for example. The discharge mechanism **45** in this case may be configured to discharge the hydrogen gas from the first connection pipe **31**.

Although the reciprocating compressor **10** is configured as a multistage compressor including the fifth-stage compression units **11** to **15** in the above embodiments, the present embodiment is not limited thereto. The number of stages of the compression units may be two or more. When the number of stages is two, for example, the first-stage compression unit **11** and the second-stage compression unit **12** are configured in a tandem type as illustrated in FIG. **11**. Then, leaked gas from the second-stage compression unit **12** (high-pressure stage compression unit) flows into the first-stage compression unit **11** (low-pressure stage compression unit), and thus the pressure sensor **47** is provided in the suction pipe **30** (pipe connected to the suction valve of the low-pressure stage compression unit), and the discharge mechanism **45** discharges hydrogen gas through the suction pipe **30**.

Here, the embodiments will be outlined.

(1) A reciprocating compressor according to the corresponding embodiments for compressing hydrogen gas, includes: a low-pressure stage compression unit that includes a low-pressure stage piston, a low-pressure stage cylinder that houses the low-pressure stage piston, and a piston ring group attached to the low-pressure stage piston to compress the hydrogen gas; a high-pressure stage compression unit that includes a high-pressure stage piston connected to the low-pressure stage piston, a high-pressure stage cylinder that houses the high-pressure stage piston and is connected to the low-pressure stage cylinder, and a piston ring group attached to the high-pressure stage piston to compress the hydrogen gas after being compressed by the low-pressure stage compression unit; a drive unit for driving the high-pressure stage compression unit and the low-pressure stage compression unit; a discharge mechanism that allows the hydrogen gas to be discharged from a suction-side flow path that allows the hydrogen gas to flow to be suctioned into the low-pressure stage compression unit; a pressure sensor for detecting a pressure of the hydrogen gas suctioned into the low-pressure stage compression unit or a pressure of the hydrogen gas discharged from the low-pressure stage compression unit; and a discharge control unit for controlling the discharge mechanism to discharge the hydrogen gas from the suction-side flow path when the pressure of the hydrogen gas detected by the pressure sensor is higher than a set value preset.

The reciprocating compressor according to the corresponding embodiments may cause pressure of the hydrogen gas suctioned into the low-pressure stage compression unit or pressure of the hydrogen gas discharged from the low-pressure stage compression unit to be higher than the set value when the hydrogen gas leaks from the high-pressure stage compression unit to the low-pressure stage compression unit. In this case, the discharge mechanism discharges the hydrogen gas from the suction-side flow path. This configuration enables preventing an excessive increase in suction pressure of the low-pressure stage compression unit or discharge pressure of the low-pressure stage compression unit even when hydrogen gas leaks from the high-pressure stage compression unit to the low-pressure stage compression unit.

(2) The drive unit may include a motor that is rotatable. In this case, the reciprocating compressor may further include: an inverter capable of adjusting rotational speed of the motor in the drive unit; and a rotational speed control unit for controlling the inverter to increase the rotational speed of the motor in compensation for an amount of hydrogen gas discharged from the suction-side flow path when discharging hydrogen gas from the suction-side flow path.

This aspect allows the motor to increase its rotational speed to increase a discharge rate of the hydrogen gas with the low-pressure stage compression unit in compensation for the hydrogen gas discharged by the discharge mechanism. This enables suppressing a decrease in throughput of hydrogen gas with the reciprocating compressor. When the rotational speed of the motor is increased, the rotational speed of the motor of the drive unit that drives both the low-pressure stage compression unit and the high-pressure stage compression unit is increased. As a result, the discharge rate of the hydrogen gas increases in both the low-pressure stage compression unit and the high-pressure stage compression unit. Thus, even when the discharge rate of the hydrogen gas with the low-pressure stage compression unit increases, the discharge pressure of the low-pressure stage compression unit hardly increases.

(3) The pressure sensor may be located in the suction-side flow path. In this case, the discharge mechanism may include a gas discharge path connected to the suction-side flow path, and a discharge valve located in the gas discharge path and capable of adjusting a valve opening. The reciprocating compressor may further include an auxiliary pressure sensor located downstream of the discharge valve in the gas discharge path. The rotational speed control unit may be configured to increase

rotational speed of the motor in compensation for the amount of the hydrogen gas corresponding to a discharge flow rate of the hydrogen gas derived based on a pressure detection value obtained by the pressure sensor, a pressure detection value obtained by the auxiliary pressure sensor, and flow rate characteristics of the discharge valve.

This aspect enables deriving the discharge flow rate of the hydrogen gas with the discharge mechanism while using the pressure sensor for detecting gas pressure in the suction-side flow path of the low-pressure stage compression unit.

(4) The discharge mechanism may include a gas discharge path connected to the suction-side flow path, an on-off valve located in the gas discharge path, and an orifice located downstream of the on-off valve in the gas discharge path. In this case, the reciprocating compressor may further include an auxiliary pressure sensor located downstream of the orifice in the gas discharge path. The rotational speed control unit may be configured to increase the rotational speed of the motor in compensation for the discharge flow rate of the hydrogen gas, the discharge flow rate being derived based on a pressure detection value obtained by the pressure sensor, a pressure detection value obtained by the auxiliary pressure sensor, and a throttle ratio of the gas discharge path, the throttle ratio being obtained by the orifice.

This aspect enables deriving the discharge flow rate of the hydrogen gas with the discharge mechanism while using the pressure sensor for detecting gas pressure in the suction-side flow path of the low-pressure stage compression unit.

(5) The reciprocating compressor discharges the hydrogen gas to a demander that may be an accumulator including a tank. The reciprocating compressor in this case may further include: a demand side pressure sensor located in the accumulator or in a demander connection flow path connecting the reciprocating compressor and the accumulator to each other; a demand side temperature sensor located in the accumulator or in the demander connection flow path; and an estimation unit for estimating a density variation per unit time of hydrogen gas accumulated in the accumulator based on a pressure detection value obtained by the demand side pressure sensor, a temperature detection value obtained by the demand side temperature sensor, and a tank capacity of the accumulator. The rotational speed control unit may be configured to increase rotational speed of the motor in compensation for the amount or a flow rate of the hydrogen gas corresponding to a difference between the density variation per unit time of the hydrogen gas accumulated in the accumulator on an assumption that there is no leakage of hydrogen gas from the high-pressure stage compression unit to the low-pressure stage compression unit and the density variation per unit time of the hydrogen gas estimated by the estimation unit.

This aspect enables preventing time for accumulating the hydrogen gas in the accumulator from increasing to more than assumed time even when the hydrogen gas leaks from the high-pressure stage compression unit to the low-pressure stage compression unit.

(6) A reciprocating compressor according to the corresponding embodiments for compressing hydrogen gas, includes: a low-pressure stage compression unit that includes a low-pressure stage piston, a low-pressure stage cylinder that houses the low-pressure stage piston, and a piston ring group attached to the low-pressure stage piston to compress the hydrogen gas; an intermediate-stage compression unit that compresses the hydrogen gas discharged from the low-pressure stage compression unit; a high-pressure stage compression unit that includes a high-pressure stage piston connected to the low-pressure stage piston, a high-pressure stage cylinder that houses the high-pressure stage piston and is connected to the low-pressure stage cylinder, and a piston ring group attached to the high-pressure stage piston to compress the hydrogen gas discharged from the intermediate-stage compression unit; a drive unit for driving the low-pressure stage compression unit, the intermediate-stage compression unit, and the high-pressure stage compression unit; a discharge mechanism that allows the hydrogen gas to be discharged from a suction-side flow path that allows the hydrogen gas to flow to be suctioned into the low-pressure stage compression unit; a pressure sensor for detecting a pressure of the hydrogen gas suctioned into the low-pressure stage compression unit, a pressure of the hydrogen gas discharged from the low-pressure stage compression unit and suctioned into the intermediate-stage compression unit, or a pressure of the hydrogen gas discharged from the intermediate-stage compression unit and suctioned into the high-pressure stage compression unit; and a discharge control unit for controlling the discharge mechanism to discharge the hydrogen gas from the suction-side flow path when the pressure of the hydrogen gas detected by the pressure sensor is higher than a set value preset.

The reciprocating compressor according to the corresponding embodiments may cause pressure of the hydrogen gas suctioned into the low-pressure stage compression unit, pressure of the hydrogen gas discharged from the low-pressure stage compression unit (or suction pressure of the intermediate-stage compression unit), or pressure of the hydrogen gas suctioned into the high-pressure stage compression unit (or discharge pressure of the intermediate-stage compression unit) to be higher than the set value when the hydrogen gas leaks from the high-pressure stage compression unit to the low-pressure stage compression unit. In this case, the discharge mechanism discharges the hydrogen gas from the suction-side flow path. This configuration enables preventing an excessive increase in suction pressure of the low-pressure stage compression unit, discharge pressure of the low-pressure stage compression unit (or suction pressure of the intermediate-stage compression unit), and suction pressure of the high-pressure stage compression unit (or discharge pressure of the intermediate-stage compression unit) even when hydrogen gas leaks from the high-pressure stage compression unit to the low-pressure state compression unit.

As described above, excessive increase in suction pressure of a compression unit on a low-pressure side (discharge pressure of a compression unit at a stage immediately before the compression unit on the low-pressure side) can be prevented even when hydrogen gas leaks from the compression unit to the compression unit on the low-pressure side.

This application is based on Japanese Patent Application No. 2022-018826 filed on Feb. 9, 2022, the contents of which are hereby incorporated by reference.

Although the present invention has been fully described by way of example with reference to the accompanying drawings, it is to be understood that various changes and modifications will be apparent to those skilled in the art. Therefore, unless otherwise such changes and modifications depart from the scope of the present invention hereinafter defined, they should be construed as being included therein.

The invention claimed is:

1. A reciprocating compressor for compressing hydrogen gas, the reciprocating compressor comprising:

a low-pressure stage compression unit that includes a low-pressure stage piston, a low-pressure stage cylinder that houses the low-pressure stage piston, and a piston ring group attached to the low-pressure stage piston to compress hydrogen gas;

a high-pressure stage compression unit that includes a high-pressure stage piston connected to the low-pressure stage piston, a high-pressure stage cylinder that houses the high-pressure stage piston and is connected to the low-pressure stage cylinder, and a piston ring group attached to the high-pressure stage piston to compress hydrogen gas after being compressed by the low-pressure stage compression unit;

a drive unit for driving the high-pressure stage compression unit and the low-pressure stage compression unit;

a discharger that allows hydrogen gas to be discharged from a suction-side flow path that allows hydrogen gas to flow to be suctioned into the low-pressure stage compression unit;

a pressure sensor for detecting a pressure of hydrogen gas suctioned into the low-pressure stage compression unit or a pressure of hydrogen gas discharged from the low-pressure stage compression unit; and

a discharge control unit for controlling the discharger to discharge hydrogen gas from the suction-side flow path when the pressure of hydrogen gas detected by the pressure sensor is higher than a set value preset;

wherein the set value is a predetermined normal pressure value of hydrogen gas suctioned into the low-pressure stage compression unit when a differential pressure between a pressure in the suction-side flow path and a pressure in a compression chamber of the low-pressure stage compression unit reaches a predetermined pressure value to open a suction valve of the low-pressure stage compression unit, or the set value is a predetermined normal pressure value of hydrogen gas discharged from the low-pressure stage compression unit.

2. A reciprocating compressor for compressing hydrogen gas, the reciprocating compressor comprising:

a low-pressure stage compression unit that includes a low-pressure stage piston, a low-pressure stage cylinder that houses the low-pressure stage piston, and a piston ring group attached to the low-pressure stage piston to compress hydrogen gas;

a high-pressure stage compression unit that includes a high-pressure stage piston connected to the low-pressure stage piston, a high-pressure stage cylinder that houses the high-pressure stage piston and is connected to the low-pressure stage cylinder, and a piston ring group attached to the high-pressure stage piston to compress hydrogen gas after being compressed by the low-pressure stage compression unit;

a drive unit for driving the high-pressure stage compression unit and the low-pressure stage compression unit;

a discharger that allows hydrogen gas to be discharged from a suction-side flow path that allows hydrogen gas to flow to be suctioned into the low-pressure stage compression unit;

a pressure sensor for detecting a pressure of hydrogen gas suctioned into the low-pressure stage compression unit or a pressure of hydrogen gas discharged from the low-pressure stage compression unit; and

a discharge control unit for controlling the discharger to discharge hydrogen gas from the suction-side flow path when the pressure of hydrogen gas detected by the pressure sensor is higher than a set value preset;

wherein the drive unit includes a motor that is rotatable; and

the reciprocating compressor further comprises:

an inverter capable of adjusting rotational speed of the motor in the drive unit; and

a rotational speed control unit for controlling the inverter to increase the rotational speed of the motor in compensation for an amount of hydrogen gas discharged from the suction-side flow path when discharging hydrogen gas from the suction-side flow path.

3. The reciprocating compressor according to claim **2**,

wherein the pressure sensor is located in the suction-side flow path,

wherein the discharger includes a gas discharge path connected to the suction-side flow path and a discharge valve located in the gas discharge path and capable of adjusting a valve opening;

wherein the reciprocating compressor further comprises:

an auxiliary pressure sensor located downstream of the discharge valve in the gas discharge path, and

wherein the rotational speed control unit is configured to increase rotational speed of the motor in compensation for the amount of hydrogen gas corresponding to a discharge flow rate of hydrogen gas derived based on a pressure detection value obtained by the pressure sensor, a pressure detection value obtained by the auxiliary pressure sensor, and flow rate characteristics of the discharge valve.

4. The reciprocating compressor according to claim **2**,

wherein the discharger includes a gas discharge path connected to the suction-side flow path, an on-off valve located in the gas discharge path, and an orifice located downstream of the on-off valve in the gas discharge path;

wherein the reciprocating compressor further comprises:

an auxiliary pressure sensor located downstream of the orifice in the gas discharge path, and

wherein the rotational speed control unit is configured to increase the rotational speed of the motor in compensation for a discharge flow rate of hydrogen gas, the discharge flow rate being derived based on a pressure detection value obtained by the pressure sensor, a pressure detection value obtained by the auxiliary pressure sensor, and a throttle ratio of the gas discharge path, the throttle ratio being obtained by the orifice.

5. The reciprocating compressor according to claim **2**,

wherein a demander to which the hydrogen gas is discharged from the reciprocating compressor is an accumulator including a tank;

wherein the reciprocating compressor further comprises:

a demand side pressure sensor located in the accumulator or in a demander connection flow path connecting the reciprocating compressor and the accumulator to each other;

a demand side temperature sensor located in the accumulator or in the demander connection flow path; and

an estimation unit for estimating a density variation per unit time of hydrogen gas accumulated in the accumulator based on a pressure detection value obtained by the demand side pressure sensor, a temperature detection value obtained by the demand side temperature sensor, and a tank capacity of the accumulator, and wherein the rotational speed control unit is configured to increase rotational speed of the motor in compensation for the amount or a flow rate of hydrogen gas corresponding to a difference between the density variation per unit time of hydrogen gas accumulated in the accumulator on an assumption that there is no leakage of hydrogen gas from the high-pressure stage compression unit to the low-pressure stage compression unit and the density variation per unit time of hydrogen gas estimated by the estimation unit.

6. A reciprocating compressor for compressing hydrogen gas, the reciprocating compressor comprising:

a low-pressure stage compression unit that includes a low-pressure stage piston, a low-pressure stage cylinder that houses the low-pressure stage piston, and a piston ring group attached to the low-pressure stage piston to compress hydrogen gas;

an intermediate-stage compression unit for compressing hydrogen gas discharged from the low-pressure stage compression unit;

a high-pressure stage compression unit that includes a high-pressure stage piston connected to the low-pressure stage piston, a high-pressure stage cylinder that houses the high-pressure stage piston and is connected to the low-pressure stage cylinder, and a piston ring group attached to the high-pressure stage piston to compress hydrogen gas discharged from the intermediate-stage compression unit;

a drive unit for driving the low-pressure stage compression unit, the intermediate-stage compression unit, and the high-pressure stage compression unit;

a discharger that allows hydrogen gas to be discharged from a suction-side flow path that allows hydrogen gas to flow to be suctioned into the low-pressure stage compression unit;

a pressure sensor for detecting a pressure of hydrogen gas suctioned into the low-pressure stage compression unit, a pressure of hydrogen gas discharged from the low-pressure stage compression unit and suctioned into the intermediate-stage compression unit, or a pressure of hydrogen gas discharged from the intermediate-stage compression unit and suctioned into the high-pressure stage compression unit; and

a discharge control unit for controlling the discharger to discharge the hydrogen gas from the suction-side flow path when the pressure of the hydrogen gas detected by the pressure sensor is higher than a set value preset;

wherein the set value is a predetermined normal pressure value of hydrogen gas suctioned into the low-pressure stage compression unit when a differential pressure between a pressure in the suction-side flow path and a pressure in a compression chamber of the low-pressure stage compression unit reaches a predetermined pressure value to open a suction valve of the low-pressure stage compression unit, or the set value is a predetermined normal pressure value of hydrogen gas discharged from the low-pressure stage compression unit, or the set value is a predetermined normal pressure value of hydrogen gas suctioned into the high-pressure stage compression unit.

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