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Egami et al.

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(54) **ROTARY MACHINE SYSTEM**

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See application file for complete search history.

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(57) **ABSTRACT**

A rotary machine system includes: a rotary machine including a gas seal portion; a gas seal device connected to the rotary machine and that supplies a seal gas to the gas seal portion; a pressure sensor that detects a pressure of the seal gas; a vent portion that discharges the seal gas discharged from the gas seal portion; and a vent pressure sensor that detects a pressure in the vent portion. The rotary machine includes: a casing through which a working fluid flows; a rotatable rotary shaft that passes; and the gas seal portion provided between the casing and the rotary shaft and that

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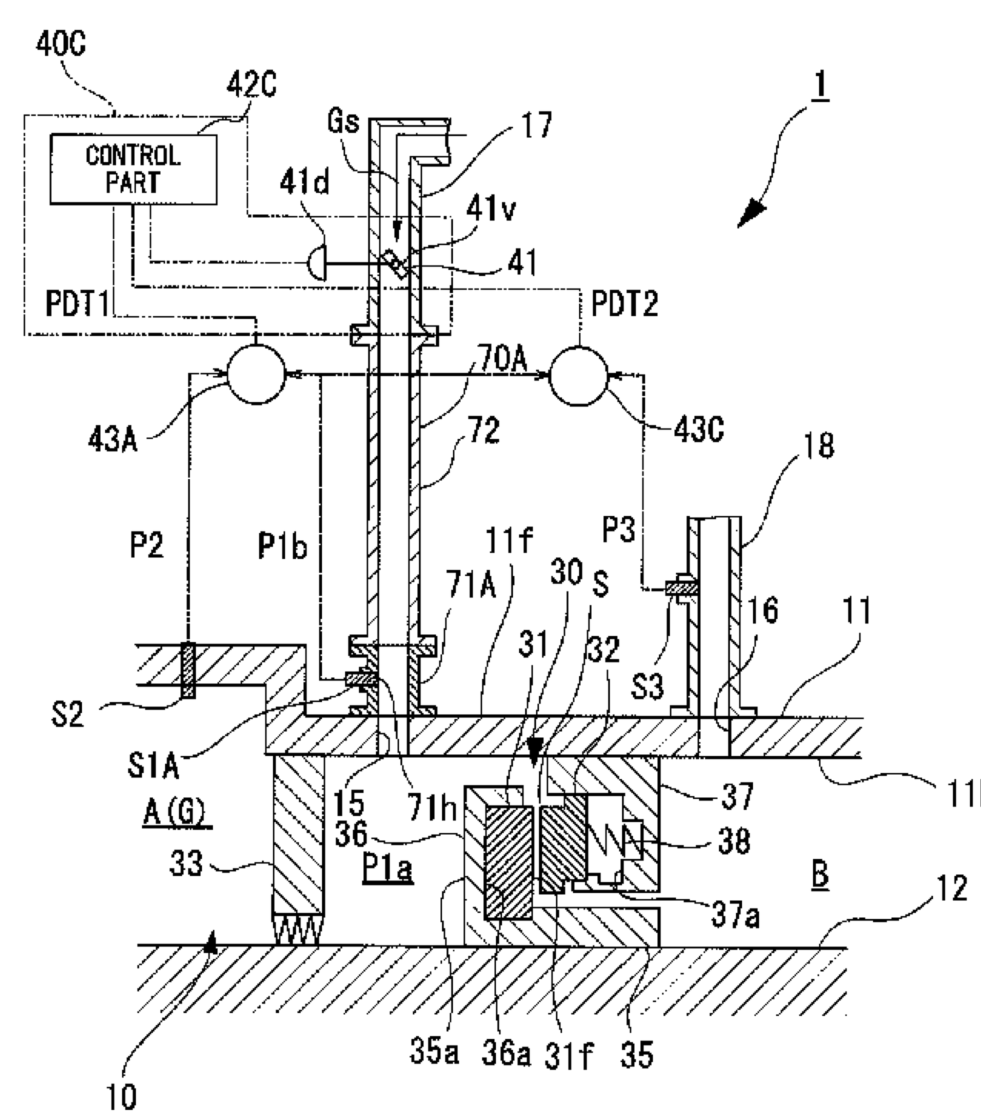

seals the working fluid by the seal gas having a pressure higher than a pressure of the working fluid in the casing. The gas seal device includes: a pressure regulating valve; and a control part that controls the pressure regulating valve.

6 Claims, 4 Drawing Sheets

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F04D 27/00 (2006.01)
F04D 29/12 (2006.01)
F16J 15/40 (2006.01)

(52) **U.S. Cl.**
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FIG. 1

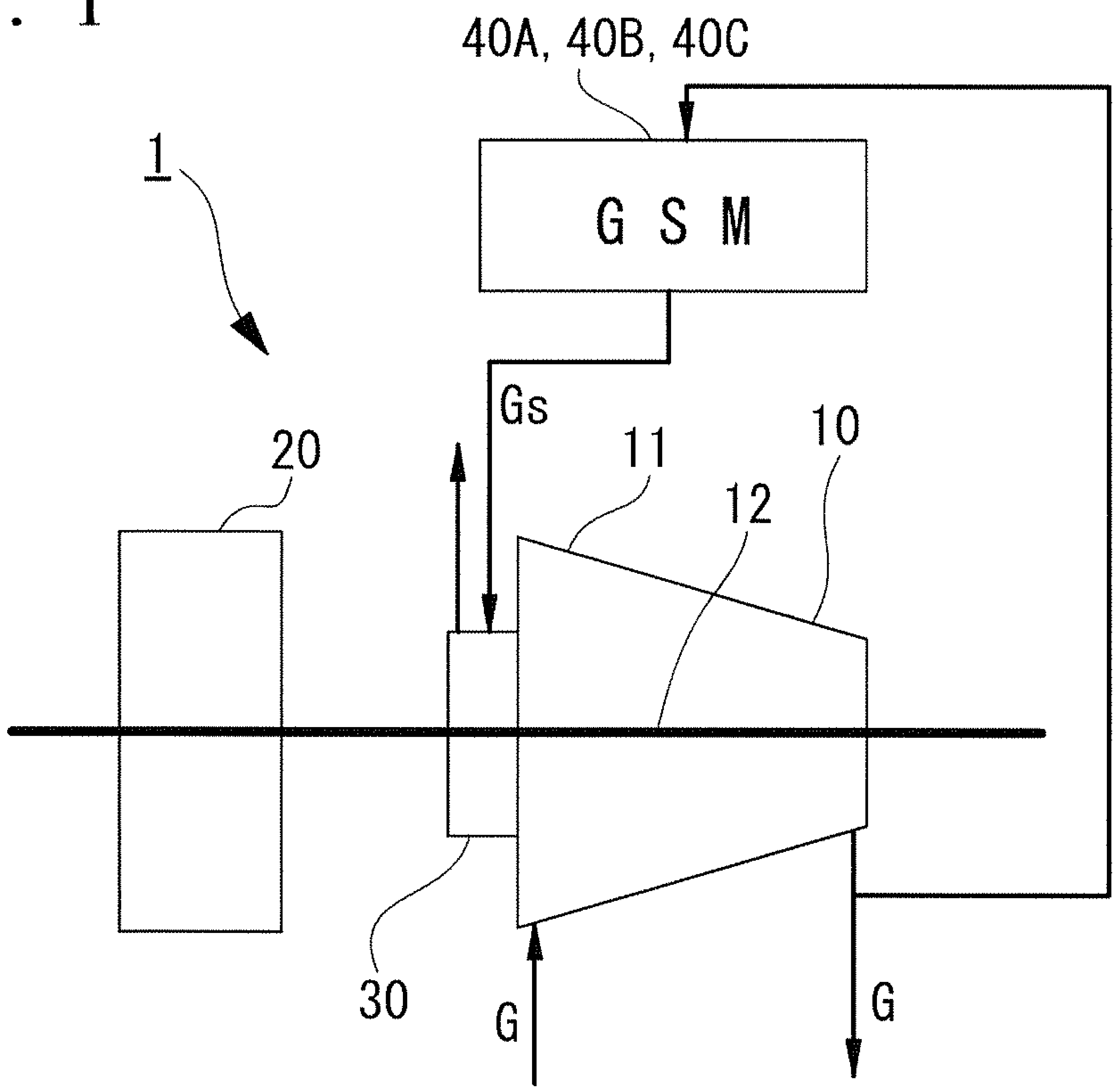
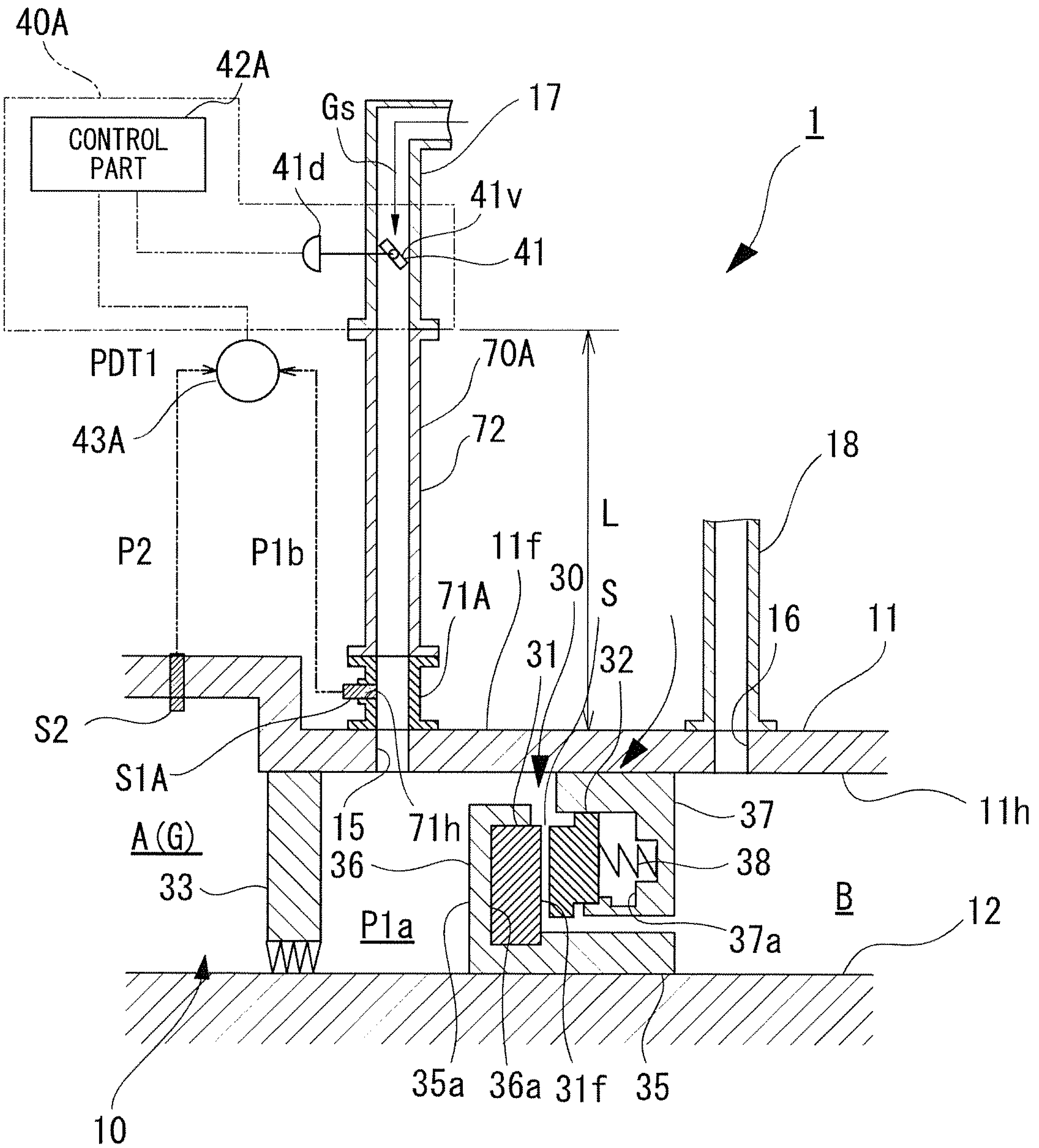


FIG. 2



40A
42A
CONTROL PART
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41v
41
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43A
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11f
30
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71A
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31
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S2
S1A
15
71h
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38
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FIG. 3

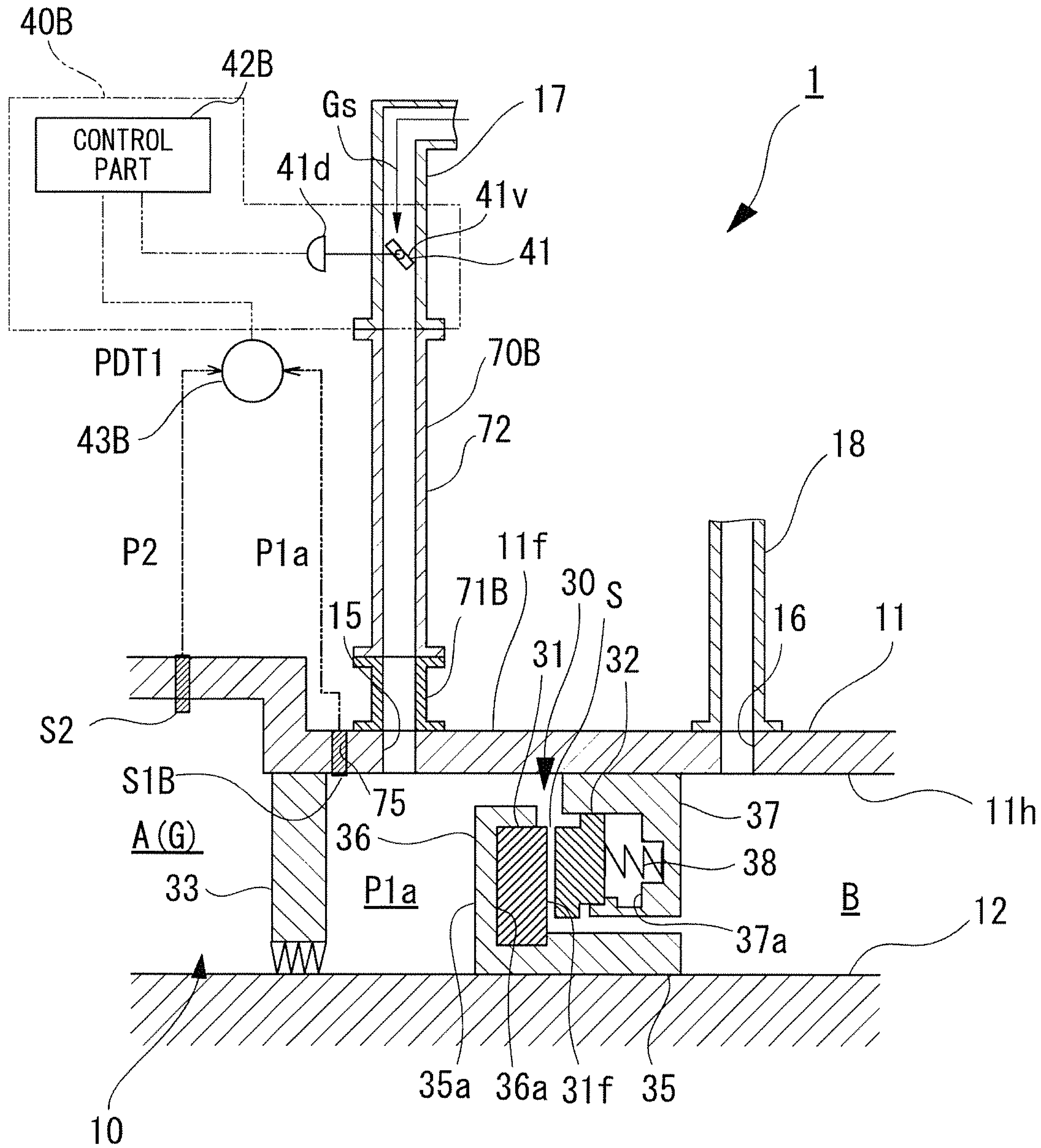
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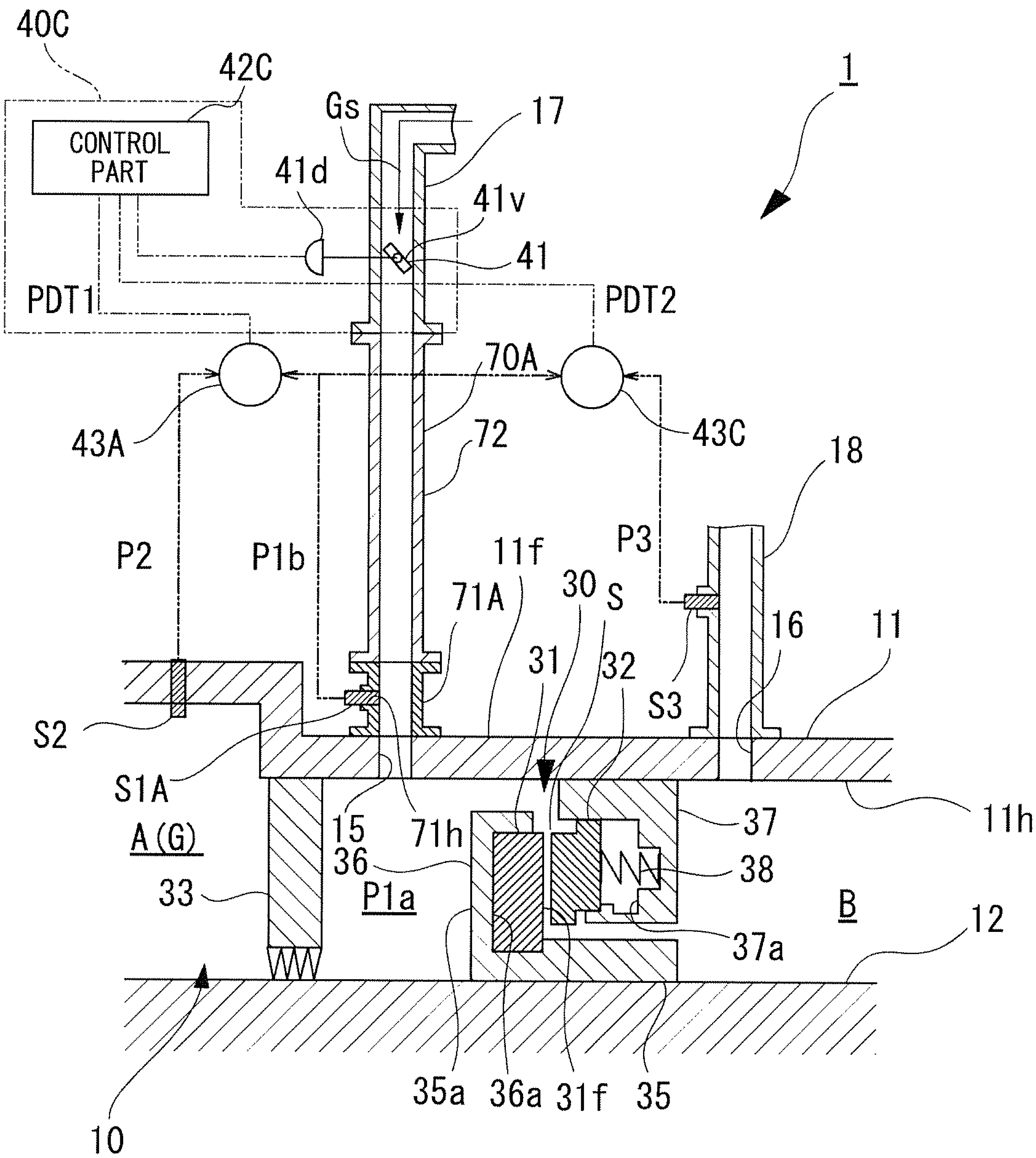
FIG. 4



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ROTARY MACHINE SYSTEM

TECHNICAL FIELD

The present invention relates to a rotary machine system. Priority is claimed on Japanese Patent Application No. 2015-11241, filed Jan. 23, 2015, the content of which is incorporated herein by reference.

BACKGROUND ART

In a rotary machine such as a centrifugal compressor, there is a rotary shaft of which an end protrudes to an outside of a casing to input or output a rotational force of a rotary shaft rotatably provided in the casing. In this case, it is necessary to prevent leakage of a working fluid in the casing to the outside of the casing and infiltration of foreign substances or the like into the casing from the outside thereof through a gap between the rotary shaft and a shaft insertion hole formed in the casing for the rotary shaft to pass through the casing. Therefore, a gas seal portion is provided between the rotary shaft and the casing.

The gas seal portion includes a rotary ring and a stationary ring. The rotary ring is provided integrally with the rotary shaft on an outer circumferential portion of the rotary shaft. The stationary ring is fixed to the casing and is provided to face the rotary ring in an axial direction of the rotary shaft. The stationary ring is pressed toward the rotary ring by a coil spring or the like. Therefore, in a state in which the rotary machine is stopped, the stationary ring and the rotary ring abut on each other. In addition, a spiral groove is formed on a surface of the rotary ring facing the stationary ring. When the rotary machine is operated and the rotary shaft rotates, a seal gas is introduced between the rotary ring and the stationary ring by the spiral groove. Due to a pressure of the gas, the stationary ring is pressed in the axial direction of the rotary shaft against a biasing force of the coil spring. As a result, a minute gap is formed between the rotary ring and the stationary ring. The seal gas is caused to flow from an inside of the rotary machine toward an outside thereof through the gap, and thus sealing between the rotary shaft and the casing is achieved. In this case, the pressure of the seal gas is higher than the pressure inside and outside the rotary machine.

In such a gas seal portion, the seal gas flowing from the inside of the rotary machine to the outside thereof via the gap between the rotary ring and the stationary ring is discharged to an outside through a vent (chimney) connected to the casing.

A gas or the like discharged from equipment other than the rotary machine may be delivered into the vent and may be discharged to the outside together with the seal gas. Further, depending on a type of the gas, the gas may be burned near an outlet of the vent. When the gas or the like is delivered into the vent from the equipment other than the rotary machine or the gas is burned, a pressure in the vent is increased. When the pressure in the vent becomes higher than that of the inside of the machine, the seal gas flows backward in the gap between the rotary ring and the stationary ring. Then, the rotary ring and the stationary ring may collide with each other, and thus the gas seal portion may be damaged.

Patent Document 1 discloses a constitution which includes a flow rate switch for detecting a flow rate of a gas leaking from the gas seal portion to the vent. Accordingly, when a working gas leaks due to breakage of the gas seal portion and the flow rate of the gas at the vent is increased, an abnormality is detected.

The constitution disclosed in Patent Document 1 is for detecting the breakage of the gas seal portion due to a backflow or the like of the seal gas from the vent to the gas seal portion as the abnormality. That is, it is not for preventing the breakage of the gas seal portion by suppressing a backflow of the seal gas.

Therefore, the pressure of the seal gas is usually controlled so that the pressure of the seal gas in the gas seal portion is reliably maintained at a higher level than the pressure of the vent inside and outside the rotary machine.

CITATION LIST

Patent Literature

[Patent Document 1]

Japanese Patent No. 3979091

However, in a pipe constituting a supply line for feeding the seal gas to the gas seal portion, pressure loss occurs. Even if the seal gas is delivered from a supply source side of the seal gas with a pressure higher than the pressure inside the vent and the pressure inside the rotary machine, the pressure of the seal gas is lowered by the pressure loss in the supply line when the seal gas reaches the gas seal portion.

Also, the pressure of the gas in the vent which is discharged through the vent is varied by combustion of the gas delivered from the equipment other than the rotary machine or the gas in the vent. Even if the variation is taken into consideration, it is necessary to keep the pressure of the seal gas in the gas seal portion high.

Therefore, the pipe is formed to be as thick as possible so that the pressure loss is suppressed and the pressure of the seal gas is kept high. However, the cost is increased as the pipe becomes thicker.

Also, a magnitude of the pressure loss generated can vary variously depending on conditions such as a pipe diameter, a piping layout, a pressure of a working fluid in a compressor and so on. Therefore, actually, whenever the rotary machine is installed, it is necessary to set an optimum pipe diameter according to various conditions at an installation position thereof, which increases effort and cost.

SUMMARY OF INVENTION

The present invention provides a rotary machine system which is capable of limiting the piping cost, the design cost and the design effort for supplying a seal gas while suppressing backflow of the seal gas.

A rotary machine system of a first aspect of the present invention may include a rotary machine having a gas seal portion, a gas seal device connected to the rotary machine and configured to supply a seal gas to the gas seal portion, and a pressure sensor configured to detect the pressure of the seal gas, wherein the rotary machine includes a casing through which a working fluid flows, a rotary shaft configured to pass through an inside and an outside of the casing and provided to be rotatable, and the gas seal portion provided between the casing and the rotary shaft and configured to seal the working fluid by the seal gas having a pressure higher than that of the working fluid in the casing, the gas seal device includes a pressure regulating valve configured to adjust the pressure of the seal gas supplied to the gas seal portion, and a control part (controller) configured to control the pressure regulating valve, the pressure sensor is provided closer to the gas seal portion side than the gas seal device, and the control part controls the pressure regulating valve according to the pressure of the seal gas detected by the pressure sensor.

According to one or more embodiments as described above, since the pressure sensor is provided closer to the gas seal portion side of the rotary machine than the gas seal device, the pressure can be detected while pressure loss occurring before the seal gas reaches the gas seal portion is suppressed compared with the case in which the pressure sensor is provided at a supply source side of the seal gas in the gas seal device. Therefore, in order to limit the pressure loss, it is not necessary to increase a pipe diameter for supplying the seal gas, and thus the pipe diameter can be suppressed, and the pressure sensor can detect the pressure with a small difference from the pressure of the seal gas in the gas seal portion.

Further, since it is not necessary to consider the pressure loss occurring before the seal gas reaches the gas seal portion, it is not necessary to consider conditions such as a layout of the pipe for supplying the seal gas or the pressure of the working fluid in the rotary machine either at the time of designing. Additionally, even when the gas seal device has a plurality of pipes, pipe diameters thereof can be unified. Further, it is not necessary to design while taking the pressure loss at connection portions of the plurality of pipes into consideration.

Further, in a rotary machine system of a second aspect of the present invention, the pressure sensor of the first aspect may be provided in a connection pipe portion which connects the gas seal portion and the gas seal device.

According to one or more embodiments as described above, the pressure sensor can be installed at a position of the gas seal device close to the gas seal portion by providing the pressure sensor at the connection pipe portion which connects the gas seal portion and the gas seal device. Furthermore, when the pressure sensor is provided in the pipe connection portion, it is not necessary to provide the opening or the like for installing the pressure sensor in the casing of the rotary machine. Therefore, the constitution of the present invention can be applied to an existing rotary machine.

Further, in a rotary machine system of a third aspect of the present invention, the pressure sensor of the second aspect may be provided in the connection pipe portion within a range of ⅓ of an overall length of the connection pipe portion from the gas seal portion side.

According to one or more embodiments as described above, the difference between the pressure of the seal gas detect by the pressure sensor and the pressure of the seal gas in the gas seal portion can be reduced to be small by providing the pressure sensor as close as possible to the gas seal portion.

Further, in a rotary machine system of a fourth aspect of the present invention, the connection pipe portion of the second or third aspect may include a connection hole portion provided at a position of the casing which faces the gas seal portion, and one or more connecting pipes configured to connect the connection hole portion and the gas seal device, and the pressure sensor may be provided in the connection hole portion.

According to one or more embodiments as described above, the pressure sensor can be provided close to the inside of the gas seal portion by providing the pressure sensor at the connection hole portion provided in the casing for connecting the connecting pipes. Therefore, the difference between the pressure of the seal gas detected by the pressure sensor and the pressure of the seal gas in the gas seal portion can be reduced to be small.

Further, in a rotary machine system of a fifth aspect of the present invention, the pressure sensor of the first aspect may be provided in an opening of the casing which faces the gas seal portion.

With such a constitution according to one or more embodiments, the pressure sensor is installed at a position which directly faces the gas seal portion. Therefore, the pressure sensor can directly detect the pressure of the seal gas in the gas seal portion without being affected by the pressure loss generated in the pipe through which the seal gas is delivered into the gas seal portion.

Further, a rotary machine system of a sixth aspect of the present invention may further include an internal pressure sensor configured to detect the internal pressure of the machine closer to an inside of the rotary machine than the gas seal portion of one of the first to fifth aspects, and the control part may control the pressure regulating valve so that the pressure of the seal gas detect by the pressure sensor is higher than the internal pressure of the machine which is detect by internal pressure sensor.

With such a constitution according to one or more embodiments, the pressure of the seal gas in the gas seal portion can be maintained higher than the internal pressure of the machine, and the leakage of the seal gas to the inside of the machine can be suppressed.

Further, a rotary machine system of a seventh aspect of the present invention may further include a vent portion configured to discharge the seal gas discharged from the gas seal portion of any one of the first to sixth aspects to the outside, and a vent pressure sensor configured to detect the pressure in the vent portion, and the control part may control the pressure regulating valve so that the pressure of the seal gas detected by the pressure sensor is higher than the pressure in the vent portion detected by the vent pressure sensor.

With such a constitution according to one or more embodiments, the pressure of the seal gas in the gas seal portion can be maintained higher than the pressure in the vent, and the leakage of the seal gas to the vent can be reliably suppressed regardless of a variation of the pressure in the vent.

According to one or more embodiments of the above-described rotary machine system, the pressure of the seal gas in the gas seal portion can be detected with high accuracy by suppressing a difference between the pressure of the seal gas detected by the pressure sensor and the pressure of the seal gas in the gas seal portion. As a result, a pipe diameter through which the seal gas is supplied to the gas seal portion can be minimized while backflow of the seal gas is suppressed, and thus the piping cost, the design cost and the design effort of the pipe for supplying the seal gas can be limited.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a view showing a schematic constitution of a rotary machine system with a compressor as an example of a rotary machine in an embodiment.

FIG. **2** is a view showing a constitution of a gas seal portion provided at the compressor in a first embodiment.

FIG. **3** is a view showing a constitution of a gas seal portion provided at the compressor in a second embodiment.

FIG. **4** is a view showing a constitution of a gas seal portion provided at the compressor in a third embodiment.

DESCRIPTION OF EMBODIMENTS

Hereinafter, embodiments for implementing a rotary machine system according to the present invention will be described with reference to the accompanying drawings. However, the present invention is not limited to only these embodiments.

(First Embodiment)

FIG. **1** is a view showing a schematic constitution of a rotary machine system with a compressor as an example of a rotary machine in an embodiment.

As shown in FIG. **1**, a rotary machine system **1** includes a compressor (rotary machine) **10**, a turbine **20** as a drive source for driving the compressor **10**, and a gas seal module (GSM: gas seal device) **40**A for supplying a seal gas Gs to the compressor **10**.

The compressor **10** is, for example, a centrifugal compressor, and includes a rotary shaft **12** and a compression part (not shown) such as an impeller, which rotates integrally with the rotary shaft **12** and compresses a gas G serving as a working fluid, in a casing **11**. A gas seal portion **30** is provided in a portion on a suction side of the compressor **10** in which the rotary shaft **12** passes through an end of the casing **11** and protrudes outward.

FIG. **2** is a view showing a constitution of the gas seal portion provided at the compressor **10** in a first embodiment.

As shown in FIG. **2**, the gas seal portion **30** includes a rotary ring **31**, a stationary ring **32** and a labyrinth seal **33** on an inside of the machine.

The rotary ring **31** is provided integrally with the rotary shaft **12** on an outer circumferential portion of the rotary shaft **12**. A cylindrical shaft sleeve **35** is fixed to the outer circumferential portion of the rotary shaft **12**. A holder portion **36** extending toward an outer circumferential side is provided at an end **35***a* of the shaft sleeve **35** on the inside A (left side in FIG. **2**) of the machine. In the holder portion **36**, a holding recess **36***a* for holding the rotary ring **31** is provided on an outside B (right side in FIG. **2**) of the machine.

The rotary ring **31** is formed in an annular shape and fitted and held in the holding recess **36***a*. In the rotary ring **31**, a spiral groove (not shown) is provided on a surface **31***f* facing the stationary ring **32**.

The stationary ring **32** is provided in the casing **11**. A shaft insertion hole **11***h* through which an end of the rotary shaft **12** passes through an inside and an outside of the casing **11** is provided in the casing **11**.

An annular retainer **37** is provided on an inner circumferential surface of the shaft insertion hole **11***h*. A holding recess **37***a* for holding the stationary ring **32** is provided on the inside A of the machine in the retainer **37**. In the holding recess **37***a*, the stationary ring **32** is provided to be slide-able in an axial direction of the rotary shaft **12**. A coil spring **38** for biasing the stationary ring **32** toward the inside A of the machine is provided in the holding recess **37***a* between the stationary ring **32** and the retainer **37**.

The rotary ring **31** and the stationary ring **32** are provided to face each other in the axial direction of the rotary shaft **12**. The stationary ring **32** is pressed toward the rotary ring **31** by the coil spring **38**.

A seal gas supply port **15** which opens on the inner circumferential surface of the shaft insertion hole **11***h* is provided in the casing **11**. The seal gas supply port **15** is provided between the rotary ring **31** and the labyrinth seal **33** on the inside of the machine in the axial direction of the rotary shaft **12**.

A seal gas supply path **17** is connected to the seal gas supply port **15**. The seal gas supply path **17** supplies a part of the gas G compressed by the compressor **10** as the seal gas Gs from a discharge side of the compressor **10** to the seal gas supply port **15**.

A vent discharge port **16** which opens on the inner circumferential surface of the shaft insertion hole **11***h* is provided in the casing **11**. The vent discharge port **16** is provided on the outside B of the machine in the casing **11** from the rotary ring **31** in the axial direction of the rotary shaft **12**.

A vent (chimney; vent portion) **18** is connected to the vent discharge port **16**. The vent **18** discharges the seal gas Gs flowing out from the gas seal portion **30** to an outside via the vent **18**. In addition to the compressor **10**, other devices are connected to the vent **18**.

In such a gas seal portion **30**, the stationary ring **32** and the rotary ring **31** abut on each other in a state in which the compressor **10** is stopped.

In a state in which the compressor **10** is operated, the seal gas Gs is introduced into a space between the shaft insertion hole **11***h* of the casing **11** and the rotary shaft **12** through the seal gas supply path **17** and the seal gas supply port **15**. When the compressor **10** is operated and the rotary shaft **12** rotates, the seal gas Gs is introduced between the rotary ring **31** and the stationary ring **32** from an outer circumference side of the rotary ring **31** by the spiral groove provided on the surface **31***f* of the rotary ring **31**. When the stationary ring **32** is pressed toward the outside B of the machine in the axial direction of the rotary shaft **12** against a biasing force of the coil spring **38** by a pressure of the seal gas Gs, a minute seal gap S is formed between the rotary ring **31** and the stationary ring **32**. The seal gas Gs passes through the seal gap S and flows toward the outside B of the machine. In this manner, the seal gas Gs is caused to flow from the inside A of the machine toward the outside B thereof, and thus sealing between the rotary shaft **12** and the casing **11** is achieved.

Further, the seal gas Gs flows from the rotary ring **31** and stationary ring **32** side to the inside A of the machine through a space between the labyrinth seal **33** on the inside of the machine and the rotary shaft **12**. As a result, foreign substances or the like are prevented from being introduced into the seal gap S between the rotary ring **31** and the stationary ring **32** from the inside A of the machine.

To prevent the seal gas Gs delivered into the casing **11** through the seal gas supply path **17** from flowing backward in the gas seal portion **30**, the gas seal module **40**A adjusts the pressure of the seal gas Gs to be higher than that of the inside A of the machine.

The gas seal module **40**A includes a pressure regulating valve **41** and a control part **42**A which controls an opening degree of the pressure regulating valve **41**.

The pressure regulating valve **41** is provided in the seal gas supply path **17**. The pressure regulating valve **41** includes a valve body **41***v* and a valve driving part **41***d*. The valve body **41***v* is provided in the seal gas supply path **17** and is driven by the valve driving part **41***d* to increase or decrease a flow path area of the seal gas supply path **17**. The pressure regulating valve **41** adjusts a supply pressure P1*b* of the seal gas Gs supplied into the casing **11** through the seal gas supply path **17** by varying the opening degree of the valve body **41***v* by the valve driving part **41***d*. An operation of the valve driving part **41***d* is controlled by the control part **42**A.

The control part **42**A controls the valve driving part **41***d* of the pressure regulating valve **41** on the basis of the supply pressure P**1***b* of the seal gas Gs and an internal pressure P**2** of the machine.

The supply pressure P**1***b* of the seal gas Gs is detected by a seal gas pressure sensor S**1**A provided closer to the compressor **10** side than the pressure regulating valve **41** of the gas seal module **40**A. The seal gas pressure sensor S**1**A may be provided at a position as close as possible to the gas seal portion **30** so that the supply pressure P**1***b* of the seal gas Gs can be detected while an influence of pressure loss in the seal gas supply path **17** is minimized as much as possible. Specifically, the seal gas pressure sensor S**1**A is provided closer to the gas seal portion **30** side than the pressure regulating valve **41** in the seal gas supply path **17**.

Here, in the seal gas supply path **17**, a port connection hole (connection hole portion) **71**A is provided on an outer circumferential surface of the casing **11** and communicates with the seal gas supply port **15**, and one or more connecting pipes **72** (the example of FIG. **2** shows one, and they are connected to each other if there are a plurality) are provided at a connection pipe portion **70**A which connects the gas seal module **40**A and the casing **11** of the compressor **10**.

The connecting pipe **72** has a straight tubular shape in FIG. **2** but is actually appropriately bent to avoid interference with various devices because the various devices are arranged around the compressor **10**. Also, a length of the connecting pipe **72** is detected according to an installation interval between the compressor **10** and the gas seal module **40** A and may have a range of, for example, 20 to 30 m.

In the embodiment, the seal gas pressure sensor S**1**A may be provided at a position of L/3 or less from an outer surface **11***f* of the casing **11** with respect to a pipe length L of the connection pipe portion **70**A from the pressure regulating valve **41** of the gas seal module **40**A to the outer surface **11***f* of the casing **11** in which the port connection hole **71**A is provided. That is, the seal gas pressure sensor S**1**A is provided in a through-hole **71***h* provided in the port connection hole **71**A which is closest to the outer circumferential surface of the casing **11** in the connection pipe portion **70**A.

The internal pressure P**2** of the machine is detected by an internal pressure sensor S**2** which is provided closer to the inside A of the machine in the casing **11** than the gas seal portion **30** and the labyrinth seal **33** on the inside of the machine.

The seal gas pressure sensor S**1**A and the internal pressure sensor S**2** are connected to a differential pressure gauge **43**A. The differential pressure gauge **43**A detects a differential pressure PDT**1**(=P**1***b*−P**2**) in the machine between the supply pressure P**1***b* of the seal gas Gs supplied into the casing **11** through the connection pipe portion **70**A with respect to the gas seal portion **30** and the internal pressure P**2** of the machine of the casing **11**. A signal indicating the detected differential pressure PDT**1** in the machine is transmitted to the control part **42**A.

During an operation of the compressor **10**, the control part **42**A obtains the differential pressure PDT**1** in the machine which is detected by the differential pressure gauge **43**A at predetermined time intervals.

When the detected differential pressure PDT**1** in the machine is equal to or more than a predetermined lower limit threshold value, or less than a predetermined upper limit threshold value, the supply pressure P**1***b* of the seal gas Gs is sufficiently higher than the internal pressure P**2** of the machine, and thus the operation is continued as it is without changing the opening degree of the pressure regulating valve **41**.

Further, when the detected differential pressure PDT**1** in the machine is less than the predetermined lower limit threshold value, the supply pressure P**1***b* of the seal gas Gs is not sufficiently higher than the internal pressure P**2** of the machine, and thus the opening degree of the pressure regulating valve **41** is increased. Then, the supply pressure P**1***b* of the seal gas Gs supplied into the casing **11** through the connection pipe portion **70**A is increased. As a result, the differential pressure PDT**1** in the machine between the supply pressure P**1***b* of the seal gas Gs and the internal pressure P**2** of the machine is increased.

Further, here, when the differential pressure PDT**1** in the machine is less than the predetermined lower limit threshold value, the opening degree of the pressure regulating valve **41** is increased, but an amount of change in the opening degree may be, for example, a preset amount of change in the opening degree according to a magnitude of the differential pressure PDT**1** in the machine, or the opening degree of the pressure regulating valve **41** may be increased by a predetermined amount in every operation process.

Further, when the detected differential pressure PDT**1** in the machine exceeds the predetermined upper limit threshold value, the supply pressure P**1***b* of the seal gas Gs is excessively higher than the internal pressure P**2** of the machine, and a flow rate of the seal gas flowing into the inside A of the machine is increased, and thus the flow rate of the gas G which is compressed by the compressor **10** is reduced. Therefore, the control part **42**A reduces the opening degree of the pressure regulating valve **41**.

As described above, by adjusting the opening degree of the pressure regulating valve **41** by the control part **42**A on the basis of the supply pressure P**1***b* of the seal gas Gs which is detected by the seal gas pressure sensor S**1**A and the internal pressure P**2** of the machine which is detected by the internal pressure sensor S**2**, a pressure P**1***a* of the seal gas Gs in the gas seal portion **30** inside the casing **11** can always be kept higher than the internal pressure P**2** of the machine.

Accordingly, a backflow of the seal gas Gs from the gas seal portion **30** toward the inside A of the machine of the compressor **10** can be prevented.

According to the rotary machine system **1** as described above, the pressure sensor S**1**A is provided closer to the connection pipe portion **70**A on the gas seal portion **30** side than the gas seal module **40**A. Further, the control part **42**A controls the pressure regulating valve **41** according to the supply pressure P**1***b* of the seal gas Gs detected by the pressure sensor S**1**A.

As described above, since the pressure sensor S**1**A is provided closer to the gas seal portion **30** side than the gas seal module **40**A, the pressure can be detected while the pressure loss occurring before the seal gas Gs reaches the gas seal portion **30** is suppressed as compared with the case in which the pressure sensor S**1**A is provided on a supply source side of the seal gas Gs in the gas seal module **40**A. Accordingly, it is not necessary to increase a pipe diameter of the seal gas supply path **17** for supplying the seal gas Gs in order to suppress the pressure loss, and thus it is possible to minimize the pipe diameter.

Further, since it is not necessary to consider the pressure loss occurring before the seal gas Gs reaches the gas seal portion **30**, it is not necessary to consider conditions such as a layout of the seal gas supply path **17** for supplying the seal gas Gs and the pressure of the gas G in the compressor **10** either at the time of designing. Additionally, even when the connection pipe portion **70**A has a plurality of pipes, pipe diameters thereof can be unified. Further, it is not necessary to design in consideration of the pressure loss at connection portions among the plurality of pipes.

Therefore, the piping cost, the design cost and the design effort of the seal gas supply path **17** can be limited while backflow of the seal gas Gs is reliably suppressed.

Further, when the pressure sensor S**1**A is provided in the connection pipe portion **70**A, it is not necessary to provide an opening or the like for installing the pressure sensor S**1**A in the casing **11** of the compressor **10**. Also, in one or more embodiments, the constitution of the present invention can be applied to an existing compressor **10**.

Further, the pressure sensor S**1**A is provided in the connection pipe portion **70**A within a range of L/3 from the gas seal portion **30** side with respect to a total length L of the connection pipe portion **70**A. As described above, a difference between the supply pressure P**1***b* of the seal gas Gs detected by the pressure sensor S**1**A and the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** can be suppressed to be small by providing the pressure sensor S**1**A as close as possible to the gas seal portion **30**.

Further, the pressure sensor S**1**A can be provided close to an inside of the gas seal portion **30** by providing the pressure sensor S**1**A in the port connection hole **71**A provided in the casing **11**. Therefore, the difference between the supply pressure P**1***b* of the seal gas Gs detected by the pressure sensor S**1**A and the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** can be suppressed to be small.

Further, the rotary machine system **1** further includes the internal pressure sensor S**2** for detecting the internal pressure of the machine closer to the inside of the compressor **10** than the gas seal portion **30**, and the control part **42**A controls the pressure regulating valve **41** so that the supply pressure P**1***b* of the seal gas Gs detected by the pressure sensor S**1**A is higher than the internal pressure P**2** of the machine detected by the internal pressure sensor S**2**. By constituting the rotary machine system **1** as described above, the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** can be maintained higher than the internal pressure P**2** of the machine, and leakage of the gas G from the compressor **10** can be suppressed.

(Second Embodiment)

Next, a second embodiment of the rotary machine system according to the present invention will be described. In the second embodiment to be described, the same reference numerals are provided for the elements common to those of the first embodiment, and a description thereof will be omitted.

As shown in FIG. **1**, the rotary machine system **1** of the embodiment includes a compressor **10**, a turbine **20** and a gas seal module (gas seal device) **40**B.

The compressor **10** includes a rotary shaft **12** and a compression part (not shown) in a casing **11**. In a suction side of the compressor **10**, a gas seal portion **30** is provided in a portion in which the rotary shaft **12** passes through an end of the casing **11** and protrudes outward.

FIG. **3** is a view showing a constitution of the gas seal portion provided at the compressor **10** in the second embodiment.

As shown in FIG. **3**, the gas seal portion **30** includes a rotary ring **31**, a stationary ring **32** and a labyrinth seal **33** on an inside of the machine.

A seal gas supply port **15** which opens on an inner circumferential surface of a shaft insertion hole **11***h* is provided in the casing **11**. A seal gas supply path **17** is connected to the seal gas supply port **15**. In the seal gas supply path **17**, a cylindrical port connection hole **71**B and a connecting pipe **72** are provided in a connection pipe portion **70**B which connects the gas seal module **40**B and the casing **11** of the compressor **10**.

Further, a vent discharge port **16** which opens on the inner circumferential surface of the shaft insertion hole **11***h* is provided in the casing **11**. A vent **18** is connected to the vent discharge port **16**.

To prevent the seal gas Gs delivered into the casing **11** through the seal gas supply path **17** from flowing backward in the gas seal portion **30**, the gas seal module **40**B adjusts a pressure thereof to be higher than that in an inside A of the machine.

The gas seal module **40**B includes a pressure regulating valve **41** which is provided in the seal gas supply path **17** and a control part **42**B which controls an opening degree of the pressure regulating valve **41**.

The control part **42**B controls a valve driving part **41***d* of the pressure regulating valve **41** on the basis of a pressure P**1***a* of the seal gas Gs in the gas seal portion **30** and an internal pressure P**2** of the machine.

The pressure P**1***a* of the seal gas Gs is detected by a seal gas pressure sensor S**1**B which is provided in the seal gas supply path **17** to be closer to the compressor **10** side than the pressure regulating valve **41** of the gas seal module **40**B. In the embodiment, the seal gas pressure sensor S**1**B is provided in an opening **75** which is provided at a position facing the gas seal portion **30** in the casing **11**.

The internal pressure P**2** of the machine is detected by an internal pressure sensor S**2** which is provided closer to the inside A of the machine in the casing **11** than the gas seal portion **30** and the labyrinth seal **33** on the inside of the machine.

The seal gas pressure sensor S**1**B and the internal pressure sensor S**2** are connected to a differential pressure gauge **43**B. The differential pressure gauge **43**B detects a differential pressure PDT**1**(=P**1***a*−P**2**) in the machine between the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** inside the casing **11** and the internal pressure P**2** of the machine of the casing **11**. A signal indicating the detected differential pressure PDT**1** in the machine is transmitted to the control part **42**B.

During an operation of the compressor **10**, the control part **42**B obtains the differential pressure PDT**1** in the machine which is detected by the differential pressure gauge **43**B at predetermined time intervals.

When the detected differential pressure PDT**1** in the machine is equal to or more than a predetermined lower limit threshold value, or less than a predetermined upper limit threshold value and the pressure P**1***b* of the seal gas Gs in the gas seal portion **30** is sufficiently higher than the internal pressure P**2** of the machine, the operation is continued as it is without changing the opening degree of the pressure regulating valve **41**.

When the detected differential pressure PDT**1** in the machine is less than the predetermined lower limit threshold value, the pressure P**1***a* of the seal gas Gs is not sufficiently higher than the internal pressure P**2** of the machine, and thus the opening degree of the pressure regulating valve **41** is increased. Then, the flow rate of the seal gas Gs supplied into the casing **11** through the seal gas supply path **17** is increased, and thus the pressure P**1***a* is also increased. As a result, the differential pressure PDT**1** in the machine between the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** and the internal pressure P**2** of the machine is increased.

Here, when the differential pressure PDT**1** in the machine is less than the predetermined lower limit threshold value, the opening degree of the pressure regulating valve **41** is increased. The amount of change in the opening degree thereof may be, for example, a preset amount of change in the opening degree according to a magnitude of the differential pressure PDT**1** in the machine. Also, the opening degree of the pressure regulating valve **41** may be increased by a predetermined amount in every operation process.

Further, in the control part **42**B, when the detected differential pressure PDT**1** in the machine exceeds the predetermined upper limit threshold value, the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** is excessively higher than the internal pressure P**2** of the machine. Additionally, the flow rate of the seal gas flowing into the inside A of the machine is increased, and thus the flow rate of the gas G which is compressed by the compressor **10** is reduced. Therefore, the control part **42**B reduces the opening degree of the pressure regulating valve **41**.

As described above, by adjusting the opening degree of the pressure regulating valve **41** by the control part **42**B on the basis of the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** inside the casing **11** which is detected by the seal gas pressure sensor S**1**B and the internal pressure P**2** of the machine which is detected by the internal pressure sensor S**2**, the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** can always be kept higher than the internal pressure P**2** of the machine. Accordingly, a backflow of the seal gas Gs from the gas seal portion **30** toward the inside A of the machine of the compressor **10** can be prevented even when the pressure in the vent **18** is sharply increased.

According to the rotary machine system **1** of the embodiment as described above, as in the first embodiment, the pressure loss occurring before the seal gas Gs reaches the gas seal portion **30** can be suppressed by providing the pressure sensor S**1**B closer to the gas seal portion **30** side than the gas seal module **40**B. Therefore, a pipe diameter of the seal gas supply path **17** through which the seal gas Gs is supplied to the gas seal portion **30** can be minimized while the backflow of the seal gas Gs is suppressed, and thus a piping cost, the design cost and the design effort of the seal gas supply path **17** can be limited.

Particularly, in the embodiment, the pressure sensor S**1**B is provided in the opening **75** formed in the casing **11** to face the gas seal portion **30**.

With such a constitution, the pressure sensor S**1**B is provided at a position which directly faces the gas seal portion **30**. Therefore, the pressure sensor S**1**B can detect the pressure of the seal gas Gs in the gas seal portion **30** without being affected by the pressure loss generated in the pipe while the seal gas Gs is delivered into the gas seal portion **30**.

(Third Embodiment)

Next, a third embodiment of the rotary machine system according to the present invention will be described. In the third embodiment to be described, the same reference numerals are provided to the elements common to those of the first embodiment and the second embodiment, and the description thereof will be omitted.

As shown in FIG. **1**, the rotary machine system **1** of the embodiment includes a compressor **10**, a turbine **20** which is a drive source for driving the compressor **10** and a gas seal module (gas seal device) **40**C which supplies the seal gas Gs to the compressor **10**.

The compressor **10** includes a rotary shaft **12** and a compression part (not shown) in a casing **11**. In a suction side of the compressor **10**, a gas seal portion **30** is provided in a portion in which the rotary shaft **12** passes through an end of the casing **11** and protrudes outward.

FIG. **4** is a view showing a constitution of the gas seal portion provided at the compressor **10** in a third embodiment.

As shown in FIG. **4**, the gas seal portion **30** includes a rotary ring **31**, a stationary ring **32** and a labyrinth seal **33** on an inside of the machine.

A seal gas supply port **15** which opens on an inner circumferential surface of a shaft insertion hole **11***h* is provided in the casing **11**. A seal gas supply path **17** is connected to the seal gas supply port **15**.

A vent discharge port **16** which opens on the inner circumferential surface of the shaft insertion hole **11***h* is provided in the casing **11**. A vent **18** is connected to the vent discharge port **16**.

To prevent the seal gas Gs delivered into the casing **11** through the seal gas supply path **17** from flowing backward in the gas seal portion **30**, the gas seal module **40**C adjusts a pressure thereof to be higher than that in an inside A of the machine and the vent **18**.

The gas seal module **40**C includes a pressure regulating valve **41** and a control part **42**C which controls an opening degree of the pressure regulating valve **41**.

The pressure regulating valve **41** is provided in the seal gas supply path **17**. The pressure regulating valve **41** adjusts a supply pressure P**1***b* of the seal gas Gs supplied into the casing **11** through the seal gas supply path **17** by varying the opening degree of a valve body **41***v* by a valve driving part **41***d*.

The control part **42**C controls the valve driving part **41***d* of the pressure regulating valve **41** on the basis of the supply pressure P**1***b* of the seal gas Gs, an internal pressure P**2** of the machine and a vent pressure P**3** in the vent **18**.

The supply pressure P**1***b* of the seal gas Gs is detected by a seal gas pressure sensor S**1**A provided closer to the compressor **10** side than the pressure regulating valve **41** of the gas seal module **40**C. In the embodiment, the seal gas pressure sensor S**1**A is provided in a through-hole **71***h* formed in a port connection hole **71**A which is closest to an outer circumferential surface of the casing **11** in a connection pipe portion **70**A that connects the gas seal module **40**C and the casing **11** of the compressor **10**.

The internal pressure P**2** of the machine is detected by an internal pressure sensor S**2** provided closer to an inside A of the machine of the casing **11** than the gas seal portion **30** and the labyrinth seal **33** on the inside of the machine.

The vent pressure P**3** is determined by a vent pressure sensor S**3** provided in the vent **18**.

The seal gas pressure sensor S**1**A and the internal pressure sensor S**2** are connected to a differential pressure gauge **43**A. The differential pressure gauge **43**A detects a differential pressure PDT**1**(=P**1***b*−P**2**) in the machine between the internal pressure P**2** of the machine of the casing **11** and the supply pressure P**1***b* of the seal gas Gs supplied into the casing **11** through the seal gas supply path **17** in the gas seal portion **30**. A signal indicating the detected differential pressure PDT**1** in the machine is transmitted to the control part **42**C.

The seal gas pressure sensor S**1**A and the vent pressure sensor S**3** are connected to a differential pressure gauge **43**C. The differential pressure gauge **43**C detects a vent differential pressure PDT**2**(=P**1***b*−P**3**) between the supply pressure P**1***b* of the seal gas Gs supplied into the casing **11** through the connection pipe portion **70**A and the pressure P**3** in the vent **18**. A signal indicating the detected vent differential pressure PDT**2** is transmitted to the control part **42**C.

During an operation of the compressor **10**, the control part **42**C obtains the differential pressure PDT**1** in the machine and the vent differential pressure PDT**2** which are detected by the differential pressure gauges **43**A and the **43**C at predetermined time intervals.

When the detected differential pressure PDT**1** in the machine is equal to or more than a predetermined lower limit threshold value, or less than a predetermined upper limit threshold value, the supply pressure P**1***b* of the seal gas Gs is sufficiently higher than the internal pressure P**2** of the machine, and thus the operation is continued as it is without changing the opening degree of the pressure regulating valve **41**.

Further, when the detected differential pressure PDT**1** in the machine is less than the predetermined lower limit threshold value, the supply pressure P**1***b* of the seal gas Gs is not sufficiently higher than the internal pressure P**2** of the machine, and thus the opening degree of the pressure regulating valve **41** is increased. Then, the supply pressure P**1***b* of the seal gas Gs supplied into the casing **11** through the seal gas supply path **17** is increased. As a result, the differential pressure PDT**1** in the machine between the supply pressure P**1***b* of the seal gas Gs and the internal pressure P**2** of the machine is increased.

Further, when the detected differential pressure PDT**1** in the machine exceeds the predetermined upper limit threshold value, the supply pressure P**1***b* of the seal gas Gs is excessively higher than the internal pressure P**2** of the machine, and the flow rate of the seal gas flowing into the inside A of the machine is increased, and thus the flow rate of the gas G which is compressed by the compressor **10** is reduced. Therefore, the control part **42**C reduces the opening degree of the pressure regulating valve **41**.

Further, when the vent differential pressure PDT**2** in the machine which is detected by the differential pressure gauge **43**C is equal to or more than a predetermined threshold value, the supply pressure P**1***b* of the seal gas Gs is sufficiently higher than the pressure P**3** in the vent **18**, and thus the operation is continued as it is without changing the opening degree of the pressure regulating valve **41**.

For example, when a safety valve is released from equipment other than the compressor **10**, the pressure P**3** in the vent **18** may be increased. In this case, when the detected vent differential pressure PDT**2** is less than the predetermined threshold value, the supply pressure P**1***b* of the seal gas Gs is not sufficiently higher than the pressure P**3** in the vent **18**, and thus the opening degree of the pressure regulating valve **41** is increased.

Then, the supply pressure P**1***b* of the seal gas Gs supplied into the casing **11** through the seal gas supply path **17** is increased. As a result, the vent differential pressure PDT**2** between the supply pressure P**1***b* of the seal gas Gs and the pressure P**3** in the vent **18** is increased.

As described above, by adjusting the opening degree of the pressure regulating valve **41** by the control part **42**C on the basis of the supply pressure P**1***b* of the seal gas Gs which is detected by the seal gas pressure sensor S**1**A, the internal pressure P**2** of the machine which is detected by the internal pressure sensor S**2**, and the vent pressure P**3** which is detected by the vent pressure sensor S**3**, the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** inside the casing **11** can always be kept higher than the internal pressure P**2** of the machine and the vent pressure P**3**. Accordingly, backflow of the seal gas Gs from the gas seal portion **30** toward the inside A of the machine of the compressor **10** can be prevented even when the pressure in the vent **18** is sharply increased.

According to the rotary machine system **1** as described above, like the first embodiment, the pressure loss occurring until the seal gas Gs reaches the gas seal portion **30**, can be suppressed by providing the pressure sensor S**1**A closer to the gas seal portion **30** side than the gas seal module **40**B. Therefore, a pipe diameter of the seal gas supply path **17** through which the seal gas Gs is supplied to the gas seal portion **30** can be minimized while the backflow of the seal gas Gs is suppressed, and thus the piping cost, the design cost and the designing effort of the seal gas supply path **17** can be limited.

Further, the above-described rotary machine system **1** further includes the vent pressure sensor S**3** which detects the pressure in the vent **18**, and the control part **42**C controls the pressure regulating valve **41** so that the pressure of the seal gas Gs which is detected by the pressure sensor S**1**A is higher than the pressure in the vent **18** which is detected by the vent pressure sensor S**3**.

By constituting the rotary machine system **1** in this way, the pressure of the seal gas Gs in the gas seal portion **30** is reliably maintained higher than the pressure in the vent, and a leak of the seal gas Gs to the vent can be reliably suppressed regardless of variations of the pressure in the vent.

(Other Embodiments)

In addition, the rotary machine system of the present invention is not limited to each of the above-described embodiments described with reference to the drawings, and various modifications are conceivable within the technical scope thereof.

For example, in the third embodiment, in addition to the constitution described in the first embodiment, the pressure P**3** in the vent **18** is detected by the vent pressure sensor S**3**, and thus the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** is adjusted. Similarly, also in the constitution described in the second embodiment, the pressure P**3** in the vent **18** may be detected by the vent pressure sensor S**3**, and the pressure P**1***a* of the seal gas Gs in the gas seal portion **30** may be adjusted.

In the first and third embodiments, the seal gas pressure sensor S**1**A is provided in the port connection hole **71**A which is the closest to the outer circumferential surface of the casing **11** in the connection pipe portion **70**A for connecting the gas seal modules **40**A and **40**C and the casing **11** of the compressor **10**, but the present invention is not limited thereto. The seal gas pressure sensor S**1**A may be provided in one of one or more connecting pipes **72** of the connection pipe portion **70**A. Further, the seal gas pressure sensor S**1**A may be provided in the connecting pipe **72** which is the closest to the casing **11**.

Further, the constitution of the gas seal portion **30** can be appropriately changed.

Further, the gas seal portion **30** has been provided on the suction side of the compressor **10**, but the present invention is not limited thereto. The gas seal portion **30** may be provided at a discharge side of the compressor **10**. In this case, the same operational effects as those in the above-described embodiments can be obtained.

In addition, for example, the overall constitution of the compressor **10** and the rotary machine system **1** may have any types.

According to the above-described rotary machine system, the pressure of the seal gas in the gas seal portion can be detected with high accuracy by suppressing the difference between the pressure of the seal gas detected by the pressure sensor and the pressure of the seal gas in the gas seal portion. As a result, the pipe diameter of the seal gas supply path through which the seal gas is supplied to the gas seal portion can be minimized while the backflow of the seal gas is suppressed, and thus the piping cost, the design cost and the designing effort of the pipe for supplying the seal gas can be limited.

Although the disclosure has been described with respect to only a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that various other embodiments may be devised without departing from the scope of the present invention. Accordingly, the scope of the invention should be limited only by the attached claims.

REFERENCE SIGNS LIST

1 Rotary machine system
10 Compressor (rotary machine)
11 Casing
11*f* Outer surface
11*h* Shaft insertion hole
12 Rotary shaft
15 Seal gas supply port
16 Vent discharge port
17 Seal gas supply path
18 Vent (vent portion)
20 Turbine
30 Gas seal portion
31 Rotary ring
31*f* Surface
32 Stationary ring
33 Labyrinth seal on inside of the machine
35 Shaft sleeve
35*a* End
36 Holder portion
36*a* Holding recess
37 Retainer
37*a* Holding recess
38 Coil spring
40A, **40**B, **40**C Gas seal module (gas seal device)
41 Pressure regulating valve
41*d* Valve driving part
41*v* Valve body
42A, **42**B, **42**C Control part
43A, **43**B, **43**C Differential pressure gauge
70A, **70**B Connection pipe portion
71A Port connection hole (connection hole portion)
71B Port connection hole
71*h* Through-hole
72 Connecting pipe
75 Opening
A Inside of machine
B Outside of machine
G Gas (working fluid)
Gs Seal gas
P**1***a* Pressure of seal gas in gas seal portion
P**1***b* Supply pressure
P**2** Internal pressure of machine
P**3** Vent pressure
PDT**1** Differential pressure in machine
PDT**2** Vent differential pressure
S Seal gap
S**1**A, S**1**B Seal gas pressure sensor
S**2** Internal pressure sensor
S**3** Vent pressure sensor

What is claimed is:

1. A rotary machine system comprising:
a rotary machine comprising a gas seal portion;
a gas seal device connected to the rotary machine and that supplies a seal gas to the gas seal portion;
a pressure sensor that detects a pressure of the seal gas;
a vent portion that discharges the seal gas discharged from the gas seal portion to the outside; and
a vent pressure sensor that detects a pressure in the vent portion,
wherein the rotary machine comprises:
a casing through which a working fluid flows;
a rotatable rotary shaft that passes through an inside and an outside of the casing; and
the gas seal portion provided between the casing and the rotary shaft and that seals the working fluid by the seal gas having a pressure higher than a pressure of the working fluid in the casing,
the gas seal device comprises:
a pressure regulating valve that adjusts the pressure of the seal gas supplied to the gas seal portion; and
a control part that controls the pressure regulating valve,
the pressure sensor is provided closer to the gas seal portion side than the gas seal device,
pressure variations occurs in the vent portion, and
the control part controls the pressure regulating valve according to the pressure of the seal gas detected by the pressure sensor and controls the pressure regulating valve so that the pressure of the seal gas detected by the pressure sensor is higher than the pressure in the vent portion detected by the vent pressure sensor.

2. The rotary machine system according to claim **1**, wherein the pressure sensor is provided in a connection pipe portion which connects the gas seal portion and the gas seal device.

3. The rotary machine system according to claim **2**, wherein the pressure sensor is provided in the connection pipe portion within a range of 1/3 of an overall length of the connection pipe portion from the gas seal portion side.

4. The rotary machine system according to claim **2**, wherein the connection pipe portion comprises:
a connection hole portion provided at a position of the casing which faces the gas seal portion, and
one or more connecting pipes that connects the connection hole portion and the gas seal device, and
the pressure sensor is provided in the connection hole portion.

5. The rotary machine system according to claim **1**, wherein the pressure sensor is provided in an opening of the casing which faces the gas seal portion.

6. The rotary machine system according to claim **1**, further comprising an internal pressure sensor that detects an internal pressure of the machine closer to an inside of the rotary machine than the gas seal portion,
wherein the control part controls the pressure regulating valve so that a pressure of the seal gas detected by the pressure sensor is higher than the internal pressure of the machine detected by the internal pressure sensor.

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