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TEMPERATURE CONTROL DEVICE

Abstract

Provided is a temperature control device capable of controlling, with high accuracy, a temperature of a fluid for temperature control to be supplied to a temperature control target in comparison to a case in which there is not provided control means for controlling temperature adjustment performance of supply means based on a result of detection performed by detection means for detecting a heat load of the temperature control target. The temperature control device includes: supply means for adjusting a fluid for temperature control to a predetermined temperature and then supplying the fluid for temperature control; detection means for detecting a heat load of a temperature control target to be supplied with the fluid for temperature control from the supply means, the detection means being arranged on the temperature control target side; and control means for controlling temperature adjustment performance of the supply means based on a result of detection performed by the detection means.

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Background/Summary

TECHNICAL FIELD
[0001] The present invention relates to a temperature control device.
BACKGROUND ART
[0002] Hitherto, as a technology relating to a temperature control device, there have already been proposed, for example, temperature control devices disclosed in Patent Literature 1 and Patent Literature 2.
BACKGROUND ART
[0003] A temperature adjustment device described in Patent Literature 1 includes: a temperature-adjusted member including a member flow passage therein; a first temperature control portion that controls a temperature of a first temperature adjustment medium to a first temperature; a second temperature control portion that controls a temperature of a second temperature adjustment medium to a second temperature different from the first temperature; a first flow passage that allows the first temperature adjustment medium to flow between the member flow passage and the first temperature control portion; a second flow passage that allows the second temperature adjustment medium to flow between the member flow passage and the second temperature control portion; a third flow passage that allows the first temperature adjustment medium to flow through the first temperature control portion without passing through the member flow passage; a fourth flow passage that allows the second temperature adjustment medium to flow through the second temperature control portion without passing through the member flow passage; a first three-way valve provided at a branching portion from which the first flow passage and the third flow passage extend; a second three-way valve provided at a branching portion from which the second flow passage and the fourth flow passage extend; and a third three-way valve provided at a branching portion from which the first flow passage and the second flow passage extend.
[0004] A temperature control method described in Patent Literature 2 includes: a switching step of switching a heating medium, which is arranged in a treatment container of a plasma treatment apparatus and is to be supplied to a flow passage provided inside a placement table on which a board is to be placed, from the heating medium having a first temperature supplied from a first temperature control portion when an etching process is performed on the board to the heating medium having a second temperature supplied from a second temperature control portion when cleaning treatment for removing a reaction product adhering to an electrostatic chuck provided in an upper part of the placement table after the board is taken out of the treatment container; an ignition step of starting supply of a cleaning gas into the treatment container and igniting plasma; a gradient calculating step of calculating a gradient of a temperature change of the heating medium based on a temperature of the heating medium on an outlet side of the flow passage; a first control step of controlling the second temperature control portion until the temperature of the heating medium on the outlet side of the flow passage is stabilized to be a third temperature lower than a predetermined set value; and a second control step of controlling the second temperature control portion so that the temperature of the heating medium on the outlet side of the flow passage

becomes equal to the set value.

CITATION LIST

Patent Literature

[0005] [PTL 1] JP 2020-107684 A [0006] [PTL 2] JP 2021-145095 A

SUMMARY OF INVENTION

Technical Problem

[0007] The present invention has an object to provide a temperature control device capable of controlling, with high accuracy, a temperature of a fluid for temperature control to be supplied to a temperature control target in comparison to a case in which there is not provided control means for controlling temperature adjustment performance of supply means based on a result of detection performed by detection means for detecting a heat load of the temperature control target.

Solution to Problem

[0008] According to the invention of claim **1**, there is provided a temperature control device, including: supply means for adjusting a fluid for temperature control to a predetermined temperature and then supplying the fluid for temperature control; detection means for detecting a heat load of a temperature control target to be supplied with the fluid for temperature control from the supply means, the detection means being arranged on the temperature control target side; and control means for controlling temperature adjustment performance of the supply means based on a result of detection performed by the detection means.

[0009] According to the invention of claim **2**, in the temperature control device as described in claim **1**, the detection means includes: a first three-way valve for flow rate control configured to split the fluid for temperature control from the supply means into the fluid for temperature control to be supplied to the temperature control target and the fluid for temperature control to be returned to the supply means without being supplied to the temperature control target; first temperature detection means for detecting a temperature of the fluid for temperature control to be supplied to the temperature control target by the first three-way valve for flow rate control; and second temperature detection means for detecting a temperature of the fluid for temperature control returned from the temperature control target.

[0010] According to the invention of claim **3**, in the temperature control device as described in claim **1**, the supply means includes: first supply means for supplying a lower temperature fluid adjusted to a first predetermined lower temperature; and second supply means for supplying a higher temperature fluid adjusted to a second predetermined higher temperature, and wherein the detection means includes: a second three-way valve for flow rate control configured to mix the lower temperature fluid supplied from the first supply means and the higher temperature fluid supplied from the second supply means while controlling a flow rate of the lower temperature fluid and a flow rate of the higher temperature fluid to form the fluid for temperature control and then supply the fluid for temperature control to the temperature control target; a third three-way valve for flow rate control configured to distribute the fluid for temperature control having flowed through the temperature control target to the first supply means and the second supply means while controlling a flow rate of the fluid for temperature control; first temperature detection means for detecting a temperature of the fluid for temperature control to be supplied to the temperature control target by the second three-way valve for flow rate control; and second temperature detection means for detecting a temperature of the fluid for temperature control returned from the temperature control target.

[0011] According to the invention of claim **4**, in the temperature control device as described in any one of claims **1** to **3**, the control means controls the temperature adjustment performance of the supply means by increasing and decreasing a flow rate of a heat exchange medium that adjusts a temperature of the fluid for temperature control through intermediation of a heat exchanger in the supply means.

[0012] According to the invention of claim **5**, in the temperature control device as described in

claim **2**, the control means calculates the heat load of the temperature control target based on a flow rate of the fluid for temperature control to be supplied to the temperature control target and results of detection performed by the first temperature detection means and the second temperature detection means, which are included in distribution information of the first three-way valve for flow rate control.
[0013] According to the invention of claim **6**, in the temperature control device as described in claim **5**, the control means controls temperature adjustment performance F**1** of the supply means based on a result H**1** of calculation of the heat load of the temperature control target by an arithmetic expression:

$F1=((H1-b)/a)$.sup.0.5
[0014] According to the invention of claim **7**, in the temperature control device as described in claim **6**, the control means controls an rpm of a drive source configured to drive a chiller in the supply means.
[0015] According to the invention of claim **8**, in the temperature control device as described in claim **1**, the control means controls a distribution ratio at the first three-way valve for flow rate control.
[0016] According to the invention of claim **9**, in the temperature control device as described in claim **1**, the supply means includes a fourth three-way valve for flow rate control configured to split the fluid for temperature control from the supply means into the fluid for temperature control to be supplied to the temperature control target and the fluid for temperature control to be returned without being supplied to the temperature control target.
[0017] According to the invention of claim **10**, in the temperature control device as described in claim **9**, the control means controls a flow rate of the fluid for temperature control flowing into the fourth three-way valve for flow rate control to a constant value.
[0018] According to the invention of claim **11**, in the temperature control device as described in claim **1**, the supply means includes: a storage tank configured to store the fluid for temperature control returned from the temperature control target; and cooling means for cooling the fluid for temperature control stored in the storage tank.
[0019] According to the invention of claim **12**, in the temperature control device as described in claim **2**, the first three-way valve for flow rate control includes: an inflow port, which allows inflow of the fluid for temperature control; and a first valve port and a second valve port, which allow the fluid for temperature control flowing in through the inflow port to be split into the fluid for temperature control to be supplied to the temperature control target and the fluid for temperature control to be returned to the supply means without being supplied to the temperature control target.
Advantageous Effects of Invention
[0020] According to the present invention, the temperature control device capable of controlling, with high accuracy, the temperature of a fluid for temperature control to be supplied to the temperature control target in comparison to a case in which there is not provided control means for controlling temperature adjustment performance of supply means based on a result of detection performed by detection means for detecting a heat load of the temperature control target can be provided.

Description

BRIEF DESCRIPTION OF DRAWINGS
[0021] FIG. **1** is a schematic configuration diagram for illustrating a constant-temperature maintaining device (chiller device) as a temperature control device according to a first embodiment

of the present invention.
[0022] FIG. **2** is a circuit configuration diagram for illustrating a refrigerator of the constant-temperature maintaining device (chiller device) as the temperature control device according to the first embodiment of the present invention.
[0023] FIG. **3** is a sectional configuration view for illustrating a plasma treatment apparatus.
[0024] FIG. **4** is a schematic configuration diagram for illustrating an operation of the constant-temperature maintaining device (chiller device) as the temperature control device according to the first embodiment of the present invention.
[0025] FIG. **5** is a characteristic graph for showing an operation of the constant-temperature maintaining device (chiller device) as the temperature control device according to the first embodiment of the present invention.
[0026] FIG. **6** is a characteristic graph for showing an operation of a related-art chiller device.
[0027] FIG. **7** is a schematic configuration diagram for illustrating a constant-temperature maintaining device (chiller device) as a temperature control device according to a second embodiment of the present invention.
[0028] FIG. **8** is a graph for showing temperature characteristics of the chiller device.
[0029] FIG. **9** is a schematic configuration diagram for illustrating an operation of the constant-temperature maintaining device (chiller device) as the temperature control device according to the second embodiment of the present invention.
[0030] FIG. **10** is a schematic configuration diagram for illustrating the operation of the constant-temperature maintaining device (chiller device) as the temperature control device according to the second embodiment of the present invention.
[0031] FIG. **11** is a graph for showing switching characteristics of a three-way valve for flow rate control.
[0032] FIG. **12**(*a*) is a front view for illustrating a three-way motor valve as one example of the three-way valve for flow rate control according to the first embodiment of the present invention.
[0033] FIG. **12**(*b*) is a left side view for illustrating the three-way motor valve as one example of the three-way valve for flow rate control according to the first embodiment of the present invention.
[0034] FIG. **12**(*c*) is a bottom view of an actuator, for illustrating the three-way motor valve as one example of the three-way valve for flow rate control according to the first embodiment of the present invention.
[0035] FIG. **13** is a sectional view taken along the line A-A of FIG. **12**(*b*), for illustrating the three-way motor valve as one example of the three-way valve for flow rate control according to the first embodiment of the present invention.
[0036] FIG. **14** is a sectional view taken along the line B-B of FIG. **12**(*a*), for illustrating the three-way motor valve as one example of the three-way valve for flow rate control according to the first embodiment of the present invention.
[0037] FIG. **15** is a sectional perspective view for illustrating relevant parts of the three-way motor valve as one example of the three-way valve for flow rate control according to the first embodiment of the present invention.
[0038] FIG. **16**(*a*) is a perspective configuration view for illustrating a valve seat.
[0039] FIG. **16**(*b*) is a front configuration view for illustrating the valve seat.
[0040] FIG. **17** is a configuration view for illustrating a relationship between the valve seat and a valve shaft.
[0041] FIG. **18**(*a*) is a partially cutaway perspective configuration view for illustrating an spring energized seal.
[0042] FIG. **18**(*b*) is a sectional configuration view for illustrating the spring energized seal.
[0043] FIG. **19** is a sectional view for illustrating the spring energized seal under a mounted state.
[0044] FIG. **20** is a configuration view for illustrating a modification example of the spring

energized seal.
[0045] FIG. **21**(*a*) is a perspective configuration view for illustrating a wave washer.
[0046] FIG. **21**(*b*) is a side configuration view for illustrating the wave washer.
[0047] FIG. **21**(*c*) is a partially cutaway front configuration view for illustrating the wave washer.
[0048] FIG. **22** is a perspective configuration view for illustrating an adjusting ring.
[0049] FIG. **23**(*a*) is a configuration view for illustrating a motion of the valve shaft.
[0050] FIG. **23**(*b*) is a configuration view for illustrating the motion of the valve shaft.
[0051] FIG. **24**(*a*) is a perspective configuration view for illustrating the valve shaft.
[0052] FIG. **24**(*b*) is a front configuration view for illustrating the valve shaft.
[0053] FIG. **25**(*a*) is a configuration view for illustrating the motion of the valve shaft.
[0054] FIG. **25**(*b*) is a configuration view for illustrating the motion of the valve shaft.
[0055] FIG. **26** is a sectional configuration view for illustrating a motion of the three-way motor valve as one example of the three-way valve for flow rate control according to the first embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0056] In the following, embodiments of the present invention are described with reference to the drawings.

First Embodiment

<Schematic Configuration of Chiller Device>

[0057] FIG. **1** is a schematic configuration diagram for illustrating a constant-temperature maintaining device (chiller device) as one example of a temperature control device according to a first embodiment of the present invention.

[0058] A chiller device **100** is used for, for example, a semiconductor manufacturing apparatus involving plasma etching as described later, and is configured to perform control so as to maintain, for example, a temperature of a semiconductor wafer as one example of a temperature control target (workpiece) W to a constant temperature.

[0059] As illustrated in FIG. **1**, the chiller device **100** mainly includes a fluid supply portion **104**, detection means **105**, and a control device **300**. The fluid supply portion **104** is one example of supply means for adjusting a temperature of a fluid **101** for temperature control to a predetermined temperature and then supplying the fluid **101** for temperature control to a temperature adjustment target device **102** via a supply pipe **103**. The temperature adjustment target device **102** is one example of the temperature control target. The detection means **105** for detecting a heat load of the temperature adjustment target device **102** is provided outside the chiller device **100** and is arranged closest to the temperature adjustment target device **102** on the temperature adjustment target device **102** side. The temperature adjustment target device **102** is supplied with the fluid **101** for temperature control by the fluid supply portion **104**. The control device **300** is one example of control means for controlling temperature adjustment performance of the fluid supply portion **104** based on a result of detection performed by the detection means **105**.

[0060] The fluid supply portion **104** includes a storage tank **106**, a supply pump **107**, and a refrigerator **108**. The storage tank **106** is configured to store the fluid **101** for temperature control. The supply pump **107** supplies the fluid **101** for temperature control from the storage tank **106**. The refrigerator **108** cools the fluid **101** for temperature control supplied by the supply pump **107** to a temperature instructed by the control device **300**.

[0061] The detection means **105** includes a first three-way valve **109** for flow rate control, a first temperature sensor **110**, and a second temperature sensor **111**. The first three-way valve **109** for flow rate control is configured to split the fluid **101** for temperature control into the fluid **101** for temperature control to be supplied from the chiller device **100** to the temperature adjustment target device **102** and the fluid **101** for temperature control to be returned to the storage tank **106** via a return pipe **112** without being supplied to the temperature adjustment target device **102**. The first temperature sensor **110** is one example of first temperature detection means for detecting a temperature of the fluid **101** for temperature control immediately before being supplied to the temperature adjustment target device **102**. The second temperature sensor **111** is one example of second temperature detection means for detecting the temperature of the fluid **101** for temperature control immediately after flowing out from the temperature adjustment target device **102**. An outflow portion for return of the first three-way valve **109** for flow rate control is connected to the return pipe **112** through intermediation of a first bypass pipe **125**.

[0062] The detection means **105** detects the heat load of the temperature adjustment target device **102**. The first three-way valve **109** for flow rate control determines a ratio (distribution ratio) of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102** to the fluid **101** for temperature control flowing into the first three-way valve **109** for flow rate control. Thus, when a flow rate of the fluid **101** for temperature control flowing into the first three-way valve **109** for flow rate control is known, a flow rate of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102** is obtained. Further, a temperature change ΔT=(Ret Temp1−Sup Temp1), which is caused along with passage of the fluid **101** for temperature control through the temperature adjustment target device **102**, is obtained by calculating a difference between a temperature (Sup Temp1) of the fluid **101** for temperature control immediately before being supplied to the temperature adjustment target device **102**, which is detected by the first temperature sensor **110**, and a temperature (Ret Temp1) of the fluid **101** for temperature control immediately after flowing out from the temperature adjustment target device **102**, which is detected by the second temperature sensor **111**. As a result, a heat load H**1** of the temperature adjustment target device **102** is detected (calculated) by the following arithmetic expression (1) based on the flow rate of the fluid **101** for temperature control flowing into the first three-way valve **109** for flow rate control, the distribution ratio of the fluids **101** for temperature control at the first three-way valve **109** for flow rate control, and the difference between the temperature of the fluid **101** for temperature control detected by the first temperature sensor **110** and the temperature of the fluid **101** for temperature control detected by the second temperature sensor **111**.

[00001] $H1 = m$ .Math. c .Math. T (1)

[0063] Here, “m” represents a mass flow rate (Kg/h) of the fluid **101** for temperature control, that is, a result of multiplication of a flow rate of the fluid **101** for temperature control per unit time by a specific gravity, and “c” represents a specific heat (Kw/Kg/° C.) of the fluid **101** for temperature control.

[0064] If the temperature (Sup Temp1) of the fluid **101** for temperature control immediately before being supplied to the temperature adjustment target device **102** and the temperature (Ret Temp1) of the fluid **101** for temperature control immediately after flowing out from the temperature adjustment target device **102** are equal to each other, the heat load H**1** of the temperature adjustment target device **102** is zero.

[0065] Meanwhile, when the temperature difference (Ret Temp1−Sup Temp1) between the temperature (Sup Temp1) of the fluid **101** for temperature control immediately before being supplied to the temperature adjustment target device **102** and the temperature (Ret Temp1) of the fluid **101** for temperature control immediately after flowing out from the temperature adjustment target device **102** has a large value and/or a flow rate Q**1** of the fluid **101** for temperature control is large, the heat load H**1** of the temperature adjustment target device **102** is large.

[0066] Further, a third temperature sensor **113** is one example of third temperature detection means for detecting the temperature of the fluid **101** for temperature control and is arranged at an inflow portion immediately before the fluid **101** for temperature control is returned to the storage tank **106** via the return pipe **112**.

[0067] Further, a fourth temperature sensor **114** is one example of fourth temperature detection means for detecting the temperature of the fluid **101** for temperature control supplied from the storage tank **106** and is arranged in a pipe **124** for allowing the fluid **101** for temperature control to be supplied from the storage tank **106** to the refrigerator **108** by the supply pump **107**.

[0068] A fifth temperature sensor **115** and a first flow rate sensor **116** are arranged in a most upstream portion of the supply pipe **103** through which the fluid **101** for temperature control flowing out from the refrigerator **108** flows. The fifth temperature sensor **115** is one example of fifth temperature detection means for detecting the temperature of the fluid **101** for temperature control immediately after flowing out from the refrigerator **108**. The first flow rate sensor **116** is one example of first flow rate detection means for detecting the flow rate of the fluid **101** for temperature control flowing out from the refrigerator **108**.

[0069] Inside the fluid supply portion **104**, there is provided a second three-way valve **117** for flow rate control that splits the fluid **101** for temperature control cooled by the refrigerator **108** into the fluid **101** for temperature control to be supplied toward the temperature adjustment target device **102** and the fluid **101** for temperature control to be returned to the storage tank **106** via the return pipe **112** without being supplied toward the temperature adjustment target device **102**. A second flow rate sensor **118** is one example of second flow rate detection means for detecting a flow rate of the fluid **101** for temperature control supplied from the fluid supply portion **104**, and is arranged on an outflow side of the second three-way valve **117** for flow rate control toward the temperature adjustment target device **102**. An outflow portion for return of the second three-way valve **117** for flow rate control is connected to the return pipe **112** through intermediation of a second bypass pipe **126**.

[0070] The supply pump **107** is driven by a first inverter motor **119**. Further, the refrigerator **108** is driven by a second inverter motor **123**. The first inverter motor **119** and the second inverter motor **123** are driven by drive circuits (not shown), respectively, and their rpms or the like are controlled by the control device **300**. The rpms of the first inverter motor **119** and the second inverter motor **123** are controlled by changing frequencies of AC power supplied to the first inverter motor **119** and the second invertor motor **123**.

[0071] As illustrated in FIG. **2**, the refrigerator **108** has the following circuit configuration. Refrigerant gas is compressed by an electric compressor **131** and is sent as a high-pressure gas to a condenser **132** on a discharge side. After the high-pressure gas is condensed in the condenser **132** and is decompressed via an expansion valve **133** of a pressure reducing mechanism, the decompressed gas is sent to an evaporator **134**.

[0072] The decompressed low-pressure gas is evaporated the evaporator **134** and is sucked into a suction side of the electric compressor **131** so as to repeat the compression again.

[0073] The refrigerator **108** cools the fluid **101** for temperature control through a heat exchanger provided in the evaporator **134**. The electric compressor **131** is driven by the second inverter motor **123**. In the refrigerator **108**, a refrigerant condensing effect in the condenser **132** is enhanced by increasing the rpm of the second inverter motor **123**, and a refrigerant vaporizing action in the evaporator **134** is increased. As a result, cooling performance is improved.

[0074] The first three-way valve **109** for flow rate control can be configured to be switched by the control device **300** so as to increase or decrease the distribution ratio of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102** in accordance with, for example, the difference (Ret Temp1-Sup Temp1) between the temperature (Sup Temp1) detected by the first temperature sensor **110** and the temperature (Ret Temp1) detected by the second temperature sensor **111**.

[0075] More specifically, when the temperature (Ret Temp1) detected by the second temperature sensor **111** is higher than the temperature (Sup Temp1) detected by the first temperature sensor **110**, the first three-way valve **109** for flow rate control is switched to increase the flow rate of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102**.

[0076] The temperature adjustment target device **102** has a flow passage **135** for temperature control (see FIG. **3**) therein. The fluid **101** for temperature control having a temperature adjusted to a predetermined temperature by the fluid supply portion **104** continuously flows through the flow passage **135** for temperature control.

[0077] Examples of a heating medium (brine) used as the fluid **101** for temperature control include fluorine-based inert liquids such as Opteon (trademark: manufactured by Chemours-Mitsui Fluoroproducts Co., Ltd.) and Novec (trademark: manufactured by 3M company), which are used, for example, at a pressure of from 0 MPa to 1 MPa and in a temperature range of from about −85° C. to about +120° C.

[0078] The control device **300** comprehensively controls an overall operation of the chiller device **100**. The control device **300** includes a central processing unit (CPU), a read only memory (ROM), a random access memory (RAM) (not shown), or a bus for connecting the CPU and the ROM, and the like. Detected signals from the first to the fifth temperature sensors **110**, **111**, **113**, **114**, and **115**, the first flow rate sensor **116** and the second flow rate sensor **118**, and the like are input to the control device **300**. Further, the control device **300** is configured to control a required arithmetic process or opening degrees (distribution ratios) of the first three-way valve **109** for flow rate control and the second three-way valve **117** for flow rate control based on a program stored in advance in the ROM (not shown).

<Configuration of Plasma Treatment Apparatus>

[0079] As the semiconductor manufacturing apparatus to which the chiller device **100** is applied, a plasma treatment apparatus **200** involving plasma treatment can be given.

[0080] As illustrated in FIG. **3**, the plasma treatment apparatus **200** includes a vacuum container (chamber) **201**. Inside the vacuum container (chamber) **201**, there is provided an electrostatic chuck **136** (ESC) as one example of the temperature control target for holding the semiconductor wafer W being the temperature control target under a state of electrostatically attracting the semiconductor wafer W. The flow passage **135** for temperature control, through which the fluid **101** for temperature control flows from the chiller device **100**, is continuously formed in the electrostatic chuck **136**. Further, the plasma treatment apparatus **200** includes a lower electrode (cathode electrode) **202** and an upper electrode (anode electrode) **203**. The lower electrode **202** is also used as the electrostatic chuck **136**, and is coupled to a lid portion. The upper electrode **203** is arranged to be opposed to the lower electrode **202**, and integrally includes the lid portion. The temperature control target may include not only the lower electrode (cathode electrode) **202** but also the upper electrode (anode electrode) **203**.

[0081] Further, a gas intake port **201***a* is formed in the vacuum container **201**, and is configured to introduce active gas (reactive gas) for etching therethrough. The upper electrode **203** is connected to a ground potential (GND) through intermediation of the lid portion extending outward. Further, the lower electrode **202** is connected to a radio-frequency (RF) oscillator **204** and a blocking capacitor **205** through intermediation of the lid portion extending outward. One end of the radio-frequency (RF) oscillator **204** is connected to the ground potential (GND). Moreover, a light emission detector **206** is provided on an outer side of a window portion formed in a wall of the vacuum container **201** opposed to the gas intake port **201***a*, and is configured to monitor a light emission state when plasma for etching is produced to perform etching by the plasma treatment.

[0082] The plasma used for etching of the semiconductor wafer W has a characteristic of reaching a high temperature within an extremely short period of time. The electrostatic chuck **136** that holds the semiconductor wafer W under a state of electrostatically attracting the semiconductor wafer W has a tendency to suddenly increase its temperature along with progress of the plasma treatment.

[0083] Under a state in which the active gas is ionized through the plasma treatment, positive ions of the active gas are attracted to the temperature control target W located on a side of the lower electrode **202** being the cathode electrode, and thus are used for etching. Electrons produced by ionizing the active gas through the plasma treatment exhibit various behaviors. The electrons flow toward the temperature control target W, or flow to the ground potential through the upper electrode **203**. Most of the electrons are stored in the blocking capacitor **205** through the lower electrode **202**.

[0084] As the temperature control target W to be controlled in temperature by the chiller device **100**, a semiconductor element such as a three-dimensional NAND flash memory, a flat panel display (FPD), or a solar cell is given.

<Basic Operation of Chiller Device>

[0085] The chiller device **100** basically operates as follows.

[0086] The chiller device **100** controls, for example, the temperature of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102** so that the temperature becomes equal to a predetermined temperature, for example, −30° C. Here, it is desired that the temperature of the fluid **101** for temperature control supplied by the fluid supply portion **104** be set to, for example, about −30° C., which is a predetermined temperature lower than 0° C., in consideration of an increase in temperature of the temperature adjustment control target along with the progress of the treatment. It is apparent that the temperature of the fluid **101** for temperature control is not limited to about −30° C. and may be higher or lower than about −30° C.

[0087] When the temperature of the temperature adjustment target device **102** is controlled to about −30° C., the chiller device **100** sets the opening degree of the first three-way valve **109** for flow rate control to, for example, 50%, as illustrated in FIG. **4**, so that the amount of the fluid **101** for temperature control flowing into the temperature adjustment target device **102** via the supply pipe **103** and the amount of the fluid **101** for temperature control to be returned to the fluid supply portion **104** are controlled to be equal to each other.

[0088] Further, the chiller device **100** sets the opening degree of the second three-way valve **117** for flow rate control to, for example, 100% so as to cause all the fluid **101** for temperature control supplied from the refrigerator **108** into the first three-way valve **109** for flow rate control.

[0089] As a result, 50% of the fluid **101** for temperature control in the fluid **101** for temperature control adjusted to the predetermined temperature of −30° C. is supplied from the fluid supply portion **104** to the flow passage **135** for temperature control in the temperature adjustment target device **102**. As a result, the temperature of the temperature adjustment target device **102** is controlled to be −30° C., which is the temperature of the fluid **101** for temperature control supplied from the fluid supply portion **104**.

[0090] The control device **300** calculates the flow rate Q**1** of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102** and a flow rate Q**2** of the fluid **101** for temperature control returning toward the chiller device **100** in accordance with opening-degree information of the first three-way valve **109** for flow rate control based on the flow rate of the fluid **101** for temperature control supplied to the first three-way valve **109** for flow rate control, which has been detected by the second flow rate sensor **118**.

[0091] Next, the control device **300** calculates the heat load H**1** of the temperature adjustment target device **102** by the arithmetic expression (1) based on the flow rate Q**1** of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102** and the results of detection performed by the first temperature sensor **110** and the second temperature sensor **111**.

[00002] $H1 = m$ .Math. c .Math. T (1)

[0092] The control device **300** controls a frequency F**1** that determines the rpm of the second inverter motor **123** of the refrigerator **108** by an arithmetic expression (2) based on the heat load H**1** of the temperature adjustment target device **102**, which has been detected by the detection means **105**.

[00003] $F1 = ((H1 - b)/a)^{0.5}$ (2)

[0093] NOW, when an etching step involving the plasma treatment on the semiconductor wafer W is started in the plasma treatment apparatus **200** as the temperature adjustment target device **102**, the fluid **101** for temperature control flows out from the electrostatic chuck **136** that holds the semiconductor wafer W under a state of electrostatically attracting the semiconductor wafer W and

a temperature T**2** of the fluid **101** for temperature control, which is detected by the second temperature sensor **111**, suddenly increases as shown in FIG. **5**.
[0094] Then, the control device **300** calculates the heat load H**1** of the temperature adjustment target device **102** based on the expression (1) described above and performs control so as to immediately and suddenly increase, as shown in FIG. **5**, the frequency F**1** of the AC power, which determines the rpm of the second inverter motor **123** of the refrigerator **108** in response to the calculated suddenly increasing heat load H**1**.
[0095] Thus, when a sudden increase in the heat load H**1** of the temperature adjustment target device **102** is detected by the first temperature sensor **110** and the second temperature sensor **111**, the control device **300** can immediately and significantly increase the rpm of the second inverter motor **123** of the refrigerator **108** so as to increase the cooling performance.
[0096] As a result, after the fluid **101** for temperature control, which has a temperature suddenly increased as a result of the passage through the temperature adjustment target device **102**, passes through the storage tank **106**, the fluid **101** for temperature control is efficiently cooled by the refrigerator **108** having the cooling performance that has been increased in advance and is supplied as the fluid **101** for temperature control, which has a temperature substantially equal to the predetermined temperature of −30° C., to the temperature adjustment target device **102**.
[0097] Simultaneously, the control device **300** controls the distribution ratio at the first three-way valve **109** for flow rate control as needed so as to increase the flow rate of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102**.
[0098] As described above, the chiller device **100** according to the first embodiment can control with high accuracy the temperature of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102** in comparison to a case in which the control device **300** for controlling temperature adjustment performance (cooling performance) of the fluid supply portion **104** based on the result of detection performed by the detection means **105** for detecting the heat load of the temperature adjustment target device **102** is not provided.
Comparative Example
[0099] Meanwhile, in the related art, as shown in FIG. **6**, the frequency F**1** that determines the rpm of the second inverter motor **123** of the refrigerator **108** is controlled by proportional control after an increase in temperature T**4** of the fluid **101** for temperature control is detected by the third temperature sensor **113** arranged on an upstream side of the storage tank **106**. Thus, when the etching step involving the plasma treatment on the semiconductor wafer W is started in the plasma treatment apparatus **200**, a temperature T**1** of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102** is increased due to overshoot. As a result, the temperature of the workpiece W in the temperature adjustment target device **102** is increased, and processing accuracy is reduced or the like. Thus, it is difficult to control with high accuracy the temperature of the fluid **101** for temperature control to be supplied to the temperature adjustment target device **102**.
Second Embodiment
[0100] FIG. **7** is a schematic configuration diagram for illustrating a constant-temperature maintaining device (chiller device) as one example of a temperature control device according to a second embodiment of the present invention.
[0101] The chiller device **100** according to the first embodiment has been described only for a case in which the fluid for temperature control with only one temperature setting is used as the fluid **101** for temperature control. Meanwhile, a chiller device **100** according to the second embodiment is configured to use two kinds of fluids for temperature control, that is, a lower temperature fluid adjusted to a predetermined first temperature being a lower temperature and a higher temperature fluid adjusted to a predetermined second temperature being a higher temperature.
[0102] That is, as illustrated in FIG. **7**, the chiller device **100** of the second embodiment includes a lower temperature fluid supply portion **104-1** and a higher temperature fluid supply portion **104-2**.

The lower temperature fluid supply portion **104-1** is one example of first supply means for supplying a lower temperature fluid adjusted to a predetermined constant lower temperature. The higher temperature fluid supply portion **104-2** is one example of second supply means for supplying a higher temperature fluid adjusted to a predetermined constant higher temperature. The lower temperature fluid **101-1** supplied from the lower temperature fluid supply portion **104-1** and the higher temperature fluid **101-2** supplied from the higher temperature fluid supply portion **104-2** are mixed under a state in which a mixture ratio between the lower temperature fluid **101-1** and the higher temperature fluid **101-2** is adjusted through a third three-way valve **109-1** for flow rate control to form a fluid for temperature control, and then the fluid for temperature control is fed through a supply pipe **103** to a temperature adjustment target device **102** being one example of temperature control target formed of, for example, an electrostatic chuck (ESC) configured to hold the temperature control target (workpiece) W.

[0103] The temperature adjustment target device **102** has a flow passage **135** for temperature control (see FIG. **3**) therein. The fluid for temperature control, which is obtained by mixing the lower temperature fluid and the higher temperature fluid at a desired mixture ratio and adjusting the mixture to a desired temperature, flows through the flow passage **135** for temperature control. On an outflow side of the flow passage **135** for temperature control, a fourth three-way valve **109-2** for flow rate control is provided. The fourth three-way valve **109-2** for flow rate control is configured to distribute the fluid for temperature control, which has flowed through the flow passage **135** for temperature control, to the lower temperature fluid supply portion **104-1** and the higher temperature fluid supply portion **104-2** through a return pipe **112** at a desired ratio (distribution ratio).

[0104] The lower temperature fluid supply portion **104-1** includes a first bypass pipe **126-1**. Of the lower temperature fluid supplied from the lower temperature fluid supply portion **104-1** to the third three-way valve **109-1** for flow rate control through a lower-temperature-side mixing pipe **103-1**, a part of the lower temperature fluid prevented from being supplied to the third three-way valve **109-1** for flow rate control is returned to the lower temperature fluid supply portion **104-1** through the first bypass pipe **126-1**. On a supply side of the lower temperature fluid supply portion **104-1**, a fifth three-way valve **117-1** for flow rate control is provided. The fifth three-way valve **117-1** for flow rate control is configured to control a flow rate of the fluid for temperature control, which flows through the flow passage **135** for temperature control and is distributed by the fourth three-way valve **109-2** for flow rate control to the lower temperature fluid supply portion **104-1** through a lower-temperature-side distributing pipe **112-1**, and a flow rate of the lower temperature fluid, which is prevented from being supplied from the lower temperature fluid supply portion **104-1** to the third three-way valve **109-1** for flow rate control and is returned to the lower temperature fluid supply portion **104-1** through the first bypass pipe **126-1**.

[0105] Meanwhile, the higher temperature fluid supply portion **104-2** includes a fourth bypass pipe **126-2**. Of the higher temperature fluid supplied from the higher temperature fluid supply portion **104-2** to the third three-way valve **109-1** for flow rate control through a higher-temperature-side mixing pipe **103-2**, a part of the higher temperature fluid prevented from being supplied to the third three-way valve **109-1** for flow rate control is returned to the higher temperature fluid supply portion **104-2** through the fourth bypass pipe **126-2**. On a supply side of the higher temperature fluid supply portion **104-2**, a sixth three-way valve **117-2** for flow rate control is provided. The sixth three-way valve **117-2** for flow rate control is configured to control a flow rate of the fluid for temperature control, which flows through the flow passage **135** for temperature control and is distributed by the fourth three-way valve **109-2** for flow rate control to the higher temperature fluid supply portion **104-2** through a higher-temperature-side distributing pipe **112-2**, and a flow rate of the higher temperature fluid, which is prevented from being supplied from the higher temperature fluid supply portion **104-2** to the fourth three-way valve **109-2** for flow rate control and is returned to the higher temperature fluid supply portion **104-2** through the second bypass pipe **126-2**. As the lower temperature fluid and the higher temperature fluid, the same heating medium (brine) is used.

[0106] As illustrated in FIG. **7**, the lower temperature fluid supply portion **104-1** includes a cooling-side brine temperature adjustment circuit **141** configured to adjust the brine to a predetermined constant lower temperature. A secondary side of an evaporator **134** is connected to the cooling-side brine temperature adjustment circuit **141** through intermediation of a lower-temperature-side circulating pipe **142**. A chiller circuit **143** is connected to a primary side of the evaporator **134**. The chiller circuit **143** is configured to cool the brine, which flows through the secondary side of the evaporator **134**, to a desired temperature. The chiller circuit **143** cools the brine flowing through the secondary side of the evaporator **134** to the desired temperature by expanding the heating medium condensed by a condenser **132** and feeding the heating medium to the primary side of the evaporator **134**. Further, the brine flowing through the chiller circuit **143** is condensed by the condenser **132**. External cooling water **145** is supplied to the condenser **132** through a cooling water pipe **144**.

[0107] Further, the higher temperature fluid supply portion **104-2** includes a heating-side brine temperature adjustment circuit **146** configured to adjust the brine to a predetermined constant higher temperature. The heating-side brine temperature adjustment circuit **146** has heating means such as a heater (not shown). A heat exchanger **148** is connected to the heating-side brine temperature adjustment circuit **146** through intermediation of a higher-temperature-side circulating pipe **147**. A fifth bypass pipe **149** is connected between the heating-side brine temperature adjustment circuit **146** and the heat exchanger **148**. The fifth bypass pipe **149** allows the heating medium flowing from the heating-side brine temperature adjustment circuit **146** to the heat exchanger **148** to flow to the heating-side brine temperature adjustment circuit **146**. Further, on an inflow side of the fifth bypass pipe **149**, a seventh three-way valve **151** for flow rate control is provided. The seventh three-way valve **151** for flow rate control is configured to control a flow rate of the fluid for temperature control supplied to the heat exchanger **148** and a flow rate of the fluid for temperature control caused to bypass the heat exchanger **148** and returned to the heating-side brine temperature adjustment circuit **146**. The external cooling water **145** is supplied to the heat exchanger **148** through the cooling water pipe **144**. The heat exchanger **148** cools the brine. For example, when a temperature of the higher temperature fluid flowing through the higher-temperature-side circulating pipe **147** is equal to or lower than a predetermined threshold value, the seventh three-way valve **151** for flow rate control adjusts an opening degree so as to return a part or entirety of the higher temperature fluid flowing through the higher-temperature-side circulating pipe **147** directly to the heating-side brine temperature adjustment circuit **146**.

<Basic Operation of Chiller Device>

[0108] The chiller device **100** basically operates as follows.

[0109] As illustrated in FIG. **8**, the chiller device **100** controls a temperature of the fluid for temperature control to be supplied to the temperature adjustment target device **102** to, for example, −30° C., −10° C., 10° C., and 50° C. in the plurality of steps in a stepwise manner. Here, the temperature of the lower temperature fluid supplied from the lower temperature fluid supply portion **104-1** is set to, for example, −30° C., which is equal to the lowest temperature among control temperatures in the plurality of steps. Further, the temperature of the higher temperature fluid supplied from the higher temperature fluid supply portion **104-2** is set to, for example, about 50° C., which is equal to the highest temperature among the control temperatures in the plurality of steps. However, in the embodiment, the temperature of the lower temperature fluid and the temperature of the higher temperature fluid are not limited to the lowest temperature and the highest temperature among the control temperatures in the plurality of steps. As a matter of course, the temperature of the lower temperature fluid and the temperature of the higher temperature fluid may be set to freely selected temperatures, for example, a temperature lower than the lowest temperature or the highest temperature among the control temperatures in the plurality of steps.

[0110] As illustrated in FIG. **9**, when the chiller device **100** controls the temperature of the fluid for temperature control to −30° C., which is the lowest temperature among the control temperatures in the plurality of steps, the chiller device **100** interrupts the higher temperature fluid flowing into the third three-way valve **109-1** for flow rate control through the higher-temperature-side mixing pipe **103-2** so as to set the flow rate of the higher temperature fluid to zero, and releases the lower temperature fluid flowing into the third three-way valve **109-1** for flow rate control through the lower-temperature-side mixing pipe **103-1** so as to set the flow rate of the lower temperature fluid to 100%. Further, the chiller device **100** interrupts the higher temperature fluid distributed from the fourth three-way valve **109-2** for flow rate control to the higher temperature fluid supply portion **104-2** through the higher-temperature-side distributing pipe **112-2** so as to set the distribution amount of the higher temperature fluid to zero, and releases the lower temperature fluid distributed from the fourth three-way valve **109-2** for flow rate control to the lower temperature fluid supply portion **104-1** through the lower-temperature-side distributing pipe **112-1** so as to set the distribution amount of the lower temperature fluid to 100%. Along with this, the chiller device **100** releases the higher temperature fluid returned by the sixth three-way valve **117-2** for flow rate control to the higher temperature fluid supply portion **104-2** through the second bypass pipe **123-2**, and returns all the higher temperature fluid supplied from the higher temperature fluid supply portion **104-2** to the higher temperature fluid supply portion **104-2**. Further, the chiller device **100** sets the flow rate of the lower temperature fluid returned by the fifth three-way valve **117-1** for flow rate control to the lower temperature fluid supply portion **104-1** through the first bypass pipe **123-1** to 50%, and supplies the 50% of the flow rate of the lower temperature fluid supplied from the lower temperature fluid supply portion **104-1** to the third three-way valve **109-1** for flow rate control.

[0111] As a result, the fluid for temperature control adjusted in temperature to −30° C. is supplied from the lower temperature fluid supply portion **104-1** to the flow passage **135** for temperature control of the temperature adjustment target device **102**, and the temperature of the temperature adjustment target device **102** is controlled to −30° C., which is the temperature of the fluid for temperature control including only the lower temperature fluid.

[0112] Further, as illustrated in FIG. **10**, when the chiller device **100** controls the temperature of the fluid for temperature control to 50° C., which is the highest temperature among the control temperatures in the plurality of steps, the chiller device **100** releases the higher temperature fluid flowing into the third three-way valve **109-1** for flow rate control through the higher-temperature-side mixing pipe **103-1** so as to set the flow rate of the higher temperature fluid to 100%, and interrupts the lower temperature fluid flowing into the third three-way valve **109-1** for flow rate control through the lower-temperature-side mixing pipe **103-2** so as to set the flow rate of the lower temperature fluid to zero. Further, the chiller device **100** releases the higher temperature fluid distributed from the fourth three-way valve **109-2** for flow rate control to the higher temperature fluid supply portion **104-2** through the higher-temperature-side distributing pipe **112-2** so as to set the distribution amount of the higher temperature fluid to 100%, and interrupts the lower temperature fluid distributed from the fourth three-way valve **109-2** for flow rate control to the lower-temperature fluid supply portion **104-1** through the lower-temperature-side distributing pipe **112-1** so as to set the distribution amount of the lower temperature fluid to zero. Along with this, the chiller device **100** interrupts the higher temperature fluid returned by the fourth three-way valve **109-2** for flow rate control to the higher temperature fluid supply portion **104-2** through the second bypass pipe **123-2**, and supplies all the higher temperature fluid supplied from the higher temperature fluid supply portion **104-2** to the third three-way valve **109-1** for flow rate control. Further, the chiller device **100** releases the lower temperature fluid returned by the fifth three-way valve **117-1** for flow rate control to the lower temperature fluid supply portion **104-1** through the first bypass pipe **123-1**, and returns all the lower temperature fluid supplied from the lower temperature fluid supply portion **104-1** to the lower temperature fluid supply portion **104-1**. Further, the chiller device **100** sets the flow rate of the lower temperature fluid returned by the sixth three-way valve **117-2** for flow rate control to the higher temperature fluid supply portion **104-2** through the second bypass pipe **123-2** to 50%, and returns 50% of the higher temperature fluid supplied from the higher temperature fluid supply portion **104-2** to the higher temperature fluid supply portion **104-2**.

[0113] As a result, the fluid for temperature control adjusted in temperature to 50° C. is supplied from the higher temperature fluid supply portion **104-2** to the flow passage **135** for temperature control of the temperature adjustment target device **102**, and the temperature of the temperature adjustment target device **102** is controlled to 50° C., which is the temperature of the fluid for temperature control including only the higher temperature fluid.

[0114] Moreover, as illustrated in FIG. **8**, when the chiller device **100** controls the temperature of the fluid for temperature control to −10° C. or 10° C. being an intermediate temperature among the control temperatures in the plurality of steps, the chiller device **100** adjusts the opening degree of the third three-way valve **109-1** for flow rate control in accordance with the intermediate temperature being a target temperature for the temperature adjustment target device **102**, and controls, to a desired value, the mixture ratio between the lower temperature fluid supplied from the lower temperature fluid supply portion **104-1** through the lower-temperature-side mixing pipe **103-1** and the higher temperature fluid supplied from the higher temperature fluid supply portion **104-2** through the higher-temperature-side mixing pipe **103-2**. From the chiller device **100**, the fluid for temperature control, which includes the lower temperature fluid and the higher temperature fluid mixed together in accordance with the opening degree of the third three-way valve **109-1** for flow rate control, is supplied to the flow passage **135** for temperature control of the temperature adjustment target device **102**. Further, the chiller device **100** adjusts the opening degree of the fourth three-way valve **109-2** for flow rate control, and controls the distribution ratio between the lower temperature fluid and the higher temperature fluid distributed to the lower temperature fluid supply portion **104-1** and the higher temperature fluid supply portion **104-2** in accordance with the mixture ratio between the lower temperature fluid and the higher temperature fluid mixed together in the third three-way valve **109-1** for flow rate control.

[0115] For example, when the mixture ratio between the lower temperature fluid and the higher temperature fluid in the third three-way valve **109-1** for flow rate control is 4:6, the opening degree of the fourth three-way valve **109-2** for flow rate control is controlled so that the same distribution ratio of 4:6 is obtained between the lower temperature fluid and the higher temperature fluid, and the fourth three-way valve **109-2** for flow rate control distributes the fluid for temperature control with such ratio to the lower temperature fluid supply portion **104-1** and the higher temperature fluid supply portion **104-2**.

[0116] Along with this, the chiller device **100** controls the flow rate of the higher temperature fluid returned by the sixth three-way valve **117-2** for flow rate control to the higher temperature fluid supply portion **104-2** through the second bypass pipe **123-2**, and thus returns the remaining higher temperature fluid, which is supplied from the higher temperature fluid supply portion **104-2** to the third three-way valve **109-1** for flow rate control, to the higher temperature fluid supply portion **104-2**. Similarly, the chiller device **100** controls the flow rate of the lower temperature fluid returned by the fifth three-way valve **117-1** for flow rate control to the lower temperature fluid supply portion **104-1** through the first bypass pipe **123-1**, and thus returns the remaining lower temperature fluid, which is supplied from the lower temperature fluid supply portion **104-1** to the third three-way valve **109-1** for flow rate control, to the lower temperature fluid supply portion **104-1**.

[0117] In the above-mentioned example, for example, when the mixture ratio between the lower temperature fluid and the higher temperature fluid in the third three-way valve **109-1** for flow rate control is 4:6, the sixth three-way valve **117-2** for flow rate control controls a ratio (flow rate ratio) between the higher temperature fluid returned to the higher temperature fluid supply portion **104-2** through the second bypass pipe **123-2** and the fluid for temperature control distributed by the fourth three-way valve **109-2** for flow rate control to the higher temperature fluid supply portion **104-2** to

4:**6**.

[0118] Similarly, in the above-mentioned example, for example, when the mixture ratio between the lower temperature fluid and the higher temperature fluid in the third three-way valve **109-1** for flow rate control is 4:6, the fifth three-way valve **117-1** for flow rate control controls a ratio (flow rate ratio) between the lower temperature fluid returned to the lower temperature fluid supply portion **104-1** through the first bypass pipe **123-1** and the fluid for temperature control distributed by the fourth three-way valve **109-2** for flow rate control to the lower temperature fluid supply portion **104-1** to **6**:**4**.

[0119] As a result, the fluid for temperature control, which is obtained by mixing the lower temperature fluid supplied from the lower temperature fluid supply portion **104-1** and the higher temperature fluid supplied from the higher temperature fluid supply portion **104-2** in accordance with the opening degree of the third three-way valve **109-1** for flow rate control, is supplied to the flow passage **135** for temperature control of the temperature adjustment target device **102**. Thus, a temperature of the temperature adjustment target device **102** is controlled to be equal to the temperature of the fluid for temperature control determined in accordance with the mixture ratio between the lower temperature fluid and the higher temperature fluid.

[0120] At this time, a control device **300** calculates a heat load H**2** of the temperature adjustment target device **102** by an arithmetic expression (3) based on flow rates Q of the fluids **101-1** and **101-2** for temperature control supplied to the temperature adjustment target device **102** via the third three-way valve **109-1** for flow rate control and the fourth three-way valve **109-2** for flow rate control and the results of detection performed by a first temperature sensor **110** and a second temperature sensor **111**.

[00004] $H2 = (m1 + m2)$ .Math. c .Math. t (3)

[0121] Here, as shown in FIG. **11**, each of the third three-way valve **109-1** for flow rate control and the fourth three-way valve **109-2** for flow rate control has a fluid distribution ratio with a substantially linear characteristic. Thus, for flow rates Qm of the fluids **101-1** and **101-2** for temperature control, when an opening degree of the third three-way valve **109-1** for flow rate control is set to x (1≥x≥0), a flow rate of one of the fluids is Qmx and a flow rate of another one of the fluids is Qm(**1**−x). The letter “m” is 1 or 2.

[0122] The control device **300** controls a frequency F**2** that determines the rpm of the second inverter motor **123** of the refrigerator **108** by an arithmetic expression (4) based on the heat load H**1** of the temperature adjustment target device **102**, which has been detected by the detection means **105**.

[00005] $F2 = ((H2 - b) / a)^{0.5}$ (4)

<Configurations of First to Seventh Three-Way Valves for Flow Rate Control>

[0123] As described above, the chiller device **100** includes the first to seventh three-way valves **109**, **1117**, **109-1**, **109-2**, **117-1**, **117-2**, and **151** for flow rate control. The first to seventh three-way valves **109**, **1117**, **109-1**, **109-2**, **117-1**, **117-2**, and **151** for flow rate control basically have the same configuration except that a relationship between an inflow port and an outflow port is reversed depending on arrangement. Here, the three-way motor valve to be used as the first three-way valve **109** for flow rate control as distribution means is described as a representative.

[0124] FIG. **12**(*a*), FIG. **12**(*b*), and FIG. **12**(*c*) are a front view, a left side view, and a bottom view for illustrating a three-way motor valve as one example of the three-way valve for flow rate control according to the first embodiment of the present invention. FIG. **13** is a sectional view taken along the line A-A of FIG. **12**(*b*), FIG. **14** is a sectional view taken along the line B-B of FIG. **12**(*a*), and FIG. **15** is a sectional perspective view for illustrating relevant parts of the three-way motor valve.

[0125] A three-way motor valve **1** is constructed as a rotary three-way valve. As illustrated in FIG. **12**, the three-way motor valve **1** mainly includes a valve portion **2** arranged at a lower portion thereof, an actuator **3** arranged at an upper portion thereof, and a sealing portion **4** and a coupling portion **5**, which are arranged between the valve portion **2** and the actuator **3**.

[0126] As illustrated in FIG. **13** to FIG. **15**, the valve portion **2** includes a valve main body **6** obtained by forming metal, for example, SUS, into a substantially rectangular parallelepiped shape. As illustrated in FIG. **13** and FIG. **14**, a first outflow port **7** and a first valve port **9** are formed in one side surface (left side surface in the illustrated example) of the valve main body **6**. The first outflow port **7** allows outflow of a fluid. The first valve port **9** as one example of a communication port has a rectangular cross section, and communicates with a valve seat **8** having a columnar space.

[0127] In the first embodiment, instead of directly forming the first outflow port **7** and the first valve port **9** in the valve main body **6**, a first valve seat **70** as one example of a first valve port forming member having the first valve port **9**, and a first flow passage forming member **15** forming the first outflow port **7** are fitted to the valve main body **6**, thereby providing the first outflow port **7** and the first valve port **9**.

[0128] As illustrated in FIGS. **16**, the first valve seat **70** integrally includes a cylindrical portion **71** and a tapered portion **72**. The cylindrical portion **71** has a cylindrical shape and is provided outside the valve main body **6**. The tapered portion **72** has a tapered shape with a distal end having an outer diameter decreasing toward an inner side of the valve main body **6**. The first valve port **9** is formed in the tapered portion **72** of the first valve seat **70**, and has a rectangular prism shape having a rectangular cross section (square cross section in the first embodiment). Further, as described later, one end portion of the first flow passage forming member **15** forming the first outflow port **7** is inserted in a hermetically sealed state (sealed state) into the cylindrical portion **71** of the first valve seat **70**.

[0129] As a material for the first valve seat **70**, for example, a polyimide (PI) resin is used. Further, as a material for the first valve seat **70**, for example, so-called “super engineering plastic” can be used. The super engineering plastic has higher heat resistance and higher mechanical strength under a high temperature than ordinary engineering plastic. Examples of the super engineering plastic include, for example, polyether ether ketone (PEEK), polyphenylene sulfide (PPS), polyether sulfone (PES), polyamide imide (PAI), a liquid crystal polymer (LCP), polytetrafluoroethylene (PTFE), polychlorotrifluoroethylene (PCTFE), polyvinylidene fluoride (PVDF), or composite materials thereof. Further, as the material for the first valve sheet **70**, there may be used, for example, “TECAPEEK” (trademark) manufactured by Ensinger Japan Co., Ltd. serving as a PEEK resin material for cutting work, and “TECAPEEK TF 10 blue” (product name) having blending therein 10% PTFE, which is excellent in sliding property, can also be used.

[0130] As illustrated in FIG. **14** and FIG. **15**, a recess **75** is formed in the valve main body **6** by, for example, machining. The recess **75** has a shape corresponding to an outer shape of the first valve seat **70** and similar to the shape of the valve seat **70**. The recess **75** includes a cylindrical portion **75***a* corresponding to the cylindrical portion **71** of the first valve seat **70** and a tapered portion **75***b* corresponding to the tapered portion **72**. A length of the cylindrical portion **75***a* of the valve main body **6** is set larger than a length of the cylindrical portion **71** of the first valve seat **70**. As described later, the cylindrical portion **75***a* of the valve main body **6** forms a part of a first pressure applying portion **94**. The first valve seat **70** is fitted to the recess **75** of the valve main body **6** so as to be movable in a direction of moving close to and away from a valve shaft **34** serving as a valve body.

[0131] Under a state in which the first valve seat **70** is fitted to the recess **75** of the valve main body **6**, a slight gap is defined between an outer peripheral surface of the first valve seat **70** and the inner peripheral surface of the recess **75** of the valve main body **6**. A fluid having flowed into the valve seat **8** may leak and flow into a region around an outer periphery of the first valve seat **70** through the slight gap. Further, the fluid having leaked into the region around the outer periphery of the first valve seat **70** is led into the first pressure applying portion **94** being a space defined on an outer side of the cylindrical portion **71** of the first valve seat **70**. The first pressure applying portion **94** is configured to apply a pressure of the fluid to a surface **70***a* of the first valve seat **70** opposite to the valve shaft **34**. As described later, the fluid flowing into the valve seat **8** is a fluid flowing out through a second valve port **18** as well as a fluid flowing out through the first valve port **9**. The first pressure applying portion **94** is partitioned under a state in which the first flow passage forming member **15** hermetically seals the first pressure applying portion **94** with respect to the first outflow port **7**.

[0132] The pressure of the fluid, which is to be applied to the valve shaft **34** arranged inside the valve seat **8**, depends on a flow rate of the fluid determined by an opening/closing degree of the valve shaft **34**. The fluid flowing into the valve seat **8** also flows (leaks) through the first valve port **9** and the second valve port **18** into a slight gap defined between the valve seat **8** and an outer peripheral surface of the valve shaft **34**. Therefore, into the first pressure applying portion **94** adapted for the first valve seat **70**, not only the fluid flowing out through the first valve port **9** flows (leaks), but also the fluid flowing out the slight gap defined between the valve seat **8** and the outer peripheral surface of the valve shaft **34** and flowing in through the second valve port **18** flows (leaks).

[0133] As illustrated in FIG. **16**(*b*), a concave portion **74** is formed at a distal end of the tapered portion **72** of the first valve seat **70**. The concave portion **74** is one example of a gap reducing portion having an arc shape in plan view, which forms part of a curved surface of a columnar shape corresponding to the valve seat **8** having a columnar shape in the valve main body **6**. A curvature radius R of the concave portion **74** is set to a value substantially equal to a curvature radius of the valve seat **8** or a curvature radius of the valve shaft **34**. In order to prevent biting of the valve shaft **34** to be rotated inside the valve seat **8**, the valve seat **8** of the valve main body **6** defines a slight gap with respect to the outer peripheral surface of the valve shaft **34**. As illustrated in FIG. **17**, the concave portion **74** of the first valve seat **70** is fitted so as to protrude toward the valve shaft **34** side more than the valve seat **8** of the valve main body **6** or so as to be brought into contact with the outer peripheral surface of the valve shaft **34** under a state in which the first valve seat **70** is fitted to the valve main body **6**. As a result, a gap G between the valve shaft **34** and an inner surface of the valve seat **8** of the valve main body **6** being a member opposed to the valve shaft **34** is partially set to a value reduced by the protruding amount of the concave portion **74** of the first valve seat **70** as compared to that of a gap between the valve shaft **34** and another portion of the valve seat **8**. Thus, a gap G**1** between the concave portion **74** of the first valve seat **70** and the valve shaft **34** is set to a desired value (G**1**<G**2**) smaller than (or a gap narrower than) a gap G**2** between the valve shaft **34** and the inner surface of the valve seat **8**. The gap G**1** between the concave portion **74** of the first valve seat **70** and the valve shaft **34** may correspond to a state in which the concave portion **74** of the first valve seat **70** is brought into contact with the valve shaft **34**, that is, a state in which no gap is defined (the gap G**1**=0).

[0134] However, in a case in which the concave portion **74** of the first valve seat **70** is brought into contact with the valve shaft **34**, there is a fear in that driving torque of the valve shaft **34** is increased due to contact resistance of the concave portion **74** when the valve shaft **34** is driven to rotate. Accordingly, a contact degree of the concave portion **74** of the first valve seat **70** with the valve shaft **34** is adjusted in consideration of rotational torque of the valve shaft **34**. That is, the contact degree is adjusted to such an extent as to involve no increase in the driving torque of the valve shaft **34** or involve slight increase even when the driving torque is increased, and cause no trouble for rotation of the valve shaft **34**.

[0135] As illustrated in FIG. **14** and FIG. **15**, the first flow passage forming member **15** is made of metal such as SUS or a synthetic resin such as a polyimide (PI) resin, and has a cylindrical shape. The first flow passage forming member **15** has the first outflow port **7** formed therein to communicate with the first valve port **9** irrespective of shift of a position of the first valve seat **70**. About half of the first flow passage forming member **15**, which is positioned on the first valve seat **70** side, is formed as a small-thickness cylindrical portion **15***a* having a cylindrical shape with a relatively small thickness. Further, about half of the first flow passage forming member **15**, which is positioned on a side opposite to the first valve seat **70**, is formed as a large-thickness cylindrical portion **15***b* having a cylindrical shape with a larger thickness than a thickness of the cylindrical portion with a small thickness. An inner surface of the first flow passage forming member **15** has a cylindrical shape and penetrates the first flow passage forming member **15**. A flange portion **15***c* having an annular shape is formed between the small-thickness cylindrical portion **15***a* and the large-thickness cylindrical portion **15***b* on an outer periphery of the first flow passage forming member **15**. The flange portion **15***c* has a relatively large thickness and extends radially outward. An outer peripheral end of the flange portion **15***c* is arranged in contact with an inner peripheral surface of the recess **75** so as to be movable therealong.

[0136] As illustrated in FIG. **15**, a gap between the cylindrical portion **71** of the first valve seat **70** and the small-thickness cylindrical portion **15***a* of the first flow passage forming member **15** is hermetically sealed (sealed) by an spring energized seal **120**, which is one example of first sealing means. The spring energized seal **120** is made of a synthetic resin, has a substantially U-shaped cross section, and is urged in an opening direction by a spring member made of metal. As illustrated in FIGS. **16**, a stepped portion **73** for receiving the spring energized seal **120** therein is formed in an end portion of an inner peripheral surface of the cylindrical portion **71** of the first valve seat **70**, which is positioned on an outer side of the valve main body **6**.

[0137] As illustrated in FIGS. **18**, the spring energized seal **120** is an annular (ring-shaped) member arranged on the inner peripheral surface of the cylindrical portion **71** of the first valve seat **70** so as to extend along its entire periphery. The spring energized seal **120** includes a spring member **121** and a sealing member **122**. The spring member **121** is made of metal such as stainless steel and has a substantially U-shaped cross section. The sealing member **122** is made of a synthetic resin such as polytetrafluoroethylene (PTFE), has a substantially U-shaped cross section, and is urged in an opening direction by the spring member **121**. The spring member **121** is made of metal such as stainless steel, and has a substantially U-shaped cross section. An elastic modulus of the spring member **121** is adjusted by forming slits or grooves at constant intervals in a longitudinal direction or appropriately setting a thickness thereof. As illustrated in FIG. **18** and FIG. **19**, the sealing member **122** includes a proximal end portion **122***a* and two lip portions **122***b* and **122***c*. The proximal end portion **122***a* is arranged in a sealing direction so as to be positioned in a space to be sealed between the stepped portion **73** formed in the cylindrical portion **71** of the first valve seat **70** and the small-thickness cylindrical portion **15***a* of the first flow passage forming member **15**. The lip portions **122***b* and **122***c* extend from both ends of the proximal end portion **122***a* in the same direction (outward in an axial direction of the first valve seat **70**) along peripheral surfaces of the two members to be sealed, and are arranged in parallel so as to be opposed to each other. Distal ends of the two lip portions **122***b* and **122***c* define a space opened outward in the axial direction of the first valve seat **70**. An opening of the spring energized seal **120** is opened toward the first pressure applying portion **94** and receives a pressure applied by the first pressure applying portion **94**. As illustrated in FIG. **18**(*b*), a protruding portion **122***d* is formed on a distal end of one lip portion **122***b*. The protruding portion **122***d* protrudes inward with a thickness corresponding to the thickness of the spring member **121**, and prevents the spring member **121** from being released therefrom. A distal end portion **122***b*′ of the lip portion **122***b* and a distal end portion **122***c*′ of the lip portion **122***c* each have a curved arc-like shape with an outer peripheral surface that starts protruding outward in its middle toward its distal end. The distal end portion **122***b*′ of the lip portion **122***b* and the distal end portion **122***c*′ of the lip portion **122***c* are in close contact with an inner peripheral surface of the first valve seat **70** and an outer peripheral surface of the first flow passage forming member **15** to thereby increase a degree of hermetical sealing.

[0138] The spring member **121** of the spring energized seal **120** is not limited to a spring member having a substantially U-shaped cross section. The spring member **121** may be, as illustrated in FIG. **20**, a spring member obtained by forming a band-shaped metal into a helical shape with a circular cross section or an elliptical cross section.

[0139] When the pressure of the fluid is not applied to the spring energized seal **120** or the pressure of the fluid is relatively low, the spring energized seal **120** hermetically seals the gap between the first valve seat **70** and the first flow passage forming member **15** with an elastic restoration force of the spring member **121**. Meanwhile, when the pressure of the fluid is relatively high, the spring energized seal **120** hermetically seals the gap between the first valve seat **70** and the first flow passage forming member **15** with the elastic restoration force of the spring member **121** and the pressure of the fluid. Thus, even when the fluid flows into the first pressure applying portion **94** through the gap between the inner peripheral surface of the valve main body **6** and the outer peripheral surface of the first valve seat **70**, the gap between the first valve seat **70** and the first flow passage forming member **15** is sealed by the spring energized seal **120** and thus the fluid does not flow into the first flow passage forming member **15**.

[0140] The spring energized seal **120** includes a combination of the spring member **121** made of metal and the sealing member **122** made of a synthetic resin. Not only the spring member **121** made of metal but also polytetrafluoroethylene (PTFE), which is a synthetic resin for forming the sealing member **122**, is excellent in heat resistance. Polytetrafluoroethylene can withstand long time of use at temperatures of about −85° C. as a lowest temperature and about 260° C. as a highest temperature.

[0141] As illustrated in FIG. **13** and FIG. **14**, the end surface **70***a* of the cylindrical portion **71** of the first valve seat **70** is a region (pressure-receiving surface) that receives the pressure of the fluid applied by the first pressure applying portion **94**.

[0142] In the first embodiment, the stepped portion **73** for allowing the spring energized seal **120** to be mounted therein is formed in the end surface **70***a* of the cylindrical portion **71** of the first valve seat **70**. Thus, the end surface **70***a* of the cylindrical portion **71** of the first valve seat **70** has a structure that is less liable to receive all the pressure of the fluid applied by the first pressure applying portion **94** because of the presence of the stepped portion **73**.

[0143] Thus, in the first embodiment, as illustrated in FIG. **13** and FIG. **14**, a first pressure-receiving plate **76** having an annular shape is provided so that the pressure of the fluid is effectively applied to the end surface **70***a* of the cylindrical portion **71** of the first valve seat **70** by the first pressure applying portion **94**. The first pressure-receiving plate **76** covers the end surface **70***a* of the cylindrical portion **71** of the first valve seat **70**, which includes the stepped portion **73** of the first valve seat **70**, to achieve closure. Specifically, the first pressure-receiving plate **76** is arranged in contact with the end surface **70***a* of the cylindrical portion **71** of the first valve seat **70** so as to close the stepped portion **73**. The first pressure-receiving plate **76** is made of the same material as that of the valve seat **70**. Further, a slight gap is set between an outer peripheral end surface of the first pressure-receiving plate **76** in its radial direction and the recess **75** of the valve main body **6** so as to allow the fluid to leak into the first pressure applying portion **94**.

[0144] Meanwhile, a gap between an end portion of the large-thickness cylindrical portion **15***b*, which is another end portion of the first flow passage forming member **15**, and the inner peripheral surface of the valve main body **6** is hermetically sealed (sealed) by a second spring energized seal **130**. The second spring energized seal **130** is one example of second sealing means that is made of a synthetic resin, has a substantially U-shaped cross section, and is urged in an opening direction by a spring member made of metal. As illustrated in FIGS. **16**, a cylindrical portion **75***c* that allows the spring energized seal **130** to be mounted therein is formed on the inner peripheral surface of the valve main body **6**. The cylindrical portion **75***c* having a short length is formed at an outer end portion of the cylindrical portion **75***a* of the recess **75** in the axial direction, and has an outer diameter slightly larger than that of the cylindrical portion **75***a* of the recess **75**. The length of the cylindrical portion **75***c* is set longer than a length of the second spring energized seal **130**.

[0145] A gap between the cylindrical portion **75***c* of the valve main body **6** and the large-thickness cylindrical portion **15***b* of the first flow passage forming member **15** is hermetically sealed (sealed) by the second spring energized seal **130**. The second spring energized seal **130** is opened toward the first pressure applying portion **94**. Specifically, the second spring energized seal **130** is arranged so that its opening receives the pressure of the fluid applied by the first pressure applying portion **94**. Although the second spring energized seal **130** has the outer diameter larger than that of the first spring energized seal **120**, the second spring energized seal **130** is basically constructed in the same manner as the first spring energized seal **120**.

[0146] A first wave washer (corrugated washer) **16** is provided on an outer side of the cylindrical portion **71** of the first valve seat **70** along an axial direction thereof. The first wave washer **16** is one example of an elastic member configured to elastically deform the first valve seat **70** to move in the direction of moving close to and away from the valve shaft **34** while allowing displacement of the first valve seat **70** in the direction of moving close to and away from the valve shaft **34**. As illustrated in FIGS. **21**, the first wave washer **16** is made of, for example, stainless steel, iron, or phosphor bronze, and has an annular shape having a desired width when a front side thereof is projected. Further, a side surface of the first wave washer **16** is formed into a wavy (corrugated) shape, and the first wave washer **16** is elastically deformable in a thickness direction thereof. An elastic modulus of the first wave washer **16** is determined by, for example, the thickness, a material, or the number of waves of the first wave washer **16**. The first wave washer **16** is received in the first pressure applying portion **94**.

[0147] Moreover, a first adjusting ring **77** is arranged on an outer side of the first wave washer **16**. The first adjusting ring **77** is one example of an annular adjusting member configured to adjust the gap G**1** between the valve shaft **34** and the concave portion **74** of the first valve seat **70** via the first wave washer **16**. As illustrated in FIG. **22**, the first adjusting ring **77** is made of metal such as SUS or a synthetic resin such as a polyimide (PI) resin having heat resistance, and is formed of a cylindrical member having a relatively small length and a male thread **77***a* formed in an outer peripheral surface thereof. Recessed grooves **77***b* are formed in an outer end surface of the first adjusting ring **77** so as to be 180 degrees opposed to each other. When the first adjusting ring **77** is fastened and fitted into a first female thread portion **78** formed in the valve main body **6**, a jig (not shown) for adjusting a fastening amount is locked to the recessed grooves **77***b* so as to turn the first adjusting ring **77**.

[0148] As illustrated in FIG. **15**, the first female thread portion **78** for fitting the first adjusting ring **77** is formed in the valve main body **6**. A cylindrical portion **79** is formed at an opening end of the valve main body **6**. The cylindrical portion **79** has a short length and has an outer diameter substantially equal to an outer diameter of the first adjusting ring **77**. Further, a cylindrical portion **75***d* for processing is formed between the first female thread portion **78** and the cylindrical portion **75***c* of the valve main body **6**. The cylindrical portion **75***d* for processing has a short length and an inner diameter larger than that of the first female portion **78** so as to allow processing for forming the first female portion **78** having a required length.

[0149] The first adjusting ring **77** is configured to adjust an amount (distance) of pushing and moving the first valve seat **70** inward by the first adjusting ring **77** through adjustment of a fastening amount of the first adjusting ring **77** with respect to the first female thread portion **78** of the valve main body **6**. When the fastening amount of the first adjusting ring **77** is increased, as illustrated in FIG. **17**, the first valve seat **70** is pushed by the first adjusting ring **77** via the first wave washer **16** and the first pressure-receiving plate **76** so that the concave portion **74** protrudes from an inner peripheral surface of the valve seat **8** and is displaced in a direction of approaching the valve shaft **34**. Thus, the gap G**1** between the concave portion **74** and the valve shaft **34** is reduced. Further, when the fastening amount of the first adjusting ring **77** is set to a small amount in advance, the distance of pushing and moving the first valve seat **70** by the first adjusting ring **77** is reduced. As a result, the first valve seat **70** is arranged apart from the valve shaft **34**, and the gap G**1** between the concave portion **74** of the first valve seat **70** and the valve shaft **34** is relatively increased. The male thread **77***a* of the first adjusting ring **77** and the first female thread portion **78** of the valve main body **6** are each set to have a small pitch. With this configuration, a protruding amount of the first valve seat **70** can be finely adjusted.

[0150] Further, as illustrated in FIG. **13**, a first flange member **10** as one example of a connecting member, which is configured to connect a pipe, or the like (not shown), for allowing outflow of the fluid, is mounted to one side surface of the valve main body **6** with four hexagon socket head cap screws **11**. In FIG. **12**(*b*), a reference symbol **11***a* denotes a screw hole in which the hexagon socket head cap screw **11** is fastened. Similarly to the valve main body **6**, the first flange member **10** is made of metal, for example, SUS. The first flange member **10** includes a flange portion **12**, an insertion portion **13**, and a pipe connecting portion **14**. The flange portion **12** has a side surface having substantially the same rectangular shape as the side surface of the valve main body **6**. The insertion portion **13** has a cylindrical shape having a short length and protrudes from an inner surface of the flange portion **12**. The pipe connecting portion **14** has a substantially cylindrical shape having a large thickness and protrudes from an outer surface of the flange portion **12**. A pipe (not shown) is connected to the pipe connecting portion **14**. As illustrated in FIG. **13**, a space between the flange portion **12** of the first flange member **10** and the valve main body **6** is sealed by an O-seal **13***a*. A recessed groove **13***b* configured to receive the O-seal **13***a* is formed in an inner peripheral surface of the flange portion **12** of the first flange member **10**. An inner periphery of the pipe connecting portion **14** is set to, for example, Rc ½ being a standard for a tapered female thread having a bore diameter of about 21 mm, or a female thread having a diameter of about 0.58 inches. The shape of the pipe connecting portion **14** is not limited to the tapered female thread or the female thread. The pipe connecting portion **14** may have, for example, a tube fitting shape that allows a tube to be fitted thereto. The pipe connecting portion **14** may have any shape as long as the pipe connecting portion **14** enables outflow of a fluid through the first outflow port **7**.

[0151] Here, the O-seal **13***a* is a sealing member having an O-ring shape, which is obtained by fully covering an outer side of a spring member with an elastically deformable synthetic resin made of a Teflon (trademark) tetrafluoroethylene-hexafluoropropylene copolymer (FEP) or the like. The spring member is made of stainless steel or the like and formed into a helical shape with a circular cross section or an elliptical cross section. The O-seal **13***a* can maintain hermetical sealability even at a low temperature of about −85° C.

[0152] As illustrated in FIG. **13**, a second outflow port **17** and a second valve port **18** are formed in another side surface (right side surface in FIG. **13**) of the valve main body **6**. The second outflow port **17** allows outflow of a fluid. The second valve port **18** has a rectangular cross section as one example of communication port, and communicates with the valve seat **8** having the columnar space.

[0153] In the first embodiment, instead of directly forming the second outflow port **17** and the second valve port **18** in the valve main body **6**, the second outflow port **17** and the second valve port **18** are formed in a second valve seat **80** that forms the second valve port **18** as one example of the valve port forming member and a second flow passage forming member **25** that forms the second outflow port **17** are fitted to the valve main body **6**, thereby providing the second outflow port **17** and the second valve port **18**.

[0154] The second valve seat **80** has a configuration similar to the configuration of the first valve seat **70** as illustrated in FIG. **16** with the reference symbol of the second valve seat **80** put in parentheses. That is, the second valve seat **80** integrally includes a cylindrical portion **81** and a tapered portion **82**. The cylindrical portion **81** has a cylindrical shape and is provided outside the valve main body **6**. The tapered portion **82** has an outer diameter decreasing toward the inner side of the valve main body **6**. The second valve port **18** is formed in the tapered portion **82** of the second valve seat **80**, and has a rectangular prism shape having a rectangular cross section (square cross section in the first embodiment). Further, one end portion of the second flow passage forming member **25** forming the second outflow port **17** is arranged so as to be inserted in a hermetically sealed state into the cylindrical portion **81** of the second valve seat **80**.

[0155] As illustrated in FIG. **14**, a recess **85** is formed in the valve main body **6** by, for example, machining. The recess **85** has a shape corresponding to an outer shape of the second valve seat **80** and similar to the shape of the valve seat **80**. The recess **85** includes a cylindrical portion **85***a* corresponding to the cylindrical portion **81** of the second valve seat **80** and a tapered portion **85***b* corresponding to the tapered portion **82**. A length of the cylindrical portion **85***a* of the valve main body **6** is set larger than a length of the cylindrical portion **81** of the second valve seat **80**. As described later, the cylindrical portion **85***a* of the valve main body **6** forms a second pressure applying portion **96**. The second valve seat **80** is fitted to the recess **85** of the valve main body **6** so as to be movable in a direction of moving close to and away from a valve shaft **34** serving as a valve body.
[0156] Under a state in which the second valve seat **80** is fitted to the recess **85** of the valve main body **6**, a slight gap is defined between the second valve seat **80** and the recess **85** of the valve main body **6**. A fluid having flowed into the valve seat **8** can flow into a region around an outer periphery of the second valve seat **80** through the slight gap. Further, the fluid having flowed into the region around the outer periphery of the second valve seat **80** is led into the second pressure applying portion **96** being a space defined on an outer side of the cylindrical portion **81** of the second valve seat **80**. The second pressure applying portion **96** is configured to apply a pressure of the fluid to a surface **80***a* of the second valve seat **80** opposite to the valve shaft **34**. The fluid flowing into the valve seat **8** is a fluid flowing out through the first valve port **9** as well as a fluid flowing out through the second valve port **18**. The second pressure applying portion **98** is partitioned under a state in which the second flow passage forming member **25** seals the second pressure applying portion **98** with respect to the second outflow port **17**.
[0157] The pressure of the fluid, which is to be applied to the valve shaft **34** arranged inside the valve seat **8**, depends on a flow rate of the fluid determined by an opening/closing degree of the valve shaft **34**. The fluid flowing into the valve seat **8** also flows (leaks) through the first valve port **9** and the second valve port **18** into a slight gap defined between the valve seat **8** and an outer peripheral surface of the valve shaft **34**. Therefore, into the second pressure applying portion **96** adapted for the second valve seat **80**, not only the fluid flowing out through the second valve port **18** flows (leaks), but also the fluid flowing into the slight gap defined between the valve seat **8** and the outer peripheral surface of the valve shaft **34** and flowing out through the first valve port **9** flows (leaks). The second valve seat **80** is made of the same material as that of the first valve seat **70**.
[0158] As illustrated in FIG. **16**(*b*), a concave portion **84** is formed at a distal end of the tapered portion **82** of the second valve seat **80**. The concave portion **84** is one example of a gap reducing portion having an arc shape in plan view, which forms part of a curved surface of a columnar shape corresponding to the valve seat **8** having a columnar shape in the valve main body **6**. A curvature radius R of the concave portion **84** is set to a value substantially equal to a curvature radius of the valve seat **8** or a curvature radius of a valve shaft **34**. In order to prevent biting of the valve shaft **34** to be rotated inside the valve seat **8**, as described later, the valve seat **8** of the valve main body **6** defines a slight gap with respect to an outer peripheral surface of the valve shaft **34**. The concave portion **84** of the second valve seat **80** is fitted so as to protrude toward the valve shaft **34** side more than the valve seat **8** of the valve main body **6** or so as to be brought into contact with the outer peripheral surface of the valve shaft **34** under a state in which the second valve seat **80** is fitted to the valve main body **6**. As a result, a gap G between the valve shaft **34** and an inner surface of the valve seat **8** of the valve main body **6** being a member opposed to the valve shaft **34** is partially set to a value reduced by the protruding amount of the concave portion **84** of the second valve seat **80** as compared to that of a gap between the valve shaft **34** and another portion of the valve seat **8**. Thus, a gap G**3** between the concave portion **84** of the second valve seat **80** and the valve shaft **34** is set to a desired value (G**3**<G**2**) smaller than (or a gap narrower than) the gap G**2** between the valve shaft **34** and the inner surface of the valve seat **8**. Further, the gap G**3** between the concave

portion **84** of the second valve seat **80** and the valve shaft **34** may correspond to a state in which the concave portion **84** of the second valve seat **80** is brought into contact with the valve shaft **34**, that is, a state in which no gap is defined (the gap G**3**=0).

[0159] However, in a case in which the concave portion **84** of the second valve seat **80** is brought into contact with the valve shaft **34**, there is a fear in that driving torque of the valve shaft **34** is increased due to contact resistance of the concave portion **84** when the valve shaft **34** is driven to rotate. Accordingly, a contact degree of the concave portion **84** of the second valve seat **80** with the valve shaft **34** is adjusted in consideration of the rotational torque of the valve shaft **34**. That is, the contact degree is adjusted to such an extent as to involve no increase in the driving torque of the valve shaft **34** or involve slight increase even when the driving torque is increased, and cause no trouble for rotation of the valve shaft **34**.

[0160] As illustrated in FIG. **15**, the second flow passage forming member **25** is made of metal such as SUS or a synthetic resin such as a polyimide (PI) resin, and has a cylindrical shape. The second flow passage forming member **25** has the second outflow port **17** formed therein to communicate with the second valve port **18** irrespective of shift of a position of the second valve seat **80**. About half of the second flow passage forming member **25**, which is positioned on the second valve seat **80** side, is formed as a small-thickness cylindrical portion **25***a* having a cylindrical shape with a relatively small thickness. Further, about half of the second flow passage forming member **25**, which is positioned on a side opposite to the second valve seat **80**, is formed as a large-thickness cylindrical portion **25***b* having a cylindrical shape with a larger thickness than a thickness of the cylindrical portion with a small thickness. An inner surface of the second flow passage forming member **25** has a cylindrical shape and penetrates the second flow passage forming member **25**. A flange portion **25***c* having an annular shape is formed between the small-thickness cylindrical portion **25***a* and the large-thickness cylindrical portion **25***b* on an outer periphery of the second flow passage forming member **25**. The flange portion **25***c* has a relatively large thickness and extends radially outward. An outer peripheral end of the flange portion **25***c* is arranged in contact with an inner peripheral surface of the recess **85** so as to be movable therealong.

[0161] As illustrated in FIG. **13**, a gap between the cylindrical portion **81** of the second valve seat **80** and the small-thickness cylindrical portion **25***a* of the second flow passage forming member **25** is hermetically sealed (sealed) by a first spring energized seal **140**, which is one example of first sealing means. The first spring energized seal **140** is made of a synthetic resin, has a substantially U-shaped cross section, and is urged in an opening direction by a spring member made of metal. As illustrated in FIGS. **16**, a stepped portion **83** for receiving the first spring energized seal **140** therein is formed in an end portion of an inner peripheral surface of the cylindrical portion **81** of the second valve seat **80**, which is positioned on an outer side of the valve main body **6**.

[0162] As illustrated in FIGS. **18**, the first spring energized seal **140** is constructed in the same manner as the first spring energized seal **120**. The first spring energized seal **140** includes a spring member and a sealing member. When the pressure of the fluid is not applied to the first spring energized seal **140** or the pressure of the fluid is relatively low, the first spring energized seal **140** hermetically seals the gap between the second valve seat **80** and the second flow passage forming member **25** with an elastic restoration force of the spring member. Meanwhile, when the pressure of the fluid is relatively high, the first spring energized seal **140** hermetically seals the gap between the second valve seat **80** and the second flow passage forming member **25** with the elastic restoration force of the spring member and the pressure of the fluid. Thus, even when the fluid flows into the second pressure applying portion **96** through the gap between the inner peripheral surface of the valve main body **6** and the outer peripheral surface of the second valve seat **80**, the gap between the second valve seat **80** and the second flow passage forming member **25** is sealed by the first spring energized seal **140** and thus the fluid does not flow into the second flow passage forming member **25**.

[0163] As illustrated in FIG. **13** and FIG. **14**, the end surface **80***a* of the cylindrical portion **81** of the second valve seat **80** is a region (pressure-receiving surface) that receives the pressure of the fluid applied by the second pressure applying portion **96**.

[0164] In the first embodiment, the stepped portion **83** for allowing the first spring energized seal **140** to be mounted therein is formed in the end surface **80***a* of the cylindrical portion **81** of the second valve seat **80**. Thus, the end surface **80***a* of the cylindrical portion **81** of the second valve seat **80** has a structure that is less liable to receive all the pressure of the pressure of the fluid applied by the second pressure applying portion **96** because of the presence of the stepped portion **83**.

[0165] Thus, in the first embodiment, as illustrated in FIG. **13** and FIG. **14**, a second pressure-receiving plate **86** having an annular shape is provided so that the pressure of the fluid is effectively applied to the end surface **80***a* of the cylindrical portion **81** of the second valve seat **80** by the second pressure applying portion **96**. The second pressure-receiving plate **86** covers the end surface **80***a* of the cylindrical portion **81** of the second valve seat **80**, which includes the stepped portion **83** of the second valve seat **80**, to achieve closure. Specifically, the second pressure-receiving plate **86** is arranged in contact with the end surface **80***a* of the cylindrical portion **81** of the second valve seat **80** so as to close the stepped portion **83**. The second pressure-receiving plate **86** is made of the same material as that of the second valve seat **80**. Further, a slight gap is set between an outer peripheral end surface of the second pressure-receiving plate **86** in its radial direction and the recess **85** of the valve main body **6** so as to allow the fluid to leak into the second pressure applying portion **96**.

[0166] Meanwhile, a gap between an end portion of the large-thickness cylindrical portion **25***b*, which is another end portion of the second flow passage forming member **25**, and the inner peripheral surface of the valve main body **6** is hermetically sealed (sealed) by a second spring energized seal **150**. The second spring energized seal **150** is one example of second sealing means that is made of a synthetic resin, has a substantially U-shaped cross section, and is urged in an opening direction by a spring member made of metal. As illustrated in FIG. **15**, a cylindrical portion **85***c* that allows the second spring energized seal **150** to be mounted therein is formed on the inner peripheral surface of the valve main body **6**. The cylindrical portion **85***c* having a short length is formed at an outer end portion of the cylindrical portion **85***a* of the recess **85** in the axial direction, and has an outer diameter slightly larger than that of the cylindrical portion **85***a* of the recess **85**. The length of the cylindrical portion **85***c* is set longer than a length of the second spring energized seal **150**.

[0167] A gap between the cylindrical portion **85***c* of the valve main body **6** and the large-thickness cylindrical portion **25***b* of the second flow passage forming member **25** is hermetically sealed (sealed) by the second spring energized seal **150**. The second spring energized seal **150** is opened toward the second pressure applying portion **96**. Specifically, the second spring energized seal **150** is arranged so that its opening receives the pressure of the fluid applied by the second pressure applying portion **96**. Although the second spring energized seal **150** has the outer diameter larger than that of the first spring energized seal **140**, the second spring energized seal **150** is basically constructed in the same manner as the first spring energized seal **140**.

[0168] A second wave washer (corrugated washer) **26** is provided on an outer side of the cylindrical portion **81** of the second valve seat **80**. The second wave washer **26** is one example of an elastic member configured to push and move the second valve seat **80** in a direction of coming into contact with the valve shaft **34** while allowing displacement of the second valve seat **80** in a direction of moving close to and away from the valve shaft **34**. As illustrated in FIGS. **21**, the second wave washer **26** is made of, for example, stainless steel, iron, or phosphor bronze, and has an annular shape having a desired width when a front side thereof is projected. Further, a side surface of the second wave washer **26** is formed into a wavy (corrugated) shape, and the second wave washer **26** is elastically deformable in a thickness direction thereof. An elastic modulus of the second wave washer **26** is determined by, for example, the thickness, a material, or the number of waves of the second wave washer **26**. The second wave washer **26** equivalent to the first wave washer **16** is used.

[0169] Moreover, a second adjusting ring **87** is arranged on an outer side of the second wave washer **26**. The second adjusting ring **87** is one example of an adjusting member configured to adjust the gap G**3** between the valve shaft **34** and the concave portion **84** of the second valve seat **80** via the second wave washer **26**. As illustrated in FIG. **22**, the second adjusting ring **87** is made of a synthetic resin having heat resistance or metal, and is formed of a cylindrical member having a relatively small length and a male thread **87***a* formed in an outer peripheral surface thereof. Recessed grooves **87***b* are formed in an outer end surface of the second adjusting ring **87** so as to be 180 degrees opposed to each other. When the second adjusting ring **87** is fastened and fitted into a second female thread portion **88** formed in the valve main body **6**, a jig (not shown) for adjusting a fastening amount is locked to the recessed grooves **87***b* so as to turn the second adjusting ring **87**.

[0170] As illustrated in FIG. **15**, a second female thread portion **88** for fitting the second adjusting ring **87** is formed in the valve main body **6**. A cylindrical portion **89** is formed at an opening end of the valve main body **6**. The cylindrical portion **89** has a short length and has an outer diameter substantially equal to an outer diameter of the second adjusting ring **87**. Further, a cylindrical portion **85***d* for processing is formed between the second female thread portion **88** and the cylindrical portion **85***c* of the valve main body **6**. The cylindrical portion **85***d* for processing has a short length and an inner diameter larger than that of the second female portion **88** so as to allow processing for forming the second female portion **88** having a required length.

[0171] The second adjusting ring **87** is configured to adjust an amount (distance) of pushing and moving the second valve seat **80** inward by the second adjusting ring **877** via the second wave washer **26** through adjustment of a fastening amount of the second adjusting ring **87** with respect to the second female thread portion **88** of the valve main body **6**. When the fastening amount of the second adjusting ring **87** is increased, as illustrated in FIG. **17**, the second valve seat **80** is pushed by the second adjusting ring **87** via the second wave washer **26** so that the concave portion **84** protrudes from an inner peripheral surface of the valve seat **8** and is displaced in a direction of approaching the valve shaft **34**. Thus, the gap G**3** between the concave portion **84** and the valve shaft **34** is reduced. Further, when the fastening amount of the second adjusting ring **87** is set to a small amount in advance, the distance of pushing and moving the second valve seat **80** by the second adjusting ring **87** is reduced. As a result, the second valve seat **80** is arranged apart from the valve shaft **34**, and the gap G**3** between the concave portion **84** of the second valve seat **80** and the valve shaft **34** is relatively increased. The male thread **87***a* of the second adjusting ring **87** and the second female thread portion **88** of the valve main body **6** are each set to have a small pitch. With this configuration, a protruding amount of the second valve seat **80** can be finely adjusted.

[0172] As illustrated in FIG. **13**, a second flange member **19** as one example of a connecting member for connecting a pipe (not shown) which allows outflow of the fluid is mounted to the another side surface of the valve main body **6** with four hexagon socket head cap screws **20**. Similarly to the first flange member **10**, the second flange member **19** is made of metal, for example, SUS. The second flange member **19** has a flange portion **21**, an insertion portion **22**, and a pipe connecting portion **23**. The flange portion **21** has a side surface having the same rectangular shape as the side surface of the valve main body **6**. The insertion portion **22** has a cylindrical shape and protrudes from an inner surface of the flange portion **21**. The pipe connecting portion **23** has a substantially cylindrical shape having a large thickness and protrudes from an outer surface of the flange portion **21**. A pipe (not shown) is connected to the pipe connecting portion **23**. As illustrated in FIG. **2**, a space between the flange portion **21** of the second flange member **19** and the valve main body **6** is sealed by an O-seal **21***a*. An annular recessed groove **21***b* configured to receive the O-seal **21***a* is formed in an inner peripheral surface of the flange portion **21** of the second flange member **19**. An inner periphery of the pipe connecting portion **23** is set to, for example, Rc ½ being a standard for a tapered female thread having a bore diameter of about 21 mm, or a female thread having a diameter of about 0.58 inches. Similarly to the pipe connecting portion **14**, the shape of the pipe connecting portion **23** is not limited to the tapered female thread or the female thread. The pipe connecting portion **23** may have, for example, a tube fitting shape that allows a tube to be fitted thereto. The pipe connecting portion **23** may have any shape as long as the pipe connecting portion **23** enables outflow of a fluid through the second outflow port **17**.

[0173] Here, examples of a fluid (brine) include fluorine-based inert liquids such as Opteon (trademark: manufactured by Chemours-Mitsui Fluoroproducts Co., Ltd.) and Novec (trademark: manufactured by 3M company), which are adaptable and used, for example, at a pressure of from 0 MPa to 1 MPa and in a temperature range of from about −85° C. to about +120° C.

[0174] Further, as illustrated in FIG. **13**, in a lower end surface of the valve main body **6**, an inflow port **26***b* having a circular cross section as the third valve port is opened. The inflow port **26***b* allows inflow of a fluid. A third flange member **27** as one example of a connecting member for connecting a pipe (not shown) which allows inflow of the fluid is mounted to the lower end surface of the valve main body **6** with four hexagon socket head cap screws **28**. A cylindrical portion **26***a* is opened at a lower end portion of the inflow port **26***b*. The cylindrical portion **26***a* has an inner diameter larger than that of the inflow port **26***b* so as to allow the third flange member **27** to be mounted thereinto. The third flange member **27** includes a flange portion **29**, an insertion portion **30**, and a pipe connecting portion **31**. The flange portion **29** has a bottom surface having the rectangular shape. The insertion portion **30** has a cylindrical shape having a short length and protrudes from an inner surface of the flange portion **29** (see FIG. **13**). The pipe connecting portion **31** has a substantially cylindrical shape having a large thickness and protrudes from an outer surface of the flange portion **29**. A pipe (not shown) is connected to the pipe connecting portion **31**. As illustrated in FIG. **2**, a space between the flange portion **29** of the third flange member **27** and the valve main body **6** is sealed by an O-seal **29***a*. A recessed groove **29***b* configured to receive the O-seal **29***a* is formed in an inner peripheral surface of the flange portion **29** of the third flange member **27**. An inner periphery of the pipe connecting portion **31** is set to, for example, Rc ½ being a standard for a tapered female thread having a bore diameter of about 21 mm and a female thread having a diameter of about 0.58 inches. The shape of the pipe connecting portion **31** is not limited to the tapered female thread or the female thread. The pipe connecting portion **31** may have, for example, a tube fitting shape that allows a tube to be fitted thereto. The pipe connecting portion **31** may have any shape as long as the pipe connecting portion **31** enables inflow of a fluid through the inflow port **26***b*.

[0175] As illustrated in FIG. **14**, the valve seat **8** is formed in a center of the valve main body **6**. The valve seat **8** forms the first valve port **9** having a rectangular cross section and the second valve port **18** having a rectangular cross section when the first valve seat **70** and the second valve seat **80** are fitted to the valve main body **6**. The valve seat **8** has a space having a columnar shape corresponding to an outer shape of a valve body to be described later. Further, part of the valve seat **8** is formed by the first valve seat **70** and the second valve seat **80**. The valve seat **8** having a columnar shape is provided in a state of penetrating an upper end surface of the valve main body **6**. As illustrated in FIGS. **23**, the first valve port **9** and the second valve port **18** provided to the valve main body **6** are arranged in an axial symmetrical manner with respect to a center axis (rotation axis) C of the valve seat **8** having a columnar shape. More specifically, the first valve port **9** and the second valve port **18** are arranged so as to be orthogonal to the valve seat **8** having a columnar shape. One end edge of the first valve port **9** is opened in a position opposed to another end edge of the second valve port **18** through the center axis C, that is, in a position different by 180°. Further, another end edge of the first valve port **9** is opened in a position opposed to one end edge of the second valve port **18** through the center axis C, that is, in a position different by 180°. In FIGS. **13**, for convenience, illustration of a gap between the valve seat **8** and the valve shaft **34** is omitted.

[0176] Further, as illustrated in FIG. **13**, the first valve port **9** and the second valve port **18** are openings each having a rectangular cross section such as a square cross section and are formed through fitting through fitting of the first valve seat **70** and the second valve seat **80** to the valve main body **6** as described above. A length of one side of the first valve port **9** and the second valve port **18** is set to be smaller than a diameter of the first outflow port **7** and the second outflow port **17**. The first valve port **9** and the second valve port **18** have rectangular tube shape having a rectangular cross section inscribed in the first outflow port **7** and the second outflow port **17**.

[0177] As illustrated in FIGS. **24**, a valve shaft **34** as one example of the valve body has an outer shape obtained by forming metal, for example, SUS, into a substantially columnar shape. The valve shaft **34** mainly includes a valve body portion **35**, upper and lower shaft support parts **36** and **37**, a sealing portion **38**, and a coupling portion **39**, which are integrally provided. The valve body portion **35** functions as a valve body. The upper and lower shaft support parts **36** and **37** are provided above and below the valve body portion **35**, respectively, and support the valve shaft **34** in a freely rotatable manner. The sealing portion **38** includes the same components as those of the upper shaft support portion **36**. The coupling portion **39** is provided to an upper portion of the sealing portion **38**.

[0178] The upper and lower shaft support parts **36** and **37** each have a cylindrical shape having an outer diameter smaller than that of the valve body portion **35** and having an equal or a different diameter. As illustrated in FIG. **15**, the lower shaft support portion **37** is supported in a rotatable manner through intermediation of a bearing **41** serving as a bearing member by a lower end of the valve seat **8** provided to the valve main body **6**. An annular support portion **42** supporting the bearing **41** is provided at a lower portion of the valve seat **8**. The bearing **41**, the support portion **42**, and the inflow port **26***b* are set to have a substantially equal inner diameter, and are configured to allow inflow of the fluid for temperature control to an inside of the valve body portion **35** with little resistance.

[0179] Further, as illustrated in FIG. **13** and FIG. **24**(*b*), the valve body portion **35** has a cylindrical shape having an opening **44** formed therein. The opening **44** has a substantially half-cylindrical shape with an opening height Hg**2**, which is smaller than an opening height Hg**1** of the first and second valve ports **9** and **18**. A valve operating portion **45** having the opening **44** of the valve body portion **35** has a half-cylindrical shape (substantially half-cylindrical shape of a cylindrical portion excluding the opening **44**) with a predetermined central angle α (for example, 180°). The valve operating portion **45** is arranged in a freely rotatable manner in the valve seat **8** and held in non-contact with an inner peripheral surface of the valve seat **8** through a slight gap to prevent metal-to-metal biting. Accordingly, with the valve body portion **35** positioned above and below the opening **44** included, the valve operating portion **45** simultaneously switches the first valve port **9** from a closed state to an opened state and the second valve port **18** from an opened state to a closed state in a reverse direction. As illustrated in FIG. **13**, upper and lower valve shaft parts **46** and **47** arranged above and below the valve operating portion **45** each have a cylindrical shape having an outer diameter equal to that of the valve operating portion **45**, and are held in non-contact with the inner peripheral surface of the valve seat **8** in a freely rotatable manner through a slight gap. In an inside the valve operating portion **45**, and the upper and lower valve shaft parts **46** and **47**, a space **48** is provided in a state of penetrating the valve shaft **34** toward a lower edge thereof. The space **48** has a columnar shape.

[0180] Further, a cross section of each of both end surfaces **45***a* and **45***b* of the valve operating portion **45** in a circumferential direction (rotation direction), which is taken along a direction intersecting (orthogonal to) the center axis C, has a flat-surface shape. More specifically, as illustrated in FIGS. **24**, the cross section of each of the both end surfaces **45***a* and **45***b* of the valve operating portion **45** in the circumferential direction, which is taken along a direction intersecting the rotation axis C, has a flat-surface shape toward the opening **44**. A thickness of each of the both end surfaces **45***a* and **45***b* is set to, for example, an equal value of a thickness T of the valve operating portion **45**.

[0181] The cross section of each of the both end surfaces **45***a* and **45***b* of the valve operating portion **45** in the circumferential direction, which is taken along a direction intersecting the rotation axis C, is not limited to a flat-surface shape. Each of the both end surfaces **45***a* and **45***b* in the circumferential direction (rotation direction) may have a curved-surface shape.
[0182] As illustrated in FIGS. **25**, when the valve shaft **34** is driven to rotate to open and close the first and second valve ports **9** and **18**, in flows of the fluid, the both end surfaces **45***a* and **45***b* of the valve operating portion **45** in the circumferential direction are moved (rotated) so as to protrude from or retreat to the ends of the first and second valve ports **9** and **18** in the circumferential direction. Accordingly, the first and second valve ports **9** and **18** are switched from the opened state to the closed state, or from the closed state to the opened state. At this moment, it is desired that each of the both end surfaces **45***a* and **45***b* of the valve operating portion **45** in the circumferential direction have a cross section having a flat-surface shape so as to linearly change opening areas of the first and second valve ports **9** and **18** with respect to a rotation angle of the valve shaft **34**.
[0183] As illustrated in FIG. **13**, the sealing portion **4** hermetically seals (seals) the valve shaft **34** in a liquid-tight state so that the valve shaft **34** is rotatable with respect to the valve main body **6**. The sealing portion **4** includes the valve main body **6**, the valve shaft **34**, spring energized seals **160** and **170**, and a bearing member **180**. The spring energized seals **160** and **170** are each one example of sealing means that is made of a synthetic resin, has a substantially U-shaped cross section, and is urged in an opening direction by a spring member made of metal. The spring energized seals **160** and **170** are arranged between the valve main body **6** and the valve shaft **34** to seal a gap between the valve main body **6** and the valve shaft **34** in a liquid-tight manner. The bearing member **180** supports the valve shaft **34** so that the valve shaft **34** is rotatable with respect to a valve main body.
[0184] As illustrated in FIG. **13**, a recess portion **51** for support is formed at an upper end portion of the valve main body **6**. The recess portion **51** for support has a columnar shape and allows the valve shaft **34** to be rotatably supported. A cylindrical portion **51***b* having a large inner diameter is formed at an upper end of the recess portion **51** for support so as to be continuous with a tapered portion **51***a*. As described above, the upper valve shaft portion **46** of the valve shaft **34** is rotatably supported in a liquid-tight manner in a lower end portion of the recess portion **51** for support through intermediation of the bearing member **180**, which is one example of a bearing member, and the spring energized seals **160** and **170**.
[0185] As illustrated in FIGS. **12**, the coupling portion **5** is arranged between the valve main body **6**, in which the sealing portion **4** is provided, and the actuator **3**. The coupling portion **5** is configured to connect the valve shaft **34** and a rotation shaft shown), which allows the valve shaft **34** to be integrally rotated, to each other.
[0186] As illustrated in FIG. **13**, the coupling portion **5** includes a spacer member **59**, an adaptor plate **60**, and a coupling member **62**. The spacer member **59** is arranged between the sealing portion **4** and the actuator **3**. The adaptor plate **60** is fixed to an upper portion of the spacer member **59**. The coupling member **62** is accommodated in a space **61** having a columnar shape formed in a state of penetrating an inside of the spacer member **59** and the adaptor plate **60**, and connects the valve shaft **34** and the rotation shaft (not shown) to each other. The spacer member **59** is obtained by forming a synthetic resin such as a polyimide (PI) resin, into a rectangular tube shape, which has substantially the same shape in plan view as that of the part of the valve main body **6** and a relatively large height. The spacer member **59** is fixed to both the valve main body **6** and the adaptor plate **60** through means such as screw **59***b* fastening of the flange portion **59***a* provided on the lower end thereof. Further, as illustrated in FIG. **12**(*c*), the adaptor plate **60** is obtained by forming metal, for example, SUS, into a plate-like shape having a planar polygonal shape. The adaptor plate **60** is mounted to the base **64** of the actuator **3** in a fixed state with hexagon socket head cap screws **63**.
[0187] As illustrated in FIG. **24**(*a*), a recessed groove **65** is formed so as to penetrate an upper end of the valve shaft **34** in a horizontal direction. The valve shaft **34** is coupled and fixed to the

coupling member **62** by fitting a projecting portion **66** of the coupling member **62** into the recessed groove **65**. Meanwhile, a recessed groove **67** is formed in an upper end of the coupling member **62** so as to penetrate the coupling member **62** in a horizontal direction. The rotation shaft (not shown) is coupled and fixed to the coupling member **62** by fitting a projecting portion (not shown) into the recessed groove **67** of the coupling member **62**. The spacer member **59** includes an O-seal **190** at its upper end portion. When liquid leaks from the sealing portion **4**, the O-seal **190** prevents the liquid from reaching the actuator **3**.

[0188] As illustrated in FIGS. **12**, the actuator **3** includes the base **64** having a planar surface having a rectangular shape. A casing **90** is mounted to an upper portion of the base **64** with screws **91**. The casing **90** is constructed as a box body having a rectangular parallelepiped shape, which contains drive means including a stepping motor, an encoder, and the like. The drive means in the actuator **3** only needs to be capable of rotating the rotation shaft (not shown) in a desired direction with predetermined accuracy based on control signals, and configuration thereof is not limited. The drive means includes a stepping motor, a driving force transmission mechanism, and an angle sensor. The driving force transmission mechanism is configured to transmit a rotational driving force of the stepping motor to the rotation shaft through intermediation of driving force transmission means, for example, a gear. The angle sensor is, for example, an encoder or the like configured to detect a rotation angle of the rotation shaft.

[0189] In FIGS. **12**, a reference symbol **92** denotes a stepping motor-side cable, and a reference symbol **93** denotes an angle sensor-side cable. The stepping motor-side cable **92** and the angle sensor-side cable **93** are connected to a control device (not shown) configured to control the three-way motor valve **1**.

<Environmental Conditions>

[0190] As described above, the three-way motor valve **1** according to the first embodiment is constructed so as to be usable for a fluid having a temperature within a range of, for example, from about −85° C. to about +120° C., in particular, a significantly low temperature of about −85° C. Thus, it is desired that surrounding environmental conditions under which the three-way motor valve **1** is used be determined in consideration of the temperature range of from about −85° C. to about +120° C. Specifically, when a fluid at about −85° C. is allowed to flow through the three-way motor valve **1**, the valve main body **6** itself has a temperature equal to about −85° C., which is the temperature of the fluid. As a result, when a condition under which the three-way motor valve **1** is used is a humid environment containing water in air, the water in air adheres to the three-way motor valve **1** and is frozen. Thus, it is considered that the freezing may cause malfunction of the three-way motor valve **1**.

[0191] Accordingly, in the first embodiment, it is desired that an ambient humidity (relative humidity) be 0.10% or lower, preferably about 0.01% under an environment replaced with a nitrogen (N.sup.2−) gas as an environmental condition under which the three-way motor valve **1** is used.

<Motion of Three-Way Motor Valve>

[0192] When a fluid having a low temperature of about −85° C. is allowed to flow through the three-way motor valve **1** according to the first embodiment, a flow rate of the fluid is controlled in the following manner.

[0193] As illustrated in FIG. **15**, at the time of assembly or adjustment for use, in the three-way motor valve **1**, the first flange member **10** and the second flange member **19** are once removed from the valve main body **6** so that the adjusting rings **77** and **87** are exposed to the outside. Under this state, when the fastening amounts of the adjusting rings **77** and **87** with respect to the valve main body **6** are adjusted through use of the jig (not shown), as illustrated in FIG. **17**, the protruding amounts of the first valve seat **70** and the second valve seat **80** from the valve seat **8** of the valve main body **6** are changed. When the fastening amounts of the adjusting rings **77** and **87** with respect to the valve main body **6** are increased, the concave portions **74** of the first valve seat **70** or the concave portion **84** of the second valve seat **80** protrudes from the inner peripheral surface of the valve seat **8** of the valve main body **6** so that the gap G**1** between the outer peripheral surface of the valve shaft **34** and the concave portion **74** of the first valve seat **70** or the concave portion **84** of the second valve seat **80** is reduced. Accordingly, the outer peripheral surface of the valve shaft **34** is brought into contact with the concave portion **74** of the first valve seat **70** or the concave portion **84** of the second valve seat **80**. Meanwhile, when the fastening amounts of the adjusting rings **77** and **87** with respect to the valve main body **6** are reduced, a protruding length of the concave portion **74** of the first valve seat **70** or the concave portion **84** of the second valve seat **80** from the inner peripheral surface of the valve seat **8** of the valve main body **6** is reduced so that the gap G**1** between the outer peripheral surface of the valve shaft **34** and the concave portion **74** of the first valve seat **70** or concave portion **84** of the second valve seat **80** is increased.

[0194] In the first embodiment, for example, the gap G**1** between the outer peripheral surface of the valve shaft **34** and the concave portion **74** of the first valve seat **70** or the concave portion **84** of the second valve seat **80** is set to be smaller than 10 μm. However, the gap G**1** between the outer peripheral surface of the valve shaft **34** and the concave portion **74** of the first valve seat **70** or the concave portion **84** of the second valve seat **80** is not limited to the above-mentioned value. The gap G**1** may be set to a value smaller than the above-mentioned value, for example, may satisfy the gap G**1**=0 μm (contact state). Alternatively, the gap G**1** may be set to 10 μm or more.

[0195] As illustrated in FIG. **13**, in the three-way motor valve **1**, the fluid flows in from the third flange member **27** via pipes (not shown), and the fluid flows out from the first flange member **10** and the second flange member **19** via pipes (not shown). Further, as illustrated in FIG. **14**(*a*), for example, in an initial state before start of operation, the three-way motor valve **1** is brought into a state in which the valve operating portion **45** of the valve shaft **34** simultaneously closes (completely closes) the first valve port **9** and opens (completely opens) the second valve port **18**.

[0196] As illustrated in FIGS. **12**, in the three-way motor valve **1**, when the stepping motor (not shown) provided in the actuator **3** is driven to rotate by a predetermined amount, the rotation shaft (not shown) is driven to rotate in accordance with a rotation amount of the stepping motor. In the three-way motor valve **1**, when the rotation shaft is driven to rotate, the valve shaft **34** coupled and fixed to the rotation shaft is rotated by an angle equivalent to the rotation amount (rotation angle) of the rotation shaft. The valve operating portion **45** is rotated in the valve seat **8** along with the rotation of the valve shaft **34**. As illustrated in FIG. **23**(*a*), the one end surface **45***a* of the valve operating portion **45** in the circumferential direction gradually opens the first valve port **9**. As a result, the fluid flows into the valve seat **8** through the first inflow port **26***b*, and flows out from the first flange member **10** through the first outflow port **7**.

[0197] At this time, as illustrated in FIG. **25**(*a*), another end surface **45***b* of the valve operating portion **45** in the circumferential direction opens the second valve port **18**. Thus, the fluid having flowed in through the inflow port **26***b* flows into the valve seat **8** and is distributed in accordance with a rotation amount of the valve shaft **34**, and flows out from the second flange member **19** through the second outflow port **17**.

[0198] As illustrated in FIG. **25**(*a*), in the three-way motor valve **1**, when the valve shaft **34** is rotationally driven, the one end surface **45***a* of the valve operating portion **45** in the circumferential direction gradually opens the first valve port **9**. As a result, the fluid passes through the valve seat **8** and an inside of the valve shaft **34** and is supplied via the first valve port **9** and the second valve port **18** to an outside through the first outflow port **7** and the second outflow port **17**.

[0199] Further, in the three-way motor valve **1**, each of the both end surfaces **45***a* and **45***b* of the valve operating portion **45** in the circumferential direction has a cross section having a curved-surface shape or a flat-surface shape. Thus, the opening areas of the first and second valve ports **9** and **18** can be linearly changed with respect to the rotation angle of the valve shaft **34**. Further, it is conceivable that the fluid regulated in flow rate by the both end surfaces **45***a* and **45***b* of the valve operating portion **45** flow in a form of a nearly laminar flow. Therefore, the distribution ratio (flow

rate) between the fluid can be controlled with high accuracy in accordance with the opening areas of the first valve port **9** and the second valve port **18**.
[0200] In the three-way motor valve **1** according to the first embodiment, as described above, under an initial state, the valve operating portion **45** of the valve shaft **34** simultaneously closes (completely closes) the first valve port **9** and opens (completely opens) the second valve port **18**.
[0201] At this time, in the three-way motor valve **1**, when the valve operating portion **45** of the valve shaft **34** closes (completely closes) the first valve port **9**, ideally, the flow rate of the fluid should be zero.
[0202] However, as illustrated in FIG. **17**, in the three-way motor valve **1**, in order to prevent metal-to-metal biting of the valve shaft **34** into the inner peripheral surface of the valve seat **8**, the valve shaft **34** is provided in a freely rotatable manner so as to be held in non-contact with the valve seat **8** with a slight gap between the outer peripheral surface of the valve shaft **34** and the inner peripheral surface of the valve seat **8**. As a result, the slight gap G**2** is defined between the outer peripheral surface of the valve shaft **34** and the inner peripheral surface of the valve seat **8**. Accordingly, in the three-way motor valve **1**, even when the valve operating portion **45** of the valve shaft **34** closes (completely closes) the first valve port **9**, the flow rate of the fluid does not become zero, and a small amount of the fluid flows to the second valve port **18** side through the slight gap G**2** defined between the outer peripheral surface of the valve shaft **34** and the inner peripheral surface of the valve seat **8**.
[0203] Incidentally, in the three-way motor valve **1** according to the first embodiment, as illustrated in FIG. **17**, the first valve seat **70** and the second valve seat **80** include the concave portion **74** and the concave portion **84**, respectively. The concave portion **74** or the concave portion **84** protrudes from the inner peripheral surface of the valve seat **8** toward the valve shaft **34** side, thereby partially reducing the gap G**1** between the outer peripheral surface of the valve shaft **34** and the inner peripheral surface of the valve seat **8**.
[0204] Therefore, in the three-way motor valve **1**, in order to prevent metal-to-metal biting of the valve shaft **34** into the inner peripheral surface of the valve seat **8**, even when the valve shaft **34** is provided in a freely rotatable manner so as to be held in non-contact with the valve seat **8** with the slight gap between the outer peripheral surface of the valve shaft **34** and the inner peripheral surface of the valve seat **8**, inflow of the fluid through the first valve port **9** into the slight gap G**2** defined between the outer peripheral surface of the valve shaft **34** and the inner peripheral surface of the valve seat **8** is significantly restricted and suppressed by the gap G**1** that is a region corresponding to a partially reduced gap between the outer peripheral surface of the valve shaft **34** and the inner peripheral surface of the valve seat **8**.
[0205] Accordingly, the three-way motor valve **1** can significantly suppress leakage of the fluid when the three-way motor valve **1** completely closes the valve port as compared to a three-way motor valve that does not include the concave portions **74** and **84** formed to partially reduce the gap between the valve shaft **34** and the first valve seat **70**, which is opposed to the valve shaft **34**, and the gap between the valve shaft **34** and the second valve seat **80**, which is opposed to the valve shaft **34**.
[0206] Preferably, the three-way motor valve **1** according to the first embodiment can significantly reduce the gaps G**1** and G**2** through contact of the concave portion **74** of the first valve seat **70** and the concave portion **84** of the second valve seat **80** with the outer peripheral surface of the valve shaft **34**, thereby significantly suppressing leakage of the fluid when the three-way motor valve **1** completely closes the valve port.
[0207] Further, similarly, the three-way motor valve **1** can significantly suppress leakage and outflow of the fluid through the second valve port **18** to another first valve port **9** side even when the valve operating portion **45** of the valve shaft **34** closes (completely closes) the second valve port **18**.
[0208] Moreover, as illustrated in FIG. **14** and FIGS. **16**, in the first embodiment, the first pressure

applying portion **94** and the second pressure applying portion **96** are respectively provided to the surface **70***a* of the first valve seat **70** and the surface **80***a* of the second valve seat **80** that are opposite to the valve shaft **34**. The first pressure applying portion **94** and the second pressure applying portion **96** are configured to apply the pressure of the fluid through the slight gap between the outer peripheral surface of the valve shaft **34** and the inner peripheral surface of the valve seat **8**. Accordingly, as illustrated in FIG. **23**(*a*), in the three-way motor valve **1**, under a state in which an opening degree is 0%, that is, the first valve port **9** is nearly completely closed, and under a state in which the opening degree is 100%, that is, the first valve port **9** is nearly completely opened, when the first valve port **9** and the second valve port **18** are each brought closer to a completely closed state, an amount of outflow of the fluid through the first valve port **9** and the second valve port **18** is significantly reduced. Along with this, in the three-way motor valve **1**, in the valve port brought closer to a completely closed state, the pressure of the fluid flowing out through the first valve port **9** or the second valve port **18** is reduced. Thus, for example, when the opening degree is 0%, that is, the first valve port **9** is completely closed, the fluid having a pressure of about 700 KPa flows in through the inflow port **26***b*, and then flows out through the second valve port **18** while maintaining the pressure of about 700 KPa. At this time, on the side of the first valve port **9** that is nearly completely closed, a pressure on an outflow side is reduced to, for example, about 100 KPa. As a result, there is a difference in pressure of about 600 KPa between the second valve port **18** and the first valve port **9**.

[0209] Therefore, in the three-way motor valve **1** against which no countermeasures are taken, due to the difference in pressure between the second valve port **18** and the first valve port **9**, the valve shaft **34** is moved (displaced) to the side of the first valve port **9** under a relatively low pressure so that the valve shaft **34** is held in unbalanced contact with the bearing **41**. As a result, there is a fear in that driving torque is increased when the valve shaft **34** is driven to rotate in a direction of closing the valve shaft **34**, thereby causing operation malfunction.

[0210] In contrast, in the three-way motor valve **1** according to the first embodiment, as illustrated in FIG. **26**, the first pressure applying portion **94** and the second pressure applying portion **96** are respectively provided to the surface of the first valve seat **70** and the surface of the second valve seat **80** that are opposite to the valve shaft **34**. The first pressure applying portion **94** and the second pressure applying portion **96** are configured to apply, to the first valve seat **70** and the second valve seat **80**, the pressure of the fluid leaking through the slight gap between the outer peripheral surface of the valve shaft **34** and the inner peripheral surface of the valve seat **8**. Thus, in the three-way motor valve **1** according to the first embodiment, even when there is a difference in pressure between the second valve port **18** and the first valve port **9**, a relatively high pressure of the fluid is applied to the first pressure applying portion **94** and the second pressure applying portion **96** through the slight gap between the outer peripheral surface of the valve shaft **34** and the inner peripheral surface of the valve seat **8**. As a result, owing to the relatively high pressure of the fluid of about 100 KPa, which is applied to the first pressure applying portion **94**, the first valve seat **70** under a relatively low pressure of about 100 KPa is operated so as to restore the valve shaft **34** to a proper position. Therefore, the three-way motor valve **1** according to the first embodiment can prevent and suppress the valve shaft **34** from being moved (displaced) to the side of the first valve port **9** under a relatively low pressure due to the difference in pressure between the second valve port **18** and the first valve port **9**, can keep a state in which the valve shaft **34** is smoothly supported by the bearing **41**, and can prevent and suppress an increase in driving torque when the valve shaft **34** is driven to rotate in the direction of closing the valve shaft **34**.

[0211] Further, the three-way motor valve **1** according to the first embodiment similarly operates also under a state in which the first valve port **9** is nearly completely opened, that is, the second valve port **18** is nearly completely closed, and thus can prevent and suppress the increase in driving torque when the valve shaft **34** is driven to rotate.

[0212] Examples of a fluid (brine) used for the three-way motor valve **1** according to the first embodiment include fluorine-based inert liquids such as Opteon (trademark: manufactured by Chemours-Mitsui Fluoroproducts Co., Ltd.) and Novec (trademark: manufactured by 3M company), which are adaptable and used, for example, at a pressure of from 0 MPa to 1 MPa and in a temperature range of from about −85° C. to about +120° C.

[0213] When an outflow amount of the fluid having a temperature of about −85° C. is switched in the three-way motor valve **1**, a temperature of the valve main body **6** itself through which the fluid flows becomes equal to about −85° C.

[0214] In the three-way motor valve **1**, the first spring energized seals **120** and **140** and the second spring energized seals **130** and **150** are used so as to hermetically seal (seal) the gaps between the first valve seat **70** and the second valve seat **80** and the first flow passage forming member **15** and the second flow passage forming member **25** and the gaps between the first flow passage forming member **15** and the second flow passage forming member **25** and the valve main body **6**. Further, the first spring energized seals **120** and **140** and the second spring energized seals **130** and **150** are arranged so as to be opened toward the first pressure applying portion **94** and the second pressure applying portion **96**, respectively. Further, the first spring energized seal **120** includes a combination of the spring member **121** made of metal and the sealing member **122** made of a synthetic resin. Not only the spring member **121** made of metal but also polytetrafluoroethylene (PTFE), which is a synthetic resin for forming the sealing member **122**, is excellent in heat resistance. Thus, polytetrafluoroethylene can withstand long time of use at temperatures of about −85° C. as a lowest temperature and about 260° C. as a highest temperature. This applies to the other first spring energized seal **140** and the second spring energized seals **130** and **150**.

[0215] Thus, the three-way motor valve **1** according to the first embodiment can improve sealability to a fluid having a low temperature of about −85° C. in comparison to a case in which the first flow passage forming member and the second flow passage forming member, which are mounted to the valve main body **6** and form the first outflow port **7** and the second outflow port **17**, are not provided to the first pressure applying portion and the second pressure applying portion, the first flow passage forming member and the second flow passage forming member each having both ends in the longitudinal direction being sealed by the sealing means, which is made of a synthetic resin, has a substantially U-shaped cross section, and is urged in the opening direction by the spring member made of metal, and the gaps between the first valve seat **70** and the second valve seat **80** and the first flow passage forming member **15** and the second flow passage forming member **25** and the gaps between the first flow passage forming member **15** and the second flow passage forming member **25** and the valve main body **6** are sealed with O-rings.

[0216] Specifically, when the gaps between the first valve seat **70** and the second valve seat **80** and the first flow passage forming member **15** and the second flow passage forming member **25** and the gaps between the first flow passage forming member **15** and the second flow passage forming member **25** and the valve main body **6** are sealed with the first spring energized seals **120** and **140** and the second spring energized seals **130** and **150**, high sealability can be achieved even to a fluid having a low temperature of about −85° C. Further, the first spring energized seals **120** and **140** and the second spring energized seals **130** and **150** each have a relatively large contact area between the first valve seat **70** and the second valve seat **80** and the first flow passage forming member **15** and the second flow passage forming member **25** and between the first flow passage forming member **15** and the second flow passage forming member **25** and the valve main body **6**. Also in this regard, high sealability can be achieved.

INDUSTRIAL APPLICABILITY

[0217] The present invention can provide a temperature control device capable of controlling, with high accuracy, a temperature of a fluid for temperature control to be supplied to a temperature control target in comparison to a case in which there is not provided control means for controlling temperature adjustment performance of supply means based on a result of detection performed by detection means for detecting a heat load of the temperature control target.

REFERENCE SIGNS LIST
[0218] **100** temperature control device [0219] **101** fluid for temperature control [0220] **102** temperature adjustment target device [0221] **103** supply pipe [0222] **104** fluid supply portion [0223] **105** detection means [0224] **106** storage tank [0225] **109** first three-way valve for flow rate control [0226] **110** first temperature sensor [0227] **111** second temperature sensor [0228] **117** second three-way valve for flow rate control

Claims

1. A temperature control device, comprising: supply means for adjusting a fluid for temperature control to a predetermined temperature and then supplying the fluid for temperature control; detection means for detecting a heat load of a temperature control target to be supplied with the fluid for temperature control from the supply means, the detection means being arranged on the temperature control target side; and control means for controlling temperature adjustment performance of the supply means based on a result of detection performed by the detection means.
2. The temperature control device according to claim 1, wherein the detection means includes: a first three-way valve for flow rate control configured to split the fluid for temperature control from the supply means into the fluid for temperature control to be supplied to the temperature control target and the fluid for temperature control to be returned to the supply means without being supplied to the temperature control target; first temperature detection means for detecting a temperature of the fluid for temperature control to be supplied to the temperature control target by the first three-way valve for flow rate control; and second temperature detection means for detecting a temperature of the fluid for temperature control returned from the temperature control target.
3. The temperature control device according to claim 1, wherein the supply means includes: first supply means for supplying a lower temperature fluid adjusted to a first predetermined lower temperature; and second supply means for supplying a higher temperature fluid adjusted to a second predetermined higher temperature, and wherein the detection means includes: a second three-way valve for flow rate control configured to mix the lower temperature fluid supplied from the first supply means and the higher temperature fluid supplied from the second supply means while controlling a flow rate of the lower temperature fluid and a flow rate of the higher temperature fluid to form the fluid for temperature control and then supply the fluid for temperature control to the temperature control target; a third three-way valve for flow rate control configured to distribute the fluid for temperature control having flowed through the temperature control target to the first supply means and the second supply means while controlling a flow rate of the fluid for temperature control; first temperature detection means for detecting a temperature of the fluid for temperature control to be supplied to the temperature control target by the second three-way valve for flow rate control; and second temperature detection means for detecting a temperature of the fluid for temperature control returned from the temperature control target.
4. The temperature control device according to claim 1, wherein the control means controls the temperature adjustment performance of the supply means by increasing and decreasing a flow rate of a heat exchange medium that adjusts a temperature of the fluid for temperature control through intermediation of a heat exchanger in the supply means.
5. The temperature control device according to claim 2, wherein the control means calculates the heat load of the temperature control target based on a flow rate of the fluid for temperature control to be supplied to the temperature control target and results of detection performed by the first temperature detection means and the second temperature detection means, which are included in distribution information of the first three-way valve for flow rate control.
6. The temperature control device according to claim 5, wherein the control means controls temperature adjustment performance F**1** of the supply means based on a result H**1** of calculation of

the heat load of the temperature control target by an arithmetic expression:

$F1=((H1-b)/a)$.sup.0.5

7. The temperature control device according to claim 6, wherein the control means controls an rpm of a drive source configured to drive a chiller in the supply means.

8. The temperature control device according to claim 1, wherein the control means controls a distribution ratio at the first three-way valve for flow rate control.

9. The temperature control device according to claim 1, wherein the supply means includes a fourth three-way valve for flow rate control configured to split the fluid for temperature control from the supply means into the fluid for temperature control to be supplied to the temperature control target and the fluid for temperature control to be returned without being supplied to the temperature control target.

10. The temperature control device according to claim 9, wherein the control means controls a flow rate of the fluid for temperature control flowing into the fourth three-way valve for flow rate control to a constant value.

11. The temperature control device according to claim 1, wherein the supply means includes: a storage tank configured to store the fluid for temperature control returned from the temperature control target; and cooling means for cooling the fluid for temperature control stored in the storage tank.

12. The temperature control device according to claim 2, wherein the first three-way valve for flow rate control includes: an inflow port, which allows inflow of the fluid for temperature control; and a first valve port and a second valve port, which allow the fluid for temperature control flowing in through the inflow port to be split into the fluid for temperature control to be supplied to the temperature control target and the fluid for temperature control to be returned to the supply means without being supplied to the temperature control target.