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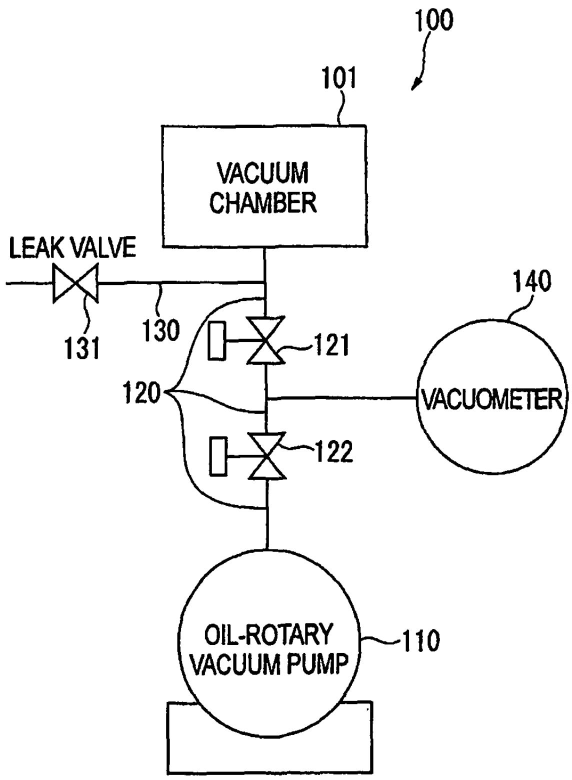
(54) **Vacuum-exhaust device and vacuum-exhaust method**

(57) In a vacuum-exhaust device, a pair of first and second on-off valves (121, 122) are provided in series between a vacuum chamber (101) and an oil-rotary vacuum pump (110). A vacuometer (140) for measuring a vacuum degree is provided between the pair of first and second on-off valves (121, 122). After storing a vacuum degree of the vacuum chamber (101) measured with the first on-off valve (121) being open, the controller closes the first on-off valve (121) and opens the second on-off valve (122) to obtain a vacuum degree in the vicinity of the oil-rotary vacuum pump (110). Then, the controller opens the first on-off valve (121) and the second on-off valve (122), so that the vacuum chamber (101) is evacuated by the driving of the oil-rotary vacuum pump (110). With this arrangement, while oil, oil vapor and the like from the oil-rotary vacuum pump (110) can be prevented from flowing into the vacuum chamber (101), the vacuum degree can be measured with the single vacuometer (140).

FIG. 1



EP 2 009 287 A2

Description

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

[0001] The present invention relates to a vacuum-exhaust device and a vacuum-exhaust method for evacuating a vacuum container using an oil-rotary vacuum pump.

2. DESCRIPTION OF RELATED ART

[0002] Various vacuum-exhaust devices for exhausting air from and forming a vacuum in (i.e., evacuating) high-vacuum requiring vacuum containers of devices such as scanning electron microscopes or space environmental testers by using oil-rotary pumps have been conventionally known.

[0003] According to a conventional arrangement of such a vacuum-exhaust device, oil, oil vapor and the like from an oil-rotary pump are prevented from counterflowing into a vacuum container (see, for instance, Document 1: JP-A-05-44643 or Document 2: JP-A-2003-157786).

[0004] The vacuum-exhaust device according to Document 1 includes: a turbo-molecular pump for highly evacuating a vacuum container, the turbo-molecular pump connected to the vacuum container via an inlet valve; and an oil-rotary pump connected in series to the turbo-molecular pump. The vacuum-exhaust device according to Document 1 further includes a container vacuometer for measuring a vacuum degree of the vacuum container and an exhaust vacuometer for measuring a vacuum degree of the turbo-molecular pump adjacent to the container. In the vacuum-exhaust device according to Document 1, a controller controls a driving of the turbo-molecular pump and the oil-rotary pump and opening and closing of an exhaust valve and the inlet valve.

[0005] However, with the arrangement of Document 1 in which two expensive vacuometers are required to be used, cost for the vacuum-exhaust device can be hardly reduced.

[0006] According to the arrangement of Document 2, an observation chamber of a scanning electron microscope, which is used for observing a sample, is linked with a spare chamber repeatedly changed between an atmospheric state and a vacuum state through a gate valve. In addition, an oil-rotary pump, which is connected to the observation chamber via a first rough-piping valve, is also connected to the spare chamber via a second rough-piping valve. According to Document 2, a vacuometer and an arrangement for introducing gas in a small amount are provided between the spare chamber and the second rough-piping valve.

[0007] However, according to Document 2, when opening or closing of the valve is erroneously operated, or when an excessively high vacuum that is beyond capabilities of the oil-rotary pump is formed in the spare chamber, oil, oil vapor and the like from the oil-rotary pump may counterflow into the spare chamber. In addition, since the vacuum-exhaust device according to Document 2 requires an arrangement for flowing gas to be separately provided and also requires gas to be constantly exhausted during observation, it may not be easy to simplify the arrangement of the vacuum-exhaust device or to reduce cost for observation.

[0008] As described above, it has been difficult to achieve simplification of arrangement and cost reduction in such conventional vacuum-exhaust devices as disclosed in Documents 1 and 2.

SUMMARY OF THE INVENTION

[0009] In view of such problems, an object of the present invention is to provide a vacuum-exhaust device and a vacuum-exhaust method capable of reducing device cost in a simplified arrangement.

[0010] A vacuum-exhaust device according to an aspect of the present invention is a vacuum-exhaust device connected to a vacuum container and adapted to evacuate the vacuum container, the vacuum-exhaust device including: an oil-rotary vacuum pump connected to the vacuum container and adapted to evacuate the vacuum container; a pair of on-off valves provided in series between the vacuum container and the oil-rotary vacuum pump; and a vacuometer positioned between the pair of on-off valves and adapted to measure a vacuum degree.

[0011] According to the aspect of the present invention, the pair of on-off valves are provided in series between the vacuum container and the oil-rotary vacuum pump for evacuating the vacuum container, and the vacuometer for measuring the vacuum degree is provided between the pair of on-off valves. By opening only the first on-off valve adjacent to the vacuum container, the vacuum degree of the vacuum container can be measured. By opening only the second on-off valve adjacent to the oil-rotary vacuum pump, the vacuum degree of the oil-rotary vacuum pump can be measured. Further, by opening both of the on-off valves, the vacuum container can be evacuated while the vacuum degree thereof during the evacuation can be measured.

[0012] Accordingly, while oil or oil vapor from the oil-rotary vacuum pump is prevented from flowing into the vacuum container, the vacuum degree can be suitably measured with a single vacuometer. Thus, a configuration of the vacuum-exhaust device can be simplified and cost for the vacuum-exhaust device can be reduced.

[0013] The vacuum-exhaust device according to the aspect of the present invention preferably further includes a controller that controls the pair of on-off valves to be opened or closed based on the vacuum degree measured by the vacuometer.

[0014] According to the aspect of the present invention, the controller controls the opening and closing of the pair of on-off valves based on the vacuum degree measured by the vacuometer.

[0015] With this arrangement, flowing of oil, oil vapor and the like from the oil-rotary vacuum pump into the vacuum container due to erroneous operations by an operator can be prevented. In addition, since the on-off valves are automatically opened and closed, workability of the vacuum-exhaust operation can be enhanced.

[0016] In the vacuum-exhaust device according to the aspect of the present invention, it is preferable that the controller controls a vacuum-exhaust operation so that: a first on-off valve provided adjacent to the vacuum container, when the oil-rotary vacuum pump is driven, is opened for a predetermined time so as to store container vacuum-degree data about a vacuum degree of the vacuum container measured by the vacuometer; the first on-off valve is closed, and a second on-off valve provided adjacent to the oil-rotary vacuum pump is subsequently opened so as to obtain pump vacuum-degree data about a vacuum degree in the vicinity of the oil-rotary vacuum pump measured by the vacuometer; and, when recognizing that the vacuum degree in the vicinity of the oil-rotary vacuum pump has become larger than the stored vacuum degree in the vacuum container by comparing the stored container vacuum-degree data with the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump measured by the vacuometer, the pair of on-off valves are opened after the vacuum degree in the vicinity of the oil-rotary vacuum pump is obtained.

[0017] According to the aspect of the present invention, when the oil-rotary vacuum pump is driven, the controller controls the vacuum-exhaust operation. Specifically, the controller opens the first on-off valve adjacent to the vacuum container to obtain the container vacuum-degree data about the vacuum degree of the vacuum container measured by the vacuometer, and subsequently closes the first on-off valve and opens the second on-off valve to obtain the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump measured by the vacuometer. Following the above, when recognizing that the vacuum degree in the vicinity of the oil-rotary vacuum pump has become larger than the vacuum degree in the vacuum container by comparing the stored container vacuum-degree data with the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump measured by the vacuometer, the controller opens both of the on-off valves, so that the vacuum container is evacuated by the driving of the oil-rotary vacuum pump.

[0018] With this arrangement, while oil, oil vapor and the like from the oil-rotary vacuum pump are prevented from flowing into the vacuum container, the vacuum container can be suitably evacuated with the single vacuometer 140 used.

[0019] The driving of the oil-rotary vacuum pump may be manually started, which may be recognized by the vacuum-exhaust device through power supply, operations of a power switch or the like. Alternatively, the driving of the oil-rotary vacuum pump may be automatically started when the vacuum-exhaust device recognizes a setting input (e.g., switch operation) for requesting the driving of the oil-rotary vacuum pump. In short, the oil-rotary vacuum pump may be automatically or manually driven.

[0020] In the vacuum-exhaust device according to the aspect of the present invention, it is preferable that the controller controls the second on-off valve to be open for a predetermined time when obtaining the pump vacuum-data about the vacuum degree in the vicinity of the oil-rotary vacuum pump measured by the vacuometer.

[0021] According to the aspect of the present invention, the controller opens the second on-off valve for the predetermined time to obtain the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump measured by the vacuometer. After obtaining the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump, the controller closes the second on-off valve once and subsequently opens the pair of on-off valves, so that the vacuum container is evacuated by the driving of the oil-rotary vacuum pump.

[0022] Accordingly, with a simple arrangement using the pair of on-off valves and the vacuometer, differences between the vacuum degree in the vicinity of the oil-rotary pump and the vacuum degree in the vicinity of the vacuum container can be easily recognized. In addition, even when both of the on-off valves are simultaneously opened, air containing oil, oil vapor and the like, which are harmful to the vacuum container, can be prevented from flowing into the vacuum container from the oil-rotary vacuum pump.

[0023] In the vacuum-exhaust device according to the aspect of the present invention, it is preferable that the controller opens the pair of on-off valves after obtaining the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump, and the controller closes the second on-off valve when recognizing that the vacuum degree of the vacuum container measured by the vacuometer has reached a predetermined vacuum degree.

[0024] According to the aspect of the present invention, after obtaining the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump, the controller opens the pair of on-off valves, so that the vacuum container is evacuated. Then, when the controller recognizes that the vacuum degree of the vacuum container measured by the vacuometer (i.e., the vacuum degree contained in the container vacuum-degree data) has reached a predetermined vacuum degree (e.g., a predetermined threshold), the controller closes the second on-off valve.

[0025] With this arrangement, even when the driving of the oil-rotary vacuum pump is stopped, not only oil, oil vapor and the like from the oil-rotary vacuum pump are prevented from flowing into the vacuum container, but also the vacuum formed in the vacuum container can be maintained for a longer time while being monitored by the vacuometer. In addition, since the driving of the oil-rotary vacuum pump can be stopped, cost for driving the oil-rotary vacuum pump to maintain the vacuum formed in the vacuum container can be reduced. Further, when, for instance, a calibration is conducted on a precision device using the vacuum container, complication of the calibration operation and reduction in accuracy of the calibration due to oscillation caused by the driving of the oil-rotary vacuum pump can be prevented by stopping the driving of the oil-rotary vacuum pump.

[0026] In the vacuum-exhaust device according to the aspect of the present invention, it is preferable that the controller controls the second on-off valve to be closed after the vacuum degree of the vacuum container has reached the predetermined vacuum degree, and subsequently controls the oil-rotary vacuum pump to stop driving.

[0027] According to the aspect of the present invention, the controller controls the second on-off valve to be closed after the vacuum degree of the vacuum container reaches the predetermined vacuum degree, and subsequently controls the oil-rotary vacuum pump to stop the driving. The controller may control the oil-rotary vacuum pump to automatically stop the driving, control the power supply to be blocked in accordance with a manual termination operation, or perform any other suitable control to stop the driving of the oil-rotary vacuum pump.

[0028] With this arrangement, it is possible to prevent the oil-rotary vacuum pump from being stopped while the vacuum container is communicated with the oil-rotary vacuum pump, thereby reliably preventing flowing of oil, oil vapor and the like from the oil-rotary vacuum pump into the vacuum container.

[0029] In the vacuum-exhaust device according to the aspect of the present invention, it is preferable that the controller controls a vacuum-re-exhaust operation so that: container vacuum-degree data about a vacuum degree of the vacuum container is stored when the stopped oil-rotary vacuum pump resumes driving due to a reduction in the vacuum degree of the container, the vacuum degree of the vacuum container being measured by the vacuometer with the first on-off valve being open while the second on-off valve being closed; the first on-off valve is closed after the container vacuum-degree data is stored, and the second on-off valve is subsequently opened so as to compare the stored container vacuum-degree data with pump vacuum-degree data about a vacuum degree in the vicinity of the oil-rotary vacuum pump sequentially measured by the vacuometer; and the first on-off valve is opened when the controller recognizes that the vacuum degree in the vicinity of the oil-rotary vacuum pump contained in the pump vacuum-degree data has become equal to or higher than the stored vacuum degree of the vacuum container.

[0030] According to the aspect of the present invention, when the vacuum degree of the vacuum container is reduced (i.e., the vacuum degree approximates to the atmospheric pressure), the stopped driving of the oil-rotary vacuum pump is resumed again. At this time, the controller controls the vacuum-re-exhaust operation. Specifically, the controller stores the container vacuum-degree data about the vacuum degree of the vacuum container, which is measured by the vacuometer with the first on-off valve being open while the second on-off valve being closed. Then, the controller closes the first on-off valve and subsequently opens the second on-off valve to obtain the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump, which is sequentially measured by the vacuometer. Following the above, the controller compares the stored container vacuum-degree data about the vacuum degree of the vacuum container with the pump vacuum-degree data about the sequentially-measured vacuum degree in the vicinity of the oil-rotary vacuum pump. When recognizing that the vacuum degree in the vicinity of the oil-rotary vacuum pump, which is sequentially measured by the vacuometer, becomes equal to or higher than the already-stored vacuum degree of the vacuum container, the controller opens the first on-off valve to open both of the on-off valves, so that the vacuum container can be evacuated again by the driving of the oil-rotary vacuum pump.

[0031] With this arrangement, also in the vacuum-re-exhaust operation, while oil, oil vapor and the like from the oil-rotary vacuum pump are prevented from flowing into the vacuum container, the vacuum container can be suitably evacuated with the single vacuometer used.

[0032] The vacuum-exhaust device according to the aspect of the present invention preferably further includes a leak portion provided in a branched manner between the vacuum container and the first on-off valve adjacent to the vacuum container , the leak portion including a leak valve adapted to equalize a pressure of a region between the vacuum container and the first on-off valve substantially with the atmospheric pressure when opened.

[0033] According to the aspect of the present invention, the leak portion having the leak valve for equalizing a pressure of the region between the vacuum container and the first on-off valve adjacent to the vacuum container substantially with the atmospheric pressure when opened is provided in a branched manner between the vacuum container and the first on-off valve.

[0034] With this arrangement, when the pressure of the evacuated vacuum container is returned to the atmospheric pressure, the leak valve is opened after the first on-off valve is opened, so that the pressure of the region between the vacuum container and the second on-off valve is equalized substantially with the atmospheric pressure. When the second on-off valve is subsequently opened, air in the vacuum container, in which a pressure has been equalized substantially with the atmospheric pressure, flows into the oil-rotary vacuum pump. Accordingly, the oil-rotary vacuum pump can be stopped after the air flows into the oil-rotary vacuum pump from the vacuum container. Thus, air containing harmful oil or oil vapor from the oil-rotary vacuum pump can be prevented from flowing into the vacuum container and the vacuometer via the second on-off valve. Accordingly, the pressure of the vacuum container can be favorably and easily equalized substantially with the atmospheric pressure with a simple arrangement.

[0035] In the vacuum-exhaust device according to the aspect of the present invention, it is preferable that the controller controls a leak operation so that: the leak valve is controlled to be opened after the second on-off valve adjacent to the oil-rotary vacuum pump is closed; the oil-rotary vacuum pump is controlled to stop driving when the controller recognizes that the vacuum degree of the vacuum container measured by the vacuometer has become substantially equal to the atmospheric pressure; and the second on-off valve is opened.

[0036] According to the aspect of the present invention, in order to control the leak operation by the controller, the leak valve is opened after the second on-off valve is closed. The leak valve may be manually opened, automatically opened by the controller, or opened by any other suitable method. When recognizing that the vacuum degree in the vacuum container measured by the vacuometer is substantially equal to the atmospheric pressure, the controller opens the second on-off valve, so that the pressure in the vicinity of the oil-rotary vacuum pump is equalized substantially with the atmospheric pressure. Then, the controller controls the oil-rotary vacuum pump to stop the driving. As described above, the oil-rotary vacuum pump may be automatically controlled to stop the driving, manually controlled to stop the driving with supply of the power being blocked by a manual termination operation, or controlled to stop the driving by any other suitable method..

[0037] With this arrangement, also in equalizing the pressure of the vacuum container substantially with the atmospheric pressure, while oil, oil vapor and the like from the oil-rotary vacuum pump are prevented from flowing into the vacuum container, the pressure of the vacuum container can be suitably equalized substantially with the atmospheric pressure with the single vacuometer used.

[0038] The vacuum-exhaust device according to the aspect of the present invention preferably further includes a leak portion provided in a branched manner between the pair of on-off valves, the leak portion including a leak valve adapted to equalize a pressure of a region between the pair of on-off valves substantially with the atmospheric pressure when opened.

[0039] According to the aspect of the present invention, the leak portion having the leak valve for equalizing the pressure of the region between the pair of on-off valves substantially with the atmospheric pressure when opened is provided in a branched manner between the pair of on-off valves.

[0040] With this arrangement, when the pressure of the evacuated vacuum container is equalized substantially with the atmospheric pressure, the leak valve is opened after the first on-off valve is opened, so that the pressure of the region between the vacuum container and the second on-off valve is equalized substantially with the atmospheric pressure. When the second on-off valve is subsequently opened, air in the vacuum container, in which the pressure has been equalized substantially with the atmospheric pressure, flows into the oil-rotary vacuum pump. Accordingly, the oil-rotary vacuum pump can be stopped after the air flows into the oil-rotary vacuum pump from the vacuum container. Thus, air containing harmful oil or oil vapor from the oil-rotary vacuum pump can be prevented from flowing into the vacuum container and the vacuometer via the second on-off valve. Accordingly, the pressure of the vacuum container can be favorably and easily equalized substantially with the atmospheric pressure with a simple arrangement.

[0041] In the vacuum-exhaust device according to the aspect of the present, it is preferable that the controller controls a leak operation so that: the leak valve is controlled to be opened and the first on-off valve adjacent to the container is controlled to be opened after the second on-off valve adjacent to the oil-rotary vacuum pump is closed; and the second on-off valve is controlled to be opened when the controller recognizes that the vacuum degree of the vacuum container measured by the vacuometer has become substantially equal to the atmospheric pressure.

[0042] According to the aspect of the present invention, in order to control the leak operation by the controller, the leak valve is opened after the second on-off valve is closed. The leak valve may be manually opened, automatically opened by the controller, or opened by any other suitable method. Then, the controller controls the first on-off valve to be opened. The first on-off valve may be manually opened or automatically opened by the controller. When the controller recognizes that the vacuum degree of the vacuum container measured by the vacuometer is substantially equal to the atmospheric pressure, the controller controls the second on-off valve to be opened, so that the pressure in the vicinity of the oil-rotary vacuum pump is equalized substantially with the atmospheric pressure. The second on-off valve may be manually opened or automatically opened by the controller.

[0043] With this arrangement, also in equalizing the pressure of the vacuum container substantially with the atmospheric pressure, while oil, oil vapor and the like from the oil-rotary vacuum pump are prevented from flowing into the vacuum container, the pressure of the vacuum container can be suitably equalized substantially with the atmospheric pressure with the single vacuometer used.

[0044] A vacuum-exhaust method according to another aspect of the present invention is a vacuum-exhaust method for evacuating a vacuum container, the method including: using: an oil-rotary vacuum pump adapted to evacuate the container via a pair of on-off valves provided in series; and a vacuometer positioned between the pair of on-off valves and adapted to measure a vacuum degree; opening a first on-off valve provided adjacent to the vacuum container for a predetermined time when the oil-rotary vacuum pump is driven, and storing container vacuum-degree data about a vacuum degree of the vacuum container measured by the vacuometer; closing the first on-off valve to subsequently open a second on-off valve provided adjacent to the oil-rotary vacuum pump after the vacuum degree of the vacuum container is stored, and obtaining pump vacuum-degree data about a vacuum degree in the vicinity of the oil-rotary vacuum pump measured by the vacuometer; and evacuating the vacuum container by the oil-rotary vacuum pump driven with the pair of on-off valves being open after the vacuum degree in the vicinity of the oil-rotary vacuum pump is obtained.

[0045] According to the aspect of the present invention, when the oil-rotary vacuum pump is driven, the vacuum-degree of the vacuum container is stored. Specifically, the vacuum degree is measured by the vacuometer with the first on-off valve adjacent to the vacuum container being open for a predetermined time while the second on-off valve adjacent to the oil-rotary pump being closed for the same predetermined time, and the measured vacuum degree is obtained and stored as the container vacuum-degree data about the vacuum degree of the vacuum container. After the vacuum degree of the vacuum container is stored, the vacuum degree in the vicinity of the oil-rotary vacuum pump is obtained. Specifically, the first on-off valve is closed and the second on-off valve adjacent to the oil-rotary vacuum pump is subsequently opened, so that the vacuum degree measured by the vacuometer is obtained as the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump. After the vacuum degree in the vicinity of the oil-rotary vacuum pump is obtained, the vacuum container is evacuated. Specifically, both of the on-off valves are opened, so that the vacuum container is evacuated by the driving of the oil-rotary vacuum pump.

[0046] With this arrangement, while oil, oil vapor and the like from the oil-rotary vacuum pump are prevented from flowing into the vacuum container, the vacuum container can be suitably evacuated with the single vacuometer used, thereby simplifying the arrangement of the vacuum-exhaust device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0047]

Fig. 1 is a block diagram schematically showing an arrangement of a vacuum-exhaust device according to a first exemplary embodiment of the present invention.

Fig. 2 is a timing chart showing operations in a vacuum-exhaust operation according to the first embodiment, in which: (A) is a graph showing vacuum pressure Pvc within a vacuum chamber; (B) is a graph showing vacuum pressure Pvp in an oil-rotary vacuum pump; (C) is a waveform chart showing a trigger signal; (D) is a waveform showing opening and closing of a first on-off valve; (E) is a waveform chart showing opening and closing of a second on-off valve; and (F) is a waveform showing timings at which vacuum degree measured by a vacuometer is read.

Fig. 3 is a timing chart showing operations in a vacuum re-exhaust operation according to the first embodiment, in which: (A) is a graph showing vacuum pressure Pvc within the vacuum chamber; (B) is a graph showing vacuum pressure Pvp in the oil-rotary vacuum pump; (C) is a waveform chart showing a trigger signal; (D) is a waveform showing opening and closing of the first on-off valve; (E) is a waveform chart showing opening and closing of the second on-off valve; and (F) is a waveform showing timings at which vacuum degree measured by a vacuometer is read.

Fig. 4 is a timing chart showing operations to stop the oil-rotary vacuum pump according to the first embodiment, in which: (A) is a graph showing vacuum pressure Pvc within the vacuum chamber, (B) is a graph showing vacuum pressure Pvp in the oil-rotary vacuum pump; (C) is a waveform chart showing a trigger signal; (D) is a waveform showing opening and closing of the first on-off valve; (E) is a waveform chart showing opening and closing of the second on-off valve; (F) is a waveform showing timings at which vacuum degree measured by a vacuometer is read; and (G) is a waveform showing opening and closing of a leak valve.

Fig. 5 is a timing chart showing operations in a leak operation according to the first embodiment, in which: (A) is a graph showing vacuum pressure Pvc within the vacuum chamber; (B) is a graph showing vacuum pressure Pvp in the oil-rotary vacuum pump; (C) is a waveform chart showing a trigger signal; (D) is a waveform showing opening and closing of the first on-off valve; (E) is a waveform chart showing opening and closing of the second on-off valve; (F) is a waveform showing timings at which vacuum degree measured by a vacuometer is read; (G) is a waveform showing opening and closing of the leak valve; and (H) is a waveform chart showing a trigger signal for opening and closing the leak valve.

Fig. 6 is a block diagram schematically showing an arrangement of a vacuum-exhaust device according to a second exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT(S)

[0048] A first exemplary embodiment of the present invention will be described below with reference to the attached drawings.

[0049] While a vacuum-exhaust device according to the present invention is exemplarily applied to, for instance, an optical interferometer in the first embodiment, the vacuum-exhaust device is applicable to structures having various vacuum containers for which vacuum evacuation is required.

[0050] Fig. 1 is a block diagram schematically showing an arrangement of a vacuum-exhaust device according to the present embodiment.

[Arrangement of Vacuum-Exhaust Device]

[0051] In Fig. 1, a vacuum-exhaust device, which is denoted by a numeral 100, is exemplarily applied to an optical interferometer (not shown). The vacuum-exhaust device 100 evacuates a vacuum chamber 101 that serves as a vacuum container for forming an interference portion of laser beams in the optical interferometer (i.e., the vacuum-exhaust device 100 exhausts air inside the vacuum chamber 101 to form a vacuum within the vacuum chamber 101).

[0052] The vacuum-exhaust device 100 includes an oil-rotary vacuum pump 110, an exhaust piping 120, a leak pipe 130 as a leak portion, a vacuometer 140 and a controller (not shown).

[0053] The oil-rotary vacuum pump 110 is connected to the vacuum chamber 101 via the exhaust piping 120. The oil-rotary vacuum pump 110 is driven to exhaust the air in the vacuum chamber 101 through the exhaust piping 120 so as to evacuate the vacuum chamber 101.

[0054] The oil-rotary vacuum pump 110 may be manually driven by power supplied from, for instance, a power supply (not shown) operated by a power switch, or may be automatically driven in a controllable manner with power supplied from a power supply being controlled by a controller adapted to recognize operations of the switch. Any driving method may be employed.

[0055] The exhaust piping 120, in which a pressure-resistant piping is exemplarily used, is connected to the vacuum chamber 101 at its first end while being connected to the oil-rotary vacuum pump 110 at its second end. The exhaust piping 120 is provided with a first on-off valve 121 and a second on-off valve 122. The first and second on-off valves 121, 122 form a pair in series. The first on-off valve 121 is located adjacent to the vacuum chamber 101 while the second on-off valve 122 is located adjacent to the oil-rotary vacuum pump 110.

[0056] The first on-off valve 121 and the second on-off valve 122 are exemplarily adapted to be electromagnetically opened and closed by a controller (i.e., adapted to be opened and closed by the controller). The first and second on-off valves 121, 122 each may be a so-called normal close valve, which is automatically closed when power supplied to the controller is blocked, or the like.

[0057] The leak pipe 130 as the leak portion, which may be, for instance, a pressure-resistant pipe as in the exhaust piping 120, is connected to the exhaust piping 120 at its first end to branch from between the vacuum chamber 101 and the second on-off valve 122 (i.e., connected to the exhaust piping 120 in a branched manner). On the other hand, a second end of the leak pipe 130 is a free end opened to the atmosphere.

[0058] The leak pipe 130 is provided with a leak valve 131. By opening the leak valve 131, the pressure of the exhaust piping 120 between the vacuum chamber 101 and the second on-off valve 122 is approximated to the atmospheric pressure.

[0059] The vacuometer 140 may be any one of various vacuometers for measuring vacuum degree as long as the vacuometer does not bring harmful effects such as air refraction on the laser beams in the optical interferometer. Examples of such a vacuometer are an ionization vacuum gauge and Pirani gauge.

[0060] The vacuometer 140 is disposed between the first on-off valve 121 and the second on-off valve 122 of the exhaust piping 120 so as to measure vacuum degree thereof. The vacuometer 140, which is connected to the controller, outputs data corresponding to the measured vacuum degree to the controller.

[0061] The controller, which exemplarily includes a central processing unit (CPU) and the like, controls the first on-off valve 121 and the second on-off valve 122 to be opened and closed in accordance with the vacuum degree measured by the vacuometer 140 in order to evacuate the vacuum chamber 101 or equalize the pressure of the vacuum chamber 101 substantially with the atmospheric pressure.

[0062] Specifically, the controller performs a vacuum-exhaust operation, a vacuum-re-exhaust operation and a leak operation. Based on a reference pulse such as internal clock, the controller obtains vacuum-degree data about the vacuum degree measured by the vacuometer 140. Specifically, when vacuum-degree data about the vacuum degree measured and output by the vacuometer 140 is input in the controller, the controller stores the data in a cache memory or the like for suitable computation.

[0063] In the vacuum-exhaust operation, the controller initially recognizes a signal requesting for the vacuum-exhaust operation (i.e., the signal requesting that the vacuum chamber 101 be evacuated) and opens the first on-off valve 121. Then, the vacuometer 140, which has been communicated with the vacuum chamber 101 via the exhaust piping 120 by the opening of the first on-off valve 121, measures the vacuum degree of the vacuum chamber 101, and the controller obtains the vacuum-degree data output by the vacuometer 140 as container vacuum-degree data to store the obtained container vacuum-degree data in a storage such as a random access memory (RAM). Subsequently, the controller closes the first on-off valve 121 while opening the second on-off valve 122, such that the vacuometer 140, which has been communicated with the oil-rotary vacuum pump 110 via the exhaust piping 120 by the opening of the second on-off valve 122, measures the vacuum degree in the vicinity of the oil-rotary vacuum pump 110, and the controller obtains the vacuum-degree data output by the vacuometer 140 as pump vacuum-degree data. The signal requesting for the vacuum-exhaust operation, which will be described later, may be a signal to the effect that a control signal from a controlling unit has been recognized, a signal to the effect that an actuation of the oil-rotary vacuum pump 110 has been recognized, or the like.

[0064] Following the above, the controller opens the first on-off valve 121 and the second on-off valve 122 to communicate the chamber 101 with the oil-rotary vacuum pump 110 via the exhaust piping 120, such that the oil-rotary vacuum pump 110 is driven to evacuate the vacuum chamber 101. When the controller recognizes that the vacuum degree of the vacuum chamber 101, which is sequentially measured by the vacuometer 140, has reached a predetermined threshold value, the controller closes the second on-off valve 122 and terminates the vacuum-exhaust operation so that the vacuum degree of the vacuum chamber 101 can be monitored through the vacuometer 140 and maintained at the threshold value irrespective of termination of the driving o the oil-rotary vacuum pump 110.

[0065] On the other hand, in the vacuum-re-exhaust operation, when the oil-rotary vacuum pump 110 under suspension is driven again due to reduction in the vacuum degree of the vacuum chamber 101 and the controller recognizes a signal requesting for the vacuum-re-exhaust operation (i.e., a signal requesting that the vacuum chamber 101 be evacuated again), the controller recognizes that the first on-off valve 121 is open while the second on-off valve 122 is closed. Then, the vacuometer 140, which is in communication with the vacuum chamber 101 via the exhaust piping 120, measures the vacuum degree of the vacuum chamber, such that the controller stores the measured vacuum degree in the storage. Incidentally, when recognizing that the first on-off valve 121 is open while the second on-off valve 122 is not closed in this operation, the controller switches the opening and closing of the first and second on-off valves 121, 122 such that the first on-off valve 121 is open while the second on-off valve 122 is closed.

[0066] After storing the vacuum degree of the vacuum chamber 101, the controller closes the first on-off valve 121 and opens the second on-off valve 122, so that the vacuometer 140 sequentially measures the vacuum degree in the vicinity of the oil-rotary vacuum pump 110. Then, the controller compares the stored vacuum degree of the vacuum chamber 101 with the sequentially-measured vacuum degree in the vicinity of the oil-rotary vacuum pump 110. When recognizing that the vacuum degree in the vicinity of the oil-rotary vacuum pump 110, which is sequentially measured by the vacuometer 140, becomes equal to or higher than the stored vacuum degree of the vacuum chamber 101, the controller opens the first on-off valve 121. Since both of the first on-off valve 121 and the second on-off valve 122 are open with the first on-off valve 121 being opened, the vacuum chamber 101 and the oil-rotary vacuum pump 110 are communicated with each other, such that the oil-rotary vacuum pump 110 is driven to evacuate the vacuum chamber 101 again.

[0067] In the leak operation, after the second on-off valve 122 is closed, the leak valve 131 is opened. The leak valve 131 may be manually opened, automatically opened by the controller, or opened by any other suitable method.

[0068] When recognizing that the vacuum degree of the vacuum chamber 101 measured by the vacuometer 140 is substantially equal to the atmospheric pressure, the controller opens the second on-off valve 122. With the second on-off valve 122 being opened, the pressure in the vicinity of the oil-rotary vacuum pump 110 is equalized substantially with the atmospheric pressure.

[0069] Then, the controller controls the oil-rotary vacuum pump 110 to terminate the driving. As described above, the controller may control the oil-rotary vacuum pump 110 to automatically terminate the driving, control the power supply to be blocked in accordance with a manual termination operation, or control the oil-rotary vacuum pump 110 to terminate the driving by any other suitable method.

[0070] As described above, the oil-rotary vacuum pump 110 is stopped after the second on-off valve 122 is opened, thereby reliably preventing contamination by air containing oil or oil vapor.

[0071] In addition, the controller is connected with, for instance, a controlling unit such as a personal computer for setting and controlling the entire operation of the optical interferometer. When an operator (i.e., a user of the optical interferometer) performs input operations on an input unit such as a keyboard of the controlling unit, the controlling unit issues various control signals based on various set signals respectively corresponding to the input operations. When the controller recognizes such control signal(s), the controller controls operations of the entire optical interferometer.

[Operation(s) of Vacuum-Exhaust Device]

[0072] Next, operations of the vacuum-exhaust device 100 will be described below with reference to the attached drawings.

(Vacuum-Exhaust Operation)

[0073] The vacuum-exhaust operation, which is one of the operations of the vacuum-exhaust device 100, will be described below with reference to the attached drawings.

[0074] While the oil-rotary vacuum pump 110 is exemplarily driven or stopped by manual operations of a user in the present embodiment, the oil-rotary vacuum pump 110 may be automatically driven or stopped by the controller in accordance with, for instance, an input operation for requesting the vacuum-exhaust operation.

[0075] Fig. 2 is a timing chart showing operations in the vacuum-exhaust operation, in which: (A) is a graph showing vacuum pressure Pvc within the vacuum chamber 101; (B) is a graph showing vacuum pressure Pvp in the oil-rotary vacuum pump 110; (C) is a waveform chart showing a trigger signal; (D) is a waveform showing opening and closing of the first on-off valve 121; (E) is a waveform chart showing opening and closing of the second on-off valve 122; and (F) is a waveform showing timings at which the vacuum degree measured by the vacuometer 140 is read.

[0076] Initially, for instance, a user of the optical interferometer switches on the oil-rotary vacuum pump 110 for driving while performing an input operation requesting for the vacuum-exhaust operation through the controlling unit so that the vacuum chamber 101 of the optical interferometer is evacuated. By this operation, the controlling unit outputs a control signal related to the request for the vacuum-exhaust operation as shown in Fig. 2(C).

[0077] As shown in Fig. 2(D), the controller, having recognized the control signal, controls the first on-off valve 121 to be open for a predetermined time. When the first on-off valve 121 is opened, the controller determines whether or not the second on-off valve 122 and the leak valve 131 are closed. When the second on-off valve 122 and the leak valve 131 are not closed, the controller closes the second on-off valve 122 and the leak valve 131 in advance. The leak valve 131 may be automatically switched to be closed by the control of the controller, or may be manually switched to be closed by a user. The controller may recognize that the leak valve 131 has been switched to be closed from a report issued when such a switching operation is conducted. In short, any automatic or manual method may be employed. When a manual method is employed, the vacuum-exhaust operation is preferably not initiated unless the controller recognizes that the leak valve 131 is switched to be closed. Then, with the first on-off valve 121 being opened, the exhaust piping 120 is communicated with the vacuum chamber 101.

[0078] After controlling the first on-off valve 121 to be switched to be opened, as shown in Fig. 2(F), the controller starts issuing reference pulse from which a trigger signal for obtaining the data about the vacuum degree measured by the vacuometer 140 is generated. When the reference pulse is issued while the first on-off valve 121 is open, the controller obtains the vacuum-degree data about the vacuum degree measured by the vacuometer 140. Specifically, the controller obtains the container vacuum-degree data obtained by the measurement of vacuum degree Pvc (i.e., vacuum pressure of the exhaust piping 120 communicated with the vacuum chamber 101) and stores the obtained container vacuum-degree data in the not-shown storage (see Fig. 2(A)).

[0079] After the container vacuum-degree data is stored, the controller closes the first on-off valve 121 and subsequently opens the second on-off valve 122 after a predetermined time is elapsed since the closure of the first on-off valve 121 as shown in Fig. 2(E). With the second on-off valve 122 being opened, the exhaust piping 120 is communicated with the oil-rotary vacuum pump 110. When the reference pulse is issued while the second on-off valve 122 is open, the controller obtains the vacuum-degree data about the vacuum degree measured by the vacuometer 140. Specifically, the controller obtains the pump vacuum-degree data obtained by the measurement of vacuum degree Pvp (i.e., vacuum pressure of the exhaust piping 120 communicated with the oil-rotary vacuum pump 110) and stores the obtained pump vacuum-degree data in the storage (see Fig. 2(B)).

[0080] After the pump vacuum-degree data is stored, the controller compares the container vacuum-degree data stored during the step for storing the vacuum degree of the vacuum container with the pump vacuum-degree data stored during the step for acquiring the vacuum degree of the oil-rotary vacuum pump. When recognizing that the vacuum degree in the vicinity of the oil-rotary vacuum pump 110 has become larger than the vacuum degree in the vacuum chamber 101, the controller opens the first on-off valve 121. As a processing after the pump vacuum-degree data is stored, for instance, the controller may close the second on-off valve 122 once and subsequently open both the first on-off valve 121 and the second on-off valve 122 in order to check the value of the vacuum degree measured by the vacuometer 140.

[0081] With the first and second on-off valves 121, 122 being opened, the oil-rotary vacuum pump 110 and the vacuum chamber 101 are communicated with each other via the exhaust piping 120. Then, the oil-rotary vacuum pump 110 is driven to exhaust the air in the vacuum chamber 101 to form a vacuum in the vacuum chamber 101 (i.e., evacuate the vacuum chamber 101). At the time of evacuating the vacuum chamber 101, the controller obtains the vacuum-degree data from the vacuometer 140 every reference pulse, and determines whether or not the measured vacuum degree has reached a vacuum degree Pm of a predetermined target value (e.g., the controller determines whether or not the measured vacuum degree has reached a value of 0.1 pa). When the controller recognizes that the vacuum degree of the vacuum chamber 101 has reached the vacuum degree Pm, i.e., the predetermined target threshold value (see Fig. 2(A) and (B)), measurement, observation or the like using the vacuum chamber 101 can be conducted.

[0082] When the controller recognizes the vacuum degree has reached the targeted vacuum degree Pm, the controller may close the second on-off valve 122 to control the oil-rotary vacuum pump 110 to stop the driving, thereby terminating the vacuum-exhaust operation. With this arrangement, unnecessary supply of power to the oil-rotary vacuum pump 110 can be prevented, thereby facilitating power saving. In addition, while the second on-off valve 122 is closed after the vacuum degree of the vacuum chamber 101 has reached the targeted vacuum degree Pm in the vacuum-exhaust operation according to the above arrangement, the second on-off valve 122 may not be closed.

(Vacuum-Re-Exhaust Operation)

[0083] The vacuum-re-exhaust operation, which is one of the operations of the vacuum-exhaust device 100, will be described below with reference to the attached drawings.

[0084] In an exemplary vacuum-re-exhaust operation, when the vacuum degree of the vacuum chamber 101 is reduced while the driving of the oil-rotary vacuum pump 110 is under suspension after the evacuation of the vacuum chamber 101, the stopped driving of the oil-rotary vacuum pump 110 is resumed so as to evacuate the vacuum chamber 101 again. As described above, while the oil-rotary vacuum pump 110 is exemplarily driven or stopped by manual operations of a user in the present embodiment, the oil-rotary vacuum pump 110 may be automatically driven or stopped by the controller in accordance with, for instance, an input operation for requesting the vacuum-exhaust operation.

[0085] Fig. 3 is a timing chart showing operations in the vacuum-re-exhaust operation, in which: (A) is a graph showing vacuum pressure Pvc in the vacuum chamber 101; (B) is a graph showing vacuum pressure Pvp in the oil-rotary vacuum pump 110; (C) is a waveform chart showing a trigger signal; (D) is a waveform showing opening and closing of the first on-off valve 121; (E) is a waveform chart showing opening and closing of the second on-off valve 122; and (F) is a waveform showing timings at which the vacuum degree measured by the vacuometer 140 is read.

[0086] Initially, for instance, a user of the optical interferometer switches on the oil-rotary vacuum pump 110 for driving while performing an input operation requesting for the vacuum-re-exhaust operation through the controlling unit so that the vacuum chamber 101 of the optical interferometer is evacuated again. By this operation, the controlling unit outputs a control signal related to the request for the vacuum-re-exhaust operation as shown in Fig. 3(C). The controller, having recognized the control signal, recognizes that the first on-off valve 121 is open while the second on-off valve 122 is closed. Then, the controller obtains the vacuum-degree data about the vacuum degree measured by the vacuometer 140 in accordance with the reference pulse (i.e., the controller obtain the container vacuum-degree data provided by the measurement of the vacuum degree Pvc of the exhaust piping 120 communicated with the vacuum chamber 101), and stores the obtained container vacuum-degree data in the storage (not shown) as shown in Fig. 3(A) and (F). Incidentally, when the first on-off valve 121 is opened while the second on-off valve 122 is not closed in this operation, the controller switches the opening and closing of the first and second on-off valves 121, 122 such that the first on-off valve 121 is open while the second on-off valve 122 is closed.

[0087] After the vacuum degree of the vacuum chamber 101 is stored, the controller initially closes the first on-off valve 121 (see Fig. 3(D)) and subsequently opens the second on-off valve 122 (see Fig. 3(E)). While the second on-off valve 122 is open, the controller obtains the vacuum-degree data about the vacuum degree measured by the vacuometer 140 in accordance with the reference pulse. Specifically, the controller sequentially obtains the pump vacuum-data provided by the measurement of the vacuum degree Pvp of the exhaust piping 120 communicated with the oil-rotary vacuum pump 110. Then, the controller compares the sequentially-obtained vacuum degree Pvp of the oil-rotary vacuum pump 110 with the already-stored vacuum data Pvc of the vacuum chamber 101. When recognizing that the vacuum degree Pvp in the vicinity of the oil-rotary vacuum pump 110, which is sequentially measured by the vacuometer 140, becomes equal to or higher than the already-stored vacuum degree Pvc of the vacuum chamber 101, the controller opens the first on-off valve 121.

[0088] As described above, when the controller controls the first on-off valve 121 to be opened, the controller may close the second on-off valve 122 once and subsequently open both of the first on-off valve 121 and the second on-off valve 122.

[0089] With both of the first on-off valve 121 and the second on-off valve 122 being open, the vacuum chamber 101 and the oil-rotary vacuum pump 110 are communicated with each other, such that the oil-rotary vacuum pump 110 is driven to evacuate the vacuum chamber 101 again. After the vacuum chamber 101 is evacuated again, the same operations as in the above-described vacuum-exhaust operation shown in Fig. 2 are performed.

(Stopping of Oil-Rotary Vacuum Pump for Calibration)

[0090] Operation(s) for stopping the oil-rotary vacuum pump 110 so as to conduct a calibration and the like, which is one of the operations of the vacuum-exhaust device 100, will be described below with reference to the attached drawings.

[0091] In view of a need to maintain a vacuum between the vacuum chamber 101 and the second on-off valve 122, the leak valve 131 is kept closed so as to more reliably maintain the vacuum. In addition, while operations for stopping the driving of the oil-rotary vacuum pump 110 in order to conduct a calibration is exemplarily described, the same operations are applied when, for instance, the driving of the oil-rotary vacuum pump 110 is stopped after the above-described vacuum-exhaust operation, vacuum-re-exhaust operation or the like in order to reduce a driving cost and the like.

[0092] Fig. 4 is a timing chart showing operations to stop the oil-rotary vacuum pump, in which: (A) is a graph showing vacuum pressure Pvc within the vacuum chamber 101; (B) is a graph showing vacuum pressure Pvp in the oil-rotary vacuum pump 110; (C) is a waveform chart showing a trigger signal; (D) is a waveform showing opening and closing of the first on-off valve 121; (E) is a waveform chart showing opening and closing of the second on-off valve 122; (F) is a waveform showing timings at which vacuum degree measured by the vacuometer 140 is read; and (G) is a waveform showing opening and closing of the leak valve 131.

[0093] Initially, for instance, a user of the optical interferometer performs an input operation requesting for stopping of the oil-rotary vacuum pump 110 through the controlling unit in order to conduct a calibration of the optical interferometer. By this operation, the controlling unit outputs a control signal related to the request for stopping of the oil-rotary vacuum pump 110 as shown in Fig. 4(C). The controller, having recognized the control signal, closes the second on-off valve 122 as shown in Fig. 4(E). With this operation, the exhaust piping 120, with which the vacuometer 140 is connected, is communicated only with the vacuum chamber 101. While the second on-off valve 122 is closed, the controller obtains the vacuum-degree data about the vacuum degree measured by the vacuometer 140 in accordance with the reference pulse while maintaining the monitoring of the vacuum degree Pvc of the vacuum chamber 101.

[0094] The controller subsequently performs operations necessary for stopping the oil-rotary vacuum pump 110. Specifically, the controller reports to a user by display or audio output that the oil-rotary vacuum pump 110 is allowed to be stopped, or automatically blocks the supply of power to the oil-rotary vacuum pump 110. Then, with the driving of the oil-rotary vacuum pump 110 being stopped, the pressure in the vicinity of the oil-rotary vacuum pump 110 gradually approximates to the atmospheric pressure.

(Leak Operation)

[0095] Next, the leak operation, which is one of the operations of the vacuum-exhaust device 100, will be described below with reference to the attached drawings.

[0096] In an exemplary leak operation, while the oil-rotary vacuum pump 110 is driven with the first and second on-off valves 121, 122 being open, the pressure of the vacuum chamber 101 is equalized substantially with the atmospheric pressure. As described above, while the oil-rotary vacuum pump 110 is exemplarily driven or stopped by manual operations of a user in the present embodiment, the oil-rotary vacuum pump 110 may be automatically driven or stopped by the controller in accordance with, for instance, an input operation for requesting the vacuum-exhaust operation.

[0097] Fig. 5 is a timing chart showing operations of the leak operation, in which: (A) is a graph showing vacuum pressure Pvc within the vacuum chamber 101; (B) is a graph showing vacuum pressure Pvp in the oil-rotary vacuum pump 110; (C) is a waveform chart showing a trigger signal; (D) is a waveform showing opening and closing of the first on-off valve 121; (E) is a waveform chart showing opening and closing of the second on-off valve 122; (F) is a waveform showing timings at which vacuum degree measured by a vacuometer 140 is read; (G) is a waveform showing opening and closing of the leak valve 131; and (H) is a waveform chart showing a trigger signal for opening and closing the leak valve 131.

[0098] For instance, when a user stops using the optical interferometer and leaves the optical interferometer unused for a relatively long time, in order to approximate the pressure in the vacuum chamber 101 of the optical interferometer to the atmospheric pressure, the user initially performs an input operation for requesting for the leak operation through the controlling unit, such that the controlling unit issues a control signal related to a request for the leak operation as shown in Fig. 5 (C). The controller, having recognized the control signal, closes the second on-off valve 122 as shown in Fig. 5(E). Then, the controller performs operations necessary for opening the leak valve 131 as shown in Fig. 5(G) and (H). Specifically, the controller reports to the user by display or audio output that the leak valve 131 is allowed to be opened, or automatically switches the leak valve 131 to be opened. With the leak valve 131 being switched to be opened, the vacuum chamber 101 is in communication with the atmosphere, so that the pressure therein approximates to the atmospheric pressure as shown in Fig. 5(A).

[0099] When subsequently recognizing that the pressure in the vacuum chamber 101 has become substantially the atmospheric pressure based on the container vacuum-degree data measured by the vacuometer 140, the controller opens the second on-off valve 122 while stopping monitoring the vacuum degree by stopping the issue of the reference pulse as shown in Fig. 5(E). Although the oil-rotary vacuum pump 110 is communicated with the atmosphere by this operation, the oil-rotary vacuum pump 110 maintains a reduced pressure that is approximate to that of the atmospheric pressure as shown in Fig. 5(B) because the oil-rotary vacuum pump 110 is being driven to vacuum suction. The controller subsequently performs operations necessary for stopping the oil-rotary vacuum pump 110. Specifically, the controller reports to a user by display or audio output that the oil-rotary vacuum pump 110 is allowed to be stopped, or automatically blocks the supply of power to the oil-rotary vacuum pump 110. Then, with the driving of the oil-rotary vacuum pump 110 being stopped, the pressure in the vicinity of the oil-rotary vacuum pump 110 gradually approximates to the atmospheric pressure. Through the above operations, the pressure in the vacuum chamber 101 of the optical interferometer is equalized substantially with the atmospheric pressure.

[Effects and Advantages of Embodiment(s)]

[0100] As described above, according to the embodiment, the pair of first on-off valve 121 and the second on-off valve 122 for evacuating the vacuum chamber 101 are provided in series between the vacuum chamber 101 and the oil-rotary vacuum pump 110, and the vacuometer 140 for measuring the vacuum degree is provided between the first on-off valve 121 and the second on-off valve 122. By opening the first on-off valve 121 adjacent to the vacuum chamber 101, the vacuum degree Pvc of the vacuum chamber 101 can be measured. By opening the second on-off valve 122 adjacent to the oil-rotary vacuum pump 110, the vacuum degree Pvp in the vicinity of the oil-rotary vacuum pump 110 can be measured. By opening both of the first and second on-off valves 121, 122, the vacuum chamber 101 can be evacuated by the driven oil-rotary vacuum pump 110 while the vacuum degree can be measured.

[0101] Accordingly, while oil or oil vapor from the oil-rotary vacuum pump 110 is prevented from flowing into the vacuum chamber 101, the vacuum degree can be suitably measured with the single vacuometer 140. Thus, a configuration of the vacuum-exhaust device can be simplified, thereby easily enhancing manufacturability and reducing cost for the vacuum-exhaust device.

[0102] According to the embodiment, the controller controls the opening and closing of the pair of first and second on-off valves 121, 122 based on the vacuum degree measured by the vacuometer 140.

[0103] With this arrangement, it is possible to prevent the vacuum chamber 101 and the oil-rotary vacuum pump 110 from being erroneously communicated with each other due to wrong operations and the like of a user of the optical interferometer while the vacuum degree in the vicinity of the vacuum chamber 101 is higher than that in the vicinity of the oil-rotary vacuum pump 110, thereby preventing flowing of oil, oil vapor and the like from the oil-rotary vacuum pump 110 into the vacuum chamber 101. In addition, since the first on-off valve 121 and the second on-off valve 122 are automatically opened and closed, workability of the vacuum-exhaust operation can be enhanced.

[0104] According to the embodiment, when the oil-rotary vacuum pump 110 is driven, the controller controls the vacuum-exhaust operation. Specifically, the controller initially opens the first on-off valve 121 adjacent to the vacuum chamber 101 to store the vacuum degree of the vacuum chamber 101 measured by the vacuometer 140, and subsequently closes the first on-off valve 121. Then, the controller opens the second on-off valve 122 adjacent to the oil-rotary vacuum pump 110 to obtain the vacuum degree in the vicinity of the oil-rotary vacuum pump 110 measured by the vacuometer 140. Following the above, the controller compares the stored container vacuum degree Pvc in the vacuum chamber 101 with the pump vacuum degree Pvp in the vicinity of the oil-rotary vacuum pump 110 measured by the vacuometer 140. When recognizing that the vacuum degree Pvp in the vicinity of the oil-rotary vacuum pump 110 has become larger than the stored vacuum degree Pvc in the vacuum container 101, the controller opens both of the first on-off valve 121 and the second on-off valve 122, so that the vacuum chamber 101 is evacuated by the driving of the oil-rotary vacuum pump 110.

[0105] With this arrangement, while oil, oil vapor and the like from the oil-rotary vacuum pump 110 are prevented from flowing into the vacuum chamber 101, the vacuum chamber 101 can be suitably evacuated with the single vacuometer 140 used.

[0106] According to the above embodiment, the controller obtains the vacuum degree in the vicinity of the oil-rotary vacuum pump 110 and subsequently opens both of the first on-off valve 121 and the second on-off valve 122 to evacuate the vacuum chamber 101. Then, when recognizing that the vacuum degree Pvc of the vacuum chamber 101 measured by the vacuometer 140 is equal to the predetermined vacuum degree Pm, the controller closes the second on-off valve 122.

[0107] With this arrangement, even when the driving of the oil-rotary vacuum pump 110 is stopped, not only oil, oil vapor and the like from the oil-rotary vacuum pump 110 are prevented from flowing into the vacuum chamber 101, but also the vacuum formed in the vacuum chamber 101 can be maintained for a longer time while being monitored by the vacuometer 140. In addition, by stopping the driving of the oil-rotary vacuum pump 110, cost required for driving the oil-rotary vacuum pump 110 to maintain the vacuum formed in the vacuum chamber 101 can be reduced. In addition, when, for instance, a calibration is conducted on a precision device such an optical interferometer in which the vacuum chamber 101 is provided, complication of the calibration operation and reduction in accuracy of the calibration due to oscillation caused by the driving of the oil-rotary vacuum pump 110 can be prevented by stopping the driving of the oil-rotary vacuum pump 110.

[0108] According to the above embodiment, after the vacuum degree Pvc of the vacuum chamber 101 reaches the predetermined vacuum degree Pm, the controller opens the first on-off valve 121 while closing the second on-off valve 122, so that the oil-rotary vacuum pump 110 is controlled to terminate the driving. For instance, the controller controls the oil-rotary vacuum pump 110 to automatically terminate the driving, controls the power supply to be blocked in accordance with a manual termination operation, or reports to a user so that the user can manually stop the oil-rotary vacuum pump 110.

[0109] With this arrangement, it is possible to prevent the oil-rotary vacuum pump 110 from being stopped while the vacuum chamber 101 is communicated with the oil-rotary vacuum pump 110, thereby reliably preventing flowing of oil, oil vapor and the like from the oil-rotary vacuum pump 110 into the vacuum chamber 101.

[0110] According to the embodiment, when the vacuum degree Pvc of the vacuum chamber 101 is larger than the predetermined vacuum degree Pm, the stopped driving of oil-rotary vacuum pump 110 is resumed again. At this time, the controller controls the vacuum-re-exhaust operation. Specifically, after storing the vacuum degree Pvc of the vacuum chamber 101 measured by the vacuometer 140 with the first on-off valve 121 being open while the second on-off valve 122 being closed, the controller closes the first on-off valve 121 and subsequently opens the second on-off valve 122, so that the vacuometer 140 sequentially measures the vacuum degree Pvp in the vicinity of the oil-rotary vacuum pump 110. Then, the controller compares the stored vacuum degree Pvc of the vacuum chamber 101 with the sequentially measured vacuum degree Pvp in the vicinity of the oil-rotary vacuum pump 110. When recognizing that the vacuum degree Pvp in the vicinity of the oil-rotary vacuum pump 110, which is sequentially measured by the vacuometer 140, becomes equal to or higher than the already-stored vacuum degree Pvc of the vacuum chamber 101, the controller opens the first on-off valve 121 to open both of the first and second on-off valves 121, 122, so that the vacuum chamber 101 can be evacuated again by the driving of the oil-rotary vacuum pump 110.

[0111] With this arrangement, also in the vacuum-re-exhaust operation, while oil, oil vapor and the like from the oil-rotary vacuum pump 110 are prevented from flowing into the vacuum chamber 101, the vacuum chamber 101 can be suitably evacuated with the single vacuometer 140 used.

[0112] According to the embodiment, the leak pipe 130 having the leak valve 131 for equalizing the pressure of the exhaust piping 120 between the vacuum chamber 101 and the first on-off valve 121 substantially with the atmospheric pressure when opened is provided in a branched manner between the vacuum chamber 101 and the first on-off valve 121 adjacent to the vacuum chamber 101.

[0113] With this arrangement, when the pressure of the evacuated vacuum chamber 101 is equalized substantially with the atmospheric pressure, the leak valve is opened after closing of the second on-off valve 122 and opening of the first on-off valve 121, so that the pressure of the exhaust piping 120 between the vacuum chamber 101 and the second on-off valve 122 is equalized substantially with the atmospheric pressure. When the second on-off valve 122 is subsequently opened, air in the vacuum chamber 101, in which the pressure has been equalized substantially with the atmospheric pressure, flows into the oil-rotary vacuum pump 110. Accordingly, the oil-rotary vacuum pump 110 is required to be stopped only after the air flows into the oil-rotary vacuum pump 110 from the vacuum chamber 101. Thus, air containing harmful oil or oil vapor from the oil-rotary vacuum pump 110 can be prevented from flowing into the vacuum chamber 101 and the vacuometer 140 via the second on-off valve 122. Accordingly, when the vacuum portion needs to be open to the atmospheric pressure exemplarily for maintenance, the pressure of the vacuum chamber 101 can be favorably equalized substantially with the atmospheric pressure with a simplified arrangement in a facilitated manner.

[0114] According to the embodiment, in order to control the leak operation by the controller, the leak valve 131 is opened after the second on-off valve 122 is closed. The leak valve 131 may be manually opened, automatically opened by the controller, or opened by any other suitable method. When recognizing that the vacuum degree Pvc of the vacuum chamber 101 measured by the vacuometer 140 is substantially equal to the atmospheric pressure, the controller opens the second on-off valve 122, so that the pressure in the vicinity of the oil-rotary vacuum pump 110 is equalized substantially with the atmospheric pressure. Then, the controller controls the oil-rotary vacuum pump 110 to terminate the driving. As described above, the controller may control the oil-rotary vacuum pump 110 to automatically terminate the driving, controls the power supply to be blocked in accordance with a manual termination operation, or report to a user so that the user can manually stop the oil-rotary vacuum pump 110.

[0115] With this arrangement, when the pressure of the vacuum chamber 101 is equalized substantially with the atmospheric pressure, the pressure of the vacuum chamber 101 can be suitably equalized substantially with the atmospheric pressure with the single vacuometer 140 used while oil, oil vapor and the like from the oil-rotary vacuum pump 110 are prevented from flowing into the vacuum chamber 101.

[Modification(s) of Embodiment(s)]

[0116] It should be understood that the above-described aspect of the present invention merely forms one aspect of the present invention. The present invention is not limited to the above-described embodiment but may include any modification or improvement made within a scope where an object and an effect of the present invention can be achieved. In addition, specific structure, shape and the like in implementing the present invention may be altered to other structure, shape and the like as long as an object and an effect of the present invention can be achieved.

[0117] Specifically, although the vacuum-exhaust device according to the present invention has been exemplified by the arrangement for evacuating the vacuum chamber 101 (the vacuum container) of the optical interferometer in the above-described embodiment, the present invention may be applied to any other arrangement for evacuating various vacuum containers used in devices such as an electronic microscope.

[0118] Although the leak pipe 130 having the leak valve 131 is provided to the exhaust piping 120 between the vacuum chamber 101 and the first on-off valve 121 in a branched manner in the above embodiment, the leak pipe 130 may be provided between the first on-off valve 121 and the second on-off valve 122 in a branched manner as exemplarily shown in Fig. 6..

[0119] According to such an arrangement as shown in Fig. 6, when a leak operation is performed, the pressure of the vacuum chamber 101 is initially equalized substantially with the atmospheric pressure by opening the first on-off valve 121, and the pressure in the vicinity of the oil-rotary vacuum pump 110 is subsequently equalized substantially with the atmospheric pressure by opening the second on-off valve 122, so that the oil-rotary vacuum pump 110 is stopped. With this arrangement, the oil and the like from the oil-rotary vacuum pump 110 is prevented from flowing into the vacuum chamber 101.

[0120] Specific structures and shapes in implementing the present invention may be altered to other structures and the like as long as an object of the present invention can be achieved.

Claims

1. A vacuum-exhaust device (100) connected to a vacuum container (101) and adapted to evacuate the vacuum container (101), the vacuum-exhaust device (100) comprising:

   an oil-rotary vacuum pump (110) connected to the vacuum container (101) and adapted to evacuate the vacuum container (101);
   a pair of on-off valves (121, 122) provided in series between the vacuum container (101) and the oil-rotary vacuum pump (110); and
   a vacuometer (140) positioned between the pair of on-off valves (121, 122) and adapted to measure a vacuum degree.

2. The vacuum-exhaust device (100) according to Claim 1, further comprising a controller that controls the pair of on-off valves (121, 122) to be opened or closed based on the vacuum degree measured by the vacuometer (140).

3. The vacuum-exhaust device (100) according to Claim 1 or 2, wherein the controller controls a vacuum-exhaust operation so that:

   a first on-off valve (121) provided adjacent to the vacuum container (101), when the oil-rotary vacuum pump (110) is driven, is opened for a predetermined time so as to store container vacuum-degree data about a vacuum degree of the vacuum container (101) measured by the vacuometer (140);
   the first on-off valve (121) is closed, and a second on-off valve (122) provided adjacent to the oil-rotary vacuum pump (110) is subsequently opened so as to obtain pump vacuum-degree data about a vacuum degree in the vicinity of the oil-rotary vacuum pump (110) measured by the vacuometer (140); and
   the pair of on-off valves (121, 122) are opened when the controller recognizes that the vacuum degree in the vicinity of the oil-rotary vacuum pump (110) has become larger than the stored container vacuum degree of the vacuum container (101) by comparing the stored container vacuum-degree data with the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump (110) measured by the vacuometer (140) after the vacuum degree in the vicinity of the oil-rotary vacuum pump (110) is obtained.

4. The vacuum-exhaust device (100) according to Claim 3, wherein the controller controls the second on-off valve (122) to be open for a predetermined time when obtaining the pump vacuum-data about the vacuum degree in the vicinity of the oil-rotary vacuum pump (110) measured by the vacuometer (140).

5. The vacuum-exhaust device (100) according to Claim 3 or 4, wherein
   the controller opens the pair of on-off valves (121, 122) after obtaining the pump vacuum-degree data about the vacuum degree in the vicinity of the oil-rotary vacuum pump (110), and
   the controller closes the second on-off valve (122) when recognizing that the vacuum degree of the vacuum container (101) measured by the vacuometer (140) has reached a predetermined vacuum degree.

6. The vacuum-exhaust device (100) according to Claim 5, wherein the controller controls the second on-off valve (122) to be closed after the vacuum degree of the vacuum container (101) has reached the predetermined vacuum degree, and subsequently controls the oil-rotary vacuum pump (110) to stop driving.

7. The vacuum-exhaust device (100) according to Claim 5 or 6, wherein the controller controls a vacuum-re-exhaust operation so that:

   container vacuum-degree data about a vacuum degree of the vacuum container (101) is stored when the stopped oil-rotary vacuum pump (110) resumes driving due to a reduction in the vacuum degree of the container (101), the vacuum degree of the vacuum container (101) being measured by the vacuometer (140) with the first on-off valve (121) being open while the second on-off valve (122) being closed;
   the first on-off valve (121) is closed after the container vacuum-degree data is stored, and the second on-off valve (122) is subsequently opened so as to compare the stored container vacuum-degree data with pump vacuum-degree data about a vacuum degree in the vicinity of the oil-rotary vacuum pump (110) sequentially measured by the vacuometer (140); and
   the first on-off valve (121) is opened when the controller recognizes that the vacuum degree in the vicinity of the oil-rotary vacuum pump (110) contained in the pump vacuum-degree data has become equal to or higher than the stored vac-

uum degree of the vacuum container (101).

8. The vacuum-exhaust device (100) according to any one of Claims 1 to 7, further comprising a leak portion (130) provided in a branched manner between the vacuum container (101) and the first on-off valve (121) adjacent to the vacuum container (101), the leak portion (130) comprising a leak valve (131) adapted to equalize a pressure of a region between the vacuum container (101) and the first on-off valve (121) substantially with the atmospheric pressure when opened.

9. The vacuum-exhaust device (100) according to Claim 7, wherein the controller controls a leak operation so that:

the leak valve (131) is controlled to be opened after the second on-off valve (122) adjacent to the oil-rotary vacuum pump (110) is closed;
the oil-rotary vacuum pump (110) is controlled to stop driving when the controller recognizes that the vacuum degree of the vacuum container (101) measured by the vacuometer (140) has become substantially equal to the atmospheric pressure; and
the second on-off valve (122) is opened.

10. The vacuum-exhaust device (100) according to any one of Claims 1 to 7, further comprising a leak portion (130) provided in a branched manner between the pair of on-off valves (121, 122), the leak portion (130) comprising a leak valve (131) adapted to equalize a pressure of a region between the pair of on-off valves (121, 122) substantially with the atmospheric pressure when opened.

11. The vacuum-exhaust device (100) according to Claim 10, wherein the controller controls a leak operation so that:

the leak valve (131) is controlled to be opened and the first on-off valve (121) adjacent to the container (101) is controlled to be opened after the second on-off valve (122) adjacent to the oil-rotary vacuum pump (110) is closed; and
the second on-off valve (122) is controlled to be opened when the controller recognizes that the vacuum degree of the vacuum container (101) measured by the vacuometer (140) has become substantially equal to the atmospheric pressure.

12. A vacuum-exhaust method of evacuating a vacuum container (101), the method comprising:

using: an oil-rotary vacuum pump (110) adapted to evacuate the container (101) via a pair of on-off valves (121, 122) provided in series; and a vacuometer (140) positioned between the pair of on-off valves (121, 122) and adapted to measure a vacuum degree;
opening a first on-off valve (121) provided adjacent to the vacuum container (101) for a predetermined time when the oil-rotary vacuum pump (110) is driven, and storing container vacuum-degree data about a vacuum degree of the vacuum container (101) measured by the vacuometer (140);
closing the first on-off valve (121) to subsequently open a second on-off valve (122) provided adjacent to the oil-rotary vacuum pump (110) after the vacuum degree of the vacuum container (101) is stored, and obtaining pump vacuum-degree data about a vacuum degree in the vicinity of the oil-rotary vacuum pump (110) measured by the vacuometer (140); and
evacuating the vacuum container (101) by the oil-rotary vacuum pump (110) driven with the pair of on-off valves (121, 122) being open after the vacuum degree in the vicinity of the oil-rotary vacuum pump (110) is obtained.

FIG.1

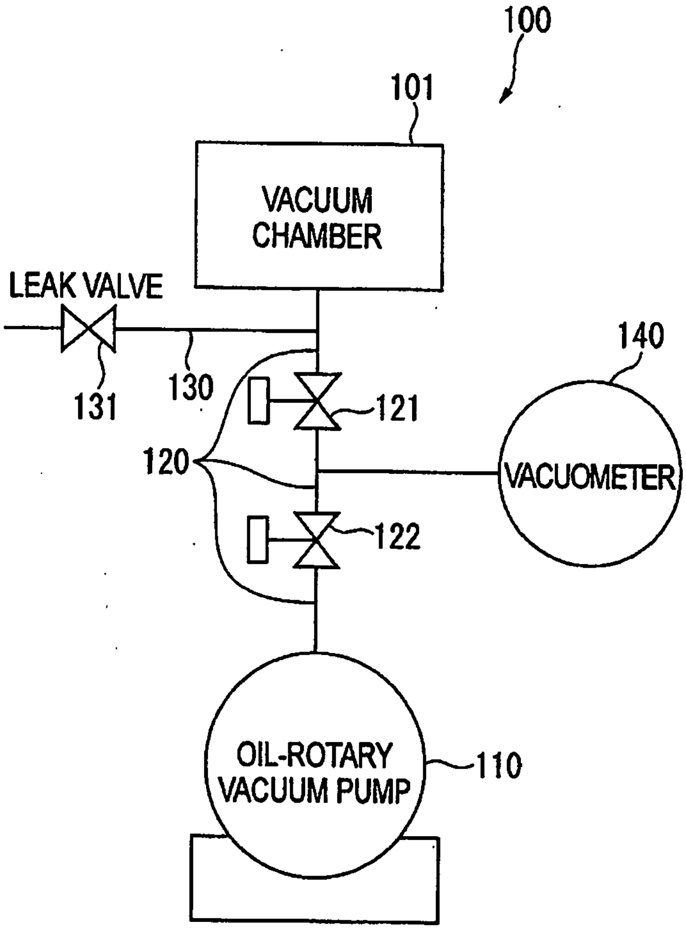

100
101
VACUUM CHAMBER
LEAK VALVE
131
130
120
121
122
140
VACUOMETER
OIL-ROTARY VACUUM PUMP
110

FIG. 2

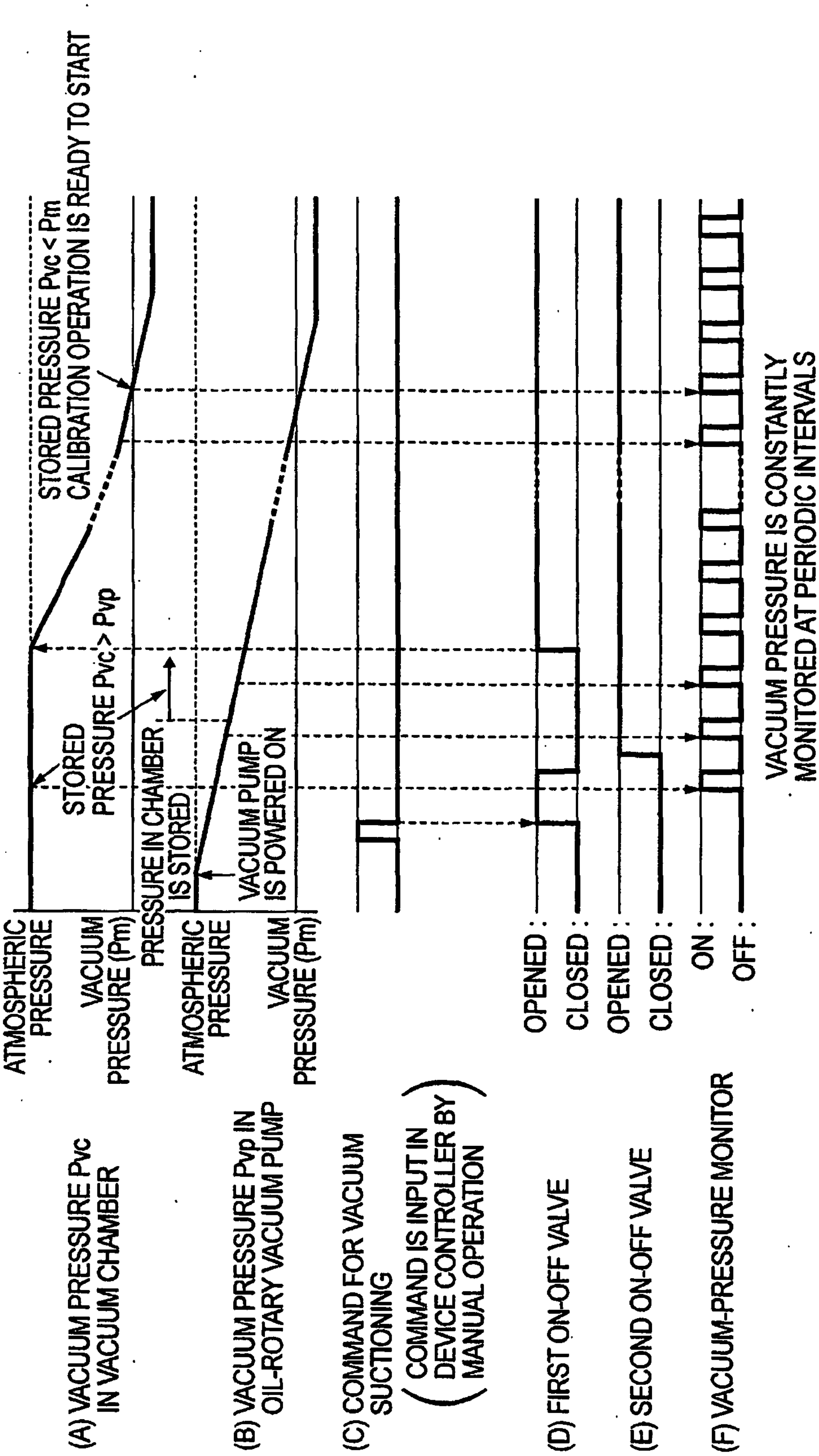

(A) VACUUM PRESSURE Pvc IN VACUUM CHAMBER
(B) VACUUM PRESSURE Pvp IN OIL-ROTARY VACUUM PUMP
(C) COMMAND FOR VACUUM SUCTIONING
(COMMAND IS INPUT IN DEVICE CONTROLLER BY MANUAL OPERATION)
(D) FIRST ON-OFF VALVE
(E) SECOND ON-OFF VALVE
(F) VACUUM-PRESSURE MONITOR
ATMOSPHERIC PRESSURE
VACUUM PRESSURE (Pm)
PRESSURE IN CHAMBER IS STORED
VACUUM PUMP IS POWERED ON
STORED PRESSURE
STORED PRESSURE Pvc > Pvp
STORED PRESSURE Pvc < Pm
CALIBRATION OPERATION IS READY TO START
OPENED :
CLOSED :
ON :
OFF :
VACUUM PRESSURE IS CONSTANTLY MONITORED AT PERIODIC INTERVALS

FIG. 3

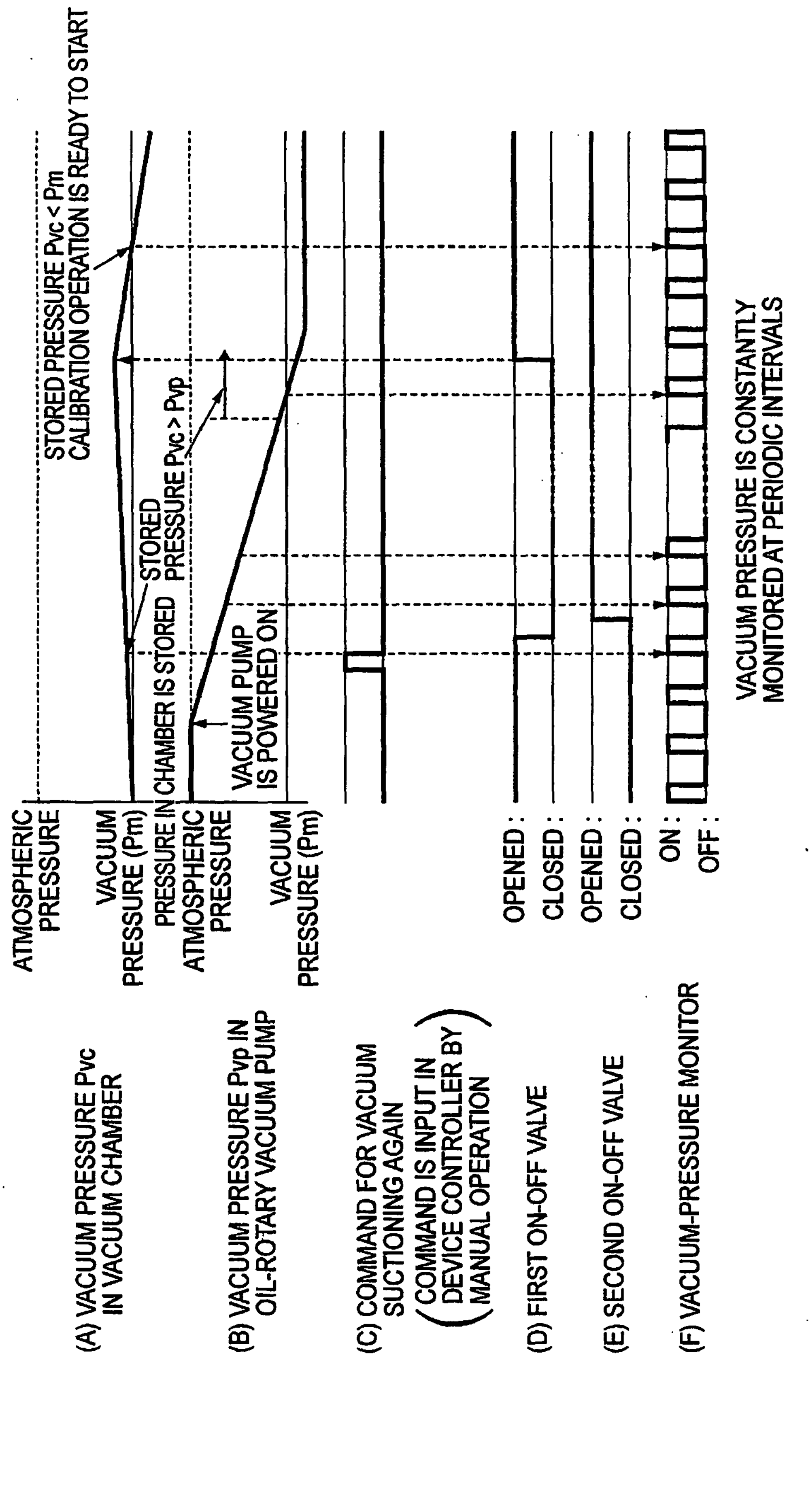

(A) VACUUM PRESSURE Pvc IN VACUUM CHAMBER
(B) VACUUM PRESSURE Pvp IN OIL-ROTARY VACUUM PUMP
(C) COMMAND FOR VACUUM SUCTIONING AGAIN
(COMMAND IS INPUT IN DEVICE CONTROLLER BY MANUAL OPERATION)
(D) FIRST ON-OFF VALVE
(E) SECOND ON-OFF VALVE
(F) VACUUM-PRESSURE MONITOR
ATMOSPHERIC PRESSURE
VACUUM PRESSURE (Pm)
PRESSURE IN CHAMBER IS STORED
ATMOSPHERIC PRESSURE
VACUUM PRESSURE (Pm)
OPENED :
CLOSED :
OPENED :
CLOSED :
ON :
OFF :
VACUUM PUMP IS POWERED ON
STORED PRESSURE
STORED PRESSURE Pvc > Pvp
STORED PRESSURE Pvc < Pm
CALIBRATION OPERATION IS READY TO START
VACUUM PRESSURE IS CONSTANTLY MONITORED AT PERIODIC INTERVALS

FIG. 4

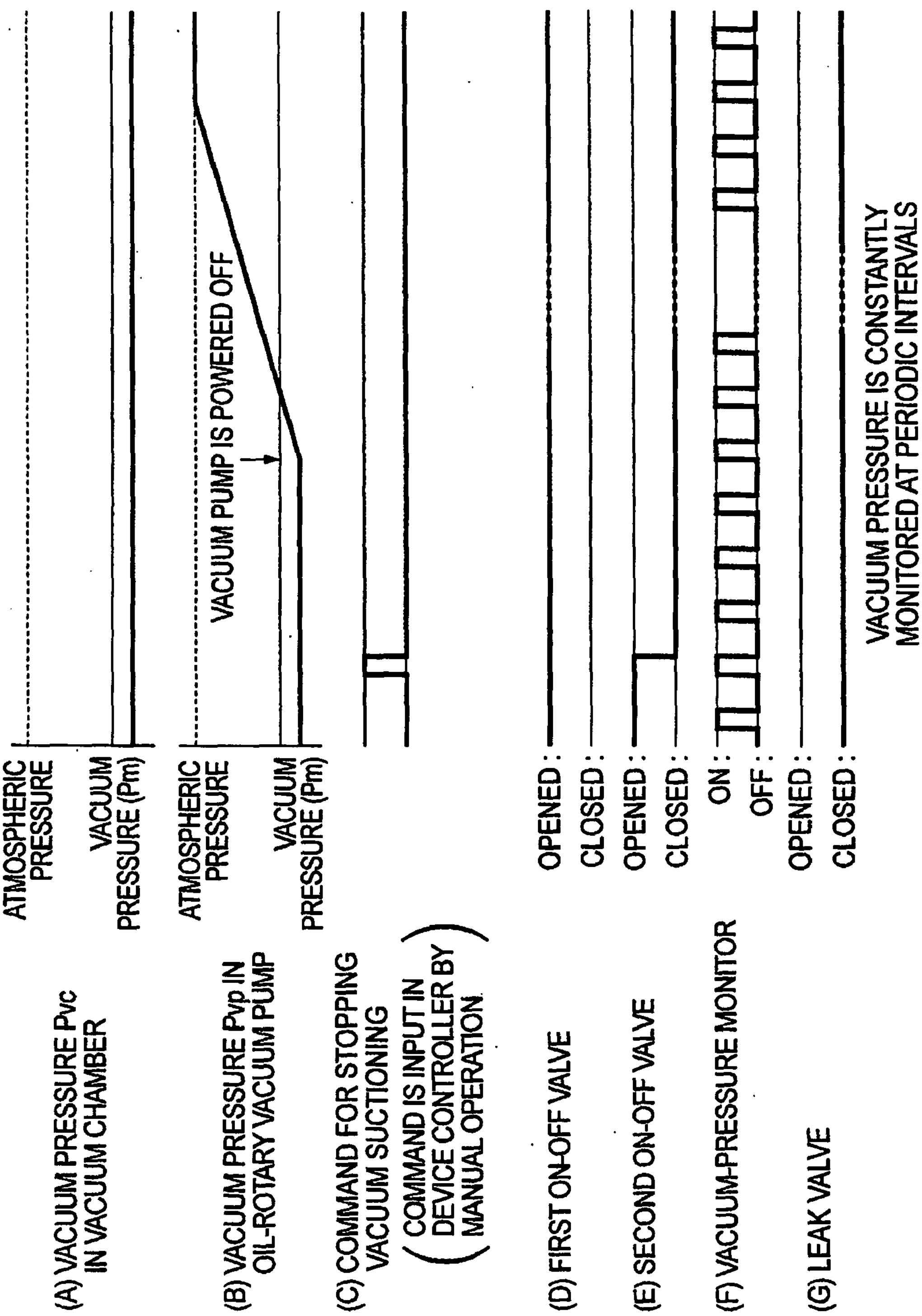

(A) VACUUM PRESSURE Pvc IN VACUUM CHAMBER
ATMOSPHERIC PRESSURE
VACUUM PRESSURE (Pm)
(B) VACUUM PRESSURE Pvp IN OIL-ROTARY VACUUM PUMP
ATMOSPHERIC PRESSURE
VACUUM PRESSURE (Pm)
VACUUM PUMP IS POWERED OFF
(C) COMMAND FOR STOPPING VACUUM SUCTIONING
(COMMAND IS INPUT IN DEVICE CONTROLLER BY MANUAL OPERATION)
(D) FIRST ON-OFF VALVE
OPENED :
CLOSED :
(E) SECOND ON-OFF VALVE
OPENED :
CLOSED :
(F) VACUUM-PRESSURE MONITOR
ON :
OFF :
(G) LEAK VALVE
OPENED :
CLOSED :
VACUUM PRESSURE IS CONSTANTLY MONITORED AT PERIODIC INTERVALS

FIG. 5

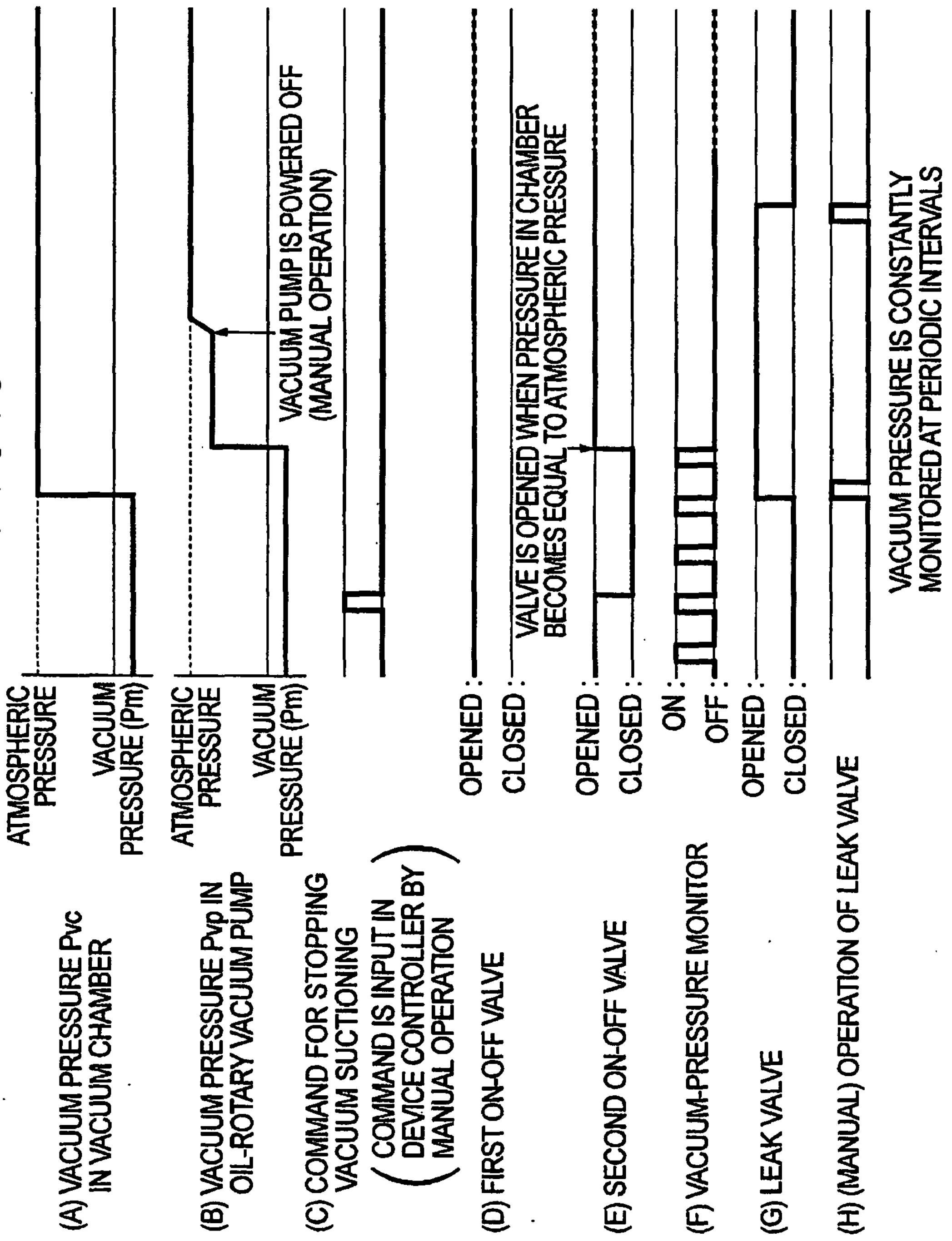
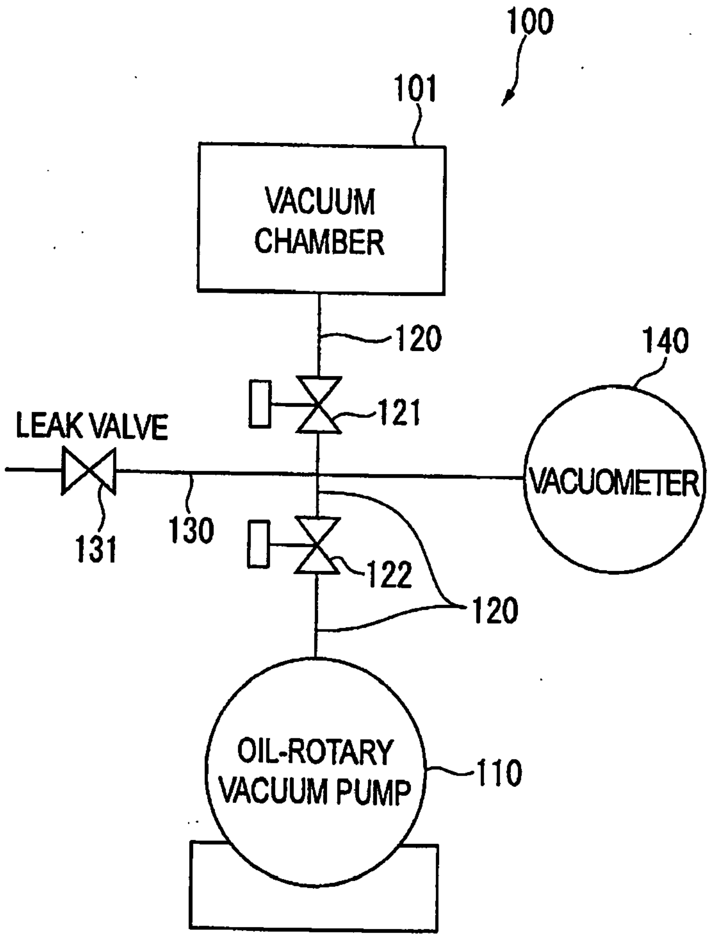

(A) VACUUM PRESSURE Pvc IN VACUUM CHAMBER
ATMOSPHERIC PRESSURE
VACUUM PRESSURE (Pm)
(B) VACUUM PRESSURE Pvp IN OIL-ROTARY VACUUM PUMP
ATMOSPHERIC PRESSURE
VACUUM PRESSURE (Pm)
VACUUM PUMP IS POWERED OFF (MANUAL OPERATION)
(C) COMMAND FOR STOPPING VACUUM SUCTIONING
(COMMAND IS INPUT IN DEVICE CONTROLLER BY MANUAL OPERATION)
(D) FIRST ON-OFF VALVE
OPENED :
CLOSED :
VALVE IS OPENED WHEN PRESSURE IN CHAMBER BECOMES EQUAL TO ATMOSPHERIC PRESSURE
(E) SECOND ON-OFF VALVE
OPENED :
CLOSED :
(F) VACUUM-PRESSURE MONITOR
ON :
OFF :
(G) LEAK VALVE
OPENED :
CLOSED :
(H) (MANUAL) OPERATION OF LEAK VALVE
VACUUM PRESSURE IS CONSTANTLY MONITORED AT PERIODIC INTERVALS

FIG.6


100
101
VACUUM
CHAMBER
120
140
121
LEAK VALVE
VACUOMETER
130
131
122
120
OIL-ROTARY
VACUUM PUMP
110

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5044643 A **[0003]**
- JP 2003157786 A **[0003]**