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(71) Applicant: **Ulvac, Inc.**
Chigasaki-shi
Kanagawa 253-8543 (JP)

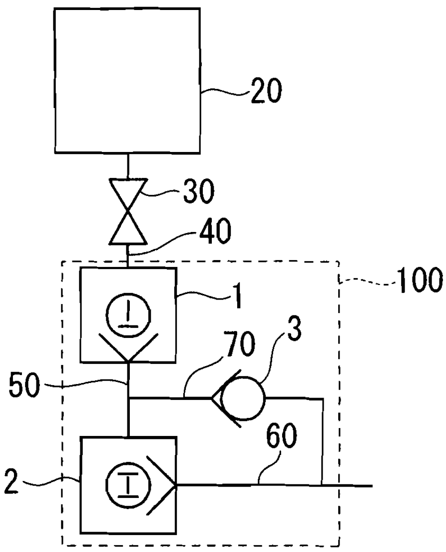
(72) Inventors:
- **SHIBAYAMA, Kouji**
  Chigasaki-shi
  Kanagawa 253-8543 (JP)
- **SUZUKI, Toshio**
  Chigasaki-shi
  Kanagawa 253-8543 (JP)

(74) Representative: **Eisenführ, Speiser & Partner**
Postfach 31 02 60
80102 München (DE)

(54) **VACUUM EVACUATION DEVICE**

(57) A vacuum evacuation device including: a main pump; an auxiliary pump connected in series to the main pump; and an inter-pump piping for interconnecting an outlet of the main pump and an inlet of the auxiliary pump, wherein the main pump includes a mechanical booster pump; a ratio of the maximum power of a motor for the main pump to the maximum pumping rate of the main pump is no less than 5 W/(m^3/h); the inter-pump piping includes a branch pipe branched from the middle of the inter-pump piping; and a check valve for releasing gas in the inter-pump piping and preventing a back flow of the gas is provided in the middle of the branch pipe.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a vacuum evacuation device in which an auxiliary pump is connected in series to a main pump, and particularly relates to a vacuum evacuation device capable of improving the pumping rate.
Priority is claimed on Japanese Patent Application No. 2008-232324, filed September 10, 2008, the content of which is incorporated herein by reference.

BACKGROUND ART

[0002] As one of the conventional vacuum evacuation devices that evacuates to the medium vacuum range, there is a device in which a mechanical booster pump (hereafter, referred to as an MBP) functioning as a main pump and a dry pump (hereafter, referred to as a DRP) functioning as an auxiliary pump are connected in series (for example, refer to Patent Document 1).

[0003] In such a vacuum evacuation device, since the principal object is to achieve the target degree of vacuum, it is configured so that the displacement of the MBP in the first stage is larger than the displacement of the DRP in the second stage. More specifically, the displacement of the main pump is set from 5 times to 10 times as large as the displacement of the auxiliary pump. In this manner, the evacuation performance of the MBP can be sufficiently achieved due to the auxiliary evacuation by the DRP in the medium vacuum region.

[0004] It should be noted that in such a vacuum evacuation device, gate valves provided between the chamber and the inlet pipe of the MBP are released when starting vacuum evacuation of the chamber at atmospheric pressure, and the pressure from the chamber is transmitted in that instant in the form of a shock wave, thereby giving an impact to the MBP. For this reason, a mechanical strength capable of withstanding the impact is required for the MBP.

[0005] Examples of the conventional techniques for alleviating the transient impact during the opening of the chamber include a constitution in which a tank such as a buffer tank for releasing the impact pressure is provided in the middle of the pipe between the MBP and the DRP, thereby alleviating transient changes in the pressure (for example, refer to Patent Document 1).

[0006] In addition, as other examples of the conventional techniques for alleviating the transient impact, there is a device provided with a bypass pipe for returning the gas from the outlet side of the main pump to the inlet side of the main pump, or a device provided with a bypass pipe for sending a gas having a pressure equal to or more than the predetermined pressure from the outlet side of the main pump to the outlet side of the auxiliary pump (refer to Patent Document 1).

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0007]

[Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2007-127048

DISCLOSURE OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0008] In those cases where a vacuum evacuation device is used for repeatedly evacuating from the atmospheric pressure to the medium vacuum region, as in the loading chamber (hereafter, referred to as an LC) of an apparatus for producing liquid crystals, the time required for reaching the target degree of vacuum will be one indicator for the performance thereof for improving the productivity. For this reason, in such a vacuum evacuation device, high evacuation characteristics are required not only in the medium vacuum region but also in the low vacuum region and in the region of reduced pressure close to atmospheric pressure.

[0009] However, in the above-mentioned conventional vacuum evacuation device where the MBP and the DRP are arranged in series and the evacuation capacity of the MBP in the first stage is larger than the evacuation capacity of the DRP in the second stage, the gas exhausted from the MBP must pass through the DRP. Accordingly, in the region of reduced pressure close to atmospheric pressure and the low vacuum region, the evacuation capacity of the MBP is governed by the evacuation capacity of the DRP, and the exhaust pressure becomes higher than the suction pressure in the MBP. For this reason, the MBP will be involved in the unnecessary compression work, thereby considerably reducing the rotational frequency thereof. As a result, the MBP cannot satisfactorily achieve the effects as a blower.

[0010] The present invention has been made in order to solve such conventional problems, and its object is to provide a vacuum evacuation device capable of shortening the evacuation time required until the target degree of vacuum is achieved without dramatically changing the structures of the main pump and the auxiliary pump.

MEANS FOR SOLVING THE PROBLEMS

[0011] In order to achieve the above-mentioned object, the present invention employs the following. In particular, a vacuum evacuation device according to an aspect of the present invention includes a main pump; an auxiliary pump connected in series to the main pump; and an interpump piping for interconnecting an outlet of the main pump and an inlet of the auxiliary pump, wherein the main pump includes a mechanical booster pump; a ratio of the maximum power of a motor for the main pump to the maximum pumping rate of the main pump is no less than 5 W/(m^3/h); the inter-pump piping includes a branch pipe branched from the middle of the inter-pump piping; and a check valve for releasing gas in the inter-pump piping and preventing a back flow of the gas is provided in the middle of the branch pipe.

[0012] The main pump may include a plurality of the aforementioned mechanical booster pumps which are arranged in parallel.

[0013] In addition, the branch pipe may be terminated with an exhaust pipe of the auxiliary pump.

[0014] Further, it is desirable that the pressure loss of the gas flow in the check valve be no more than 10,000 Pa when operating the main pump at atmospheric pressure.

EFFECTS OF THE INVENTION

[0015] According to the above aspect of the present invention, by increasing the power of the motor of the main pump and also providing the check valve and the branch pipe, the pumping rate of the main pump will not be controlled by the pumping rate of the auxiliary pump even in the region close to atmospheric pressure, and thus the pumping rate in the region close to atmospheric pressure and the low vacuum region can be improved. As a result, the evacuation time required until the target degree of vacuum is achieved can be shortened without dramatically changing the structures of the main pump and the auxiliary pump.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 is a schematic diagram for explaining the constitution of a vacuum evacuation device according to a first embodiment of the present invention.

FIG. 2 is a schematic diagram for explaining the constitution of a vacuum evacuation device according to Comparative Example 1.

FIG. 3 is a schematic diagram for explaining the constitution of a vacuum evacuation device according to Comparative Example 2.

FIG. 4A is a diagram for explaining the pumping rate characteristics (evacuation performances) of the vacuum evacuation devices according to the first embodiment of the present invention and Comparative Examples 1 and 2.

FIG. 4B is a diagram for explaining the pressure characteristics of the LC20 in the first embodiment of the present invention and Comparative Examples 1 and 2.

FIG. 5 is a schematic diagram for explaining the constitution of a vacuum evacuation device according to a second embodiment of the present invention.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

[0017] Embodiments of the present invention will be described in more detail below with reference to the drawings. It should be noted that the present invention is not limited to these embodiments, and various modifications can be made without departing from the scope of the present invention.

<First embodiment>

[0018] FIG. 1 is a schematic diagram for explaining the constitution of a vacuum evacuation device according to a first embodiment of the present invention. A vacuum evacuation device 100 according to the first embodiment includes a main pump 1, an auxiliary pump 2 and a check valve 3.

[0019] A chamber 20 serves, for example, as a processing chamber or a transfer chamber which constitutes an apparatus for manufacturing a semiconductor or the like, and is evacuated by the vacuum evacuation device 100. Here, the chamber 20 is a loading chamber (hereafter, referred to as an LC) of an apparatus for producing liquid crystals.

[0020] A gate valve 30 is provided in the middle of a pipe (suction pipe) 40 that connects the outlet of the LC20 and the inlet of the MBP1. The gate valve 30 opens when starting the evacuation of the LC20, which is opened to atmospheric pressure, by the vacuum evacuation device 100 and closes when opening the evacuated LC20 to atmospheric pressure.

[0021] In the vacuum evacuation device 100, the main pump 1 and the auxiliary pump 2 are connected in series by a pipe (inter-pump piping) 50 which connects the outlet of the main pump 1 and the inlet of the auxiliary pump 2. The outlet of the auxiliary pump 2 is connected to a pipe (exhaust pipe) 60.

[0022] As described above, in the vacuum evacuation device 100, the main pump 1 and the auxiliary pump 2 are connected in series. In addition, a pump in the first stage which is directly connected to the outlet of the LC20 via the gate valve 30 is the main pump, and a pump in the second stage which is arranged on the outlet side of the main pump is the auxiliary pump. Here, the main pump 1 is a mechanical booster pump (hereafter, referred to as an MBP). Further, the auxiliary pump 2 is a dry pump (hereafter, referred to as a DRP). Note that the main pump 1 is not limited to a pump constituted by one (one stage) MBP and may be a pump constituted by a two stage MBP known as a multibooster pump, a pump constituted by several stages of MBPs, or the like.

[0023] The MBP1 is a pump prepared by increasing the power of the motor in an MBP constituting the conventional vacuum evacuation device without changing the pump section thereof. In the MBP of a conventional device, the ratio of the maximum power (unit: W) of the above-mentioned motor to the maximum pumping rate (unit: m^3/h) is less than 5 W/(m^3/h) (for example, 10,000 (W)/ 3,600 (m^3/h) = 2.77). However, in the MBP1 according to the present embodiment, the above-mentioned ratio is no less than 5 W/(m^3/h) (for example, 30,000 (W)/ 3,600 (m^3/h) = 8.33). Note that the pumping rate of the MBP reaches the maximum in the medium vacuum region (for example, when the suction pressure is 13 Pa).

[0024] In addition, in the vacuum evacuation device 100, a pipe (branch pipe) 70 branched from the inter-pump piping 50 and the terminal thereof is connected to the exhaust pipe 60 of the DRP2 is provided. The check valve 3 is provided partway along the pipe 70.

[0025] The check valve 3 releases the gas inside the inter-pump piping 50 to the exhaust pipe 60 and also prevents the back flow of the gas inside the exhaust pipe 60 to the inter-pump piping 50 when the pressure inside the inter-pump piping 50 becomes higher than the pressure inside the exhaust pipe 60. It is desirable that the check valve 3 have a sufficient capacity so that the pressure loss does not occur even when the MBP1 is operated at atmospheric pressure. For example, it is desirable that the pressure loss of the gas flow at atmospheric pressure in the check valve 3 be no more than 10,000 Pa when operating the MBP1 at atmospheric pressure.

[0026] By using the vacuum evacuation device according to the present embodiment, since the MBP1 having a high power motor is adopted, the evacuation performance mainly in the low vacuum region can be improved. Since there is originally no need to carry out the compression by the MBP in a region close to atmospheric pressure, the pumping rate of a single MBP is larger than the pumping rate of a single DRP. However, in the constitution where the MBP and the DRP are connected in series, since the exhaust pressure of the MBP will be higher than the suction pressure thereof in the region close to atmospheric pressure and in the low vacuum region, the pumping rate of the MBP will be governed by the pumping rate of the DRP and the rotational frequency of the MBP reduces. By employing a high power motor as the motor of the MBP1, reduction of the rotational frequency mainly in the low vacuum region can be suppressed, and the pumping rate can be improved.

[0027] Moreover, since the check valve 3 and the branch pipe 70 are provided in the vacuum evacuation device according to the present embodiment, the evacuation characteristics in the region close to atmospheric pressure can be improved. By arranging the check valve 3 with a low pressure loss, in the low vacuum region and the region close to atmospheric pressure, when the exhaust pressure (pressure inside the inter-pump piping 50) of the MBP1 is increased, the gas inside the inter-pump piping 50 is released to the exhaust pipe 60 so that the exhaust pressure of the MBP1 can be suppressed. In this manner, the MBP1 can be efficiently used as a blower, and as a result, the MBP1 will not be governed by the evacuation performance of the DRP2. The less the pressure loss in the check valve 3 is, the more significant the effects thereof is.

[0028] As described above, in the vacuum evacuation device according to the present embodiment, by adopting the MBP1 having a high power motor and providing the check valve 3 and the branch pipe 70, the pumping rate in the low vacuum region and the region close to atmospheric pressure can be improved. As a result, the evacuation time in the LC20 can be shortened.

[0029] Moreover, by providing the check valve 3 and the branch pipe 70, since the pressure shock wave from the LC20 can be released via the check valve 3 when opening the gate valve 30 in order to start the evacuation of the LC20 at atmospheric pressure, the impact received by the MBP1 can be alleviated. In this manner, the MBP1 is hardly restricted by the strength design, and the durability of the MBP1 can be further improved.

[0030] FIG. 2 is a schematic diagram for explaining the constitution of a vacuum evacuation device according to Comparative Example 1, and the same component as that in FIG. 1 will be provided with the same reference symbol. In this vacuum evacuation device 101 according to Comparative Example 1, an MBP11 and a DRP2 are arranged in series. The MBP11 includes the same pump section as that of the MBP1 according to the first embodiment and a motor with a power lower than that of the MBP1. That is, in the MBP11, the ratio of the maximum power (unit: W) of the motor to the maximum pumping rate is less than 5 W/(m^3/h).

[0031] FIG. 3 is a schematic diagram for explaining the constitution of a vacuum evacuation device according to Comparative Example 2, and the same component as that in FIG. 1 will be provided with the same reference symbol. In this vacuum evacuation device 102 according to Comparative Example 2, the MBP1 and the DRP2 are arranged in series. In other words, the vacuum evacuation device 102 according to Comparative Example 2 has a constitution, which is different from that of the vacuum evacuation device 100 (refer to FIG. 1) according to the first embodiment in that the check valve 3 and the branch pipe 70 are not provided, and also a constitution, which is different from the vacuum evacuation device 101 (refer to FIG. 2) according to Comparative Example 1 in that the MBP11 is changed to the MBP1.

[0032] FIGS. 4A and 4B are diagrams for explaining the evacuation characteristics of the vacuum evacuation devices according to the first embodiment of the present invention and Comparative Examples 1 and 2. More specifically, FIG. 4A is indicating the pumping rate characteristics (evacuation performances) of the single DRP2 and the vacuum evacuation devices according to the first embodiment of the present invention and Comparative Examples 1 and 2, and FIG. 4B is indicating the pressure characteristics of the LC20 (pressure change of the LC20) in the first embodiment of the present invention and Comparative Examples 1 and 2. In these FIGS. 4A and 4B, A represents the atmospheric pressure A1 and the region of reduced pressure close to atmospheric pressure (i.e., the region close to atmospheric pressure), B represents the low vacuum region and C represents the high vacuum region. In addition, a1 indicates the characteristics in the single DRP2, b1 and b2 indicate the characteristics of the vacuum evacuation device 101 according to Comparative Example 1, c1 and c2 indicate the characteristics of the vacuum evacuation device 102 according to Comparative Example 2, and d1 and d2 indicate the characteristics of the vacuum evacuation device 100 according to the first embodiment.

[0033] For example, the range of the region A is from 101,300 Pa (atmospheric pressure A1) to 30,000 Pa, the range of the low vacuum region B is from 30,000 Pa to 1,330 Pa and the range of the medium vacuum region C is no more than 1,330 Pa.

[0034] As shown in the characteristic curve a1 in FIG. 4A, the pumping rate of the single DRP2 is substantially constant in the region A close to atmospheric pressure and the low vacuum region B and remains constant even in the medium vacuum region C, but then gradually reduces as it approaches the target degree of vacuum.

[0035] In addition, as shown in the characteristic curve b1 in FIG. 4A, the pumping rate of the vacuum evacuation device 101 according to Comparative Example 1 increases starting from the region A close to atmospheric pressure, followed by the low vacuum region B, and then in the medium vacuum region C. Thereafter, the pumping rate of the vacuum evacuation device 101 reaches the maximum in the medium vacuum region C which is close to the middle between the boundary with the low vacuum region B and the target degree of vacuum, and then reduces as it approaches the target degree of vacuum.

[0036] As shown in the characteristic curve c1 in FIG. 4A, the pumping rate of Comparative Example 2 in the low vacuum region B improves, as compared to the case of Comparative Example 1 (i.e., characteristic curve b1), by adopting the MBP1 having a higher power than that of the MBP11 in Comparative Example 1. However, in the region A close to atmospheric pressure, since the evacuation performance of the MBP1 is governed by the evacuation performance of the DRP2, although the pumping rate of Comparative Examples 2 is improved compared to that of Comparative Example 1, the evacuation capacity of the MBP1 is not necessarily attained satisfactorily. Note that the pumping rate characteristics of Comparative Example 2 in the medium vacuum region C are the same as those in the case of Comparative Example 1 since they include the same pump section.

[0037] On the other hand, as shown in the characteristic curve d1 in FIG. 4A, in the vacuum evacuation device 100 according to the first embodiment, by adopting the MBP1 having a higher power than that of the MBP11 in Comparative Example 1, the pumping rate in the low vacuum region B improves, as compared to the above-mentioned Comparative Example 1 (i.e., characteristic curve b1), and becomes equal to that in the case of Comparative Example 2 (i.e., characteristic curve c2). Moreover, since the check valve 3 and the branch pipe 70 are provided in the vacuum evacuation device 100 according to the first embodiment, the evacuation performance of the MBP1 will not be governed by the evacuation performance of the DRP2. Accordingly, the evacuation performance in the region A close to atmospheric pressure in the present embodiment improves, as compared to the case of Comparative Example 2 (i.e., characteristic curve c1). Note that the pumping rate characteristics of the vacuum evacuation device 100 according to the first embodiment in the low vacuum region B and the medium vacuum region C will be equivalent to those in the case of Comparative Example 2 since they include the same MBP.

[0038] As shown in FIG. 4B, pressure change in the LC20 corresponds to the evacuation performance of the vacuum evacuation device. For this reason, in the low vacuum region B and the medium vacuum region C, the characteristic curve c2 of Comparative Example 2 becomes parallel to the characteristic curve d2 of the vacuum evacuation device 100 according to the first embodiment. Further, in the medium vacuum region C, the characteristic curve b2 of Comparative Example 1, the characteristic curve c2 of Comparative Example 2, and the characteristic curve d2 of the vacuum evacuation device 100 according to the first embodiment become parallel to each other.

[0039] Since the vacuum evacuation device 102 according to Comparative Example 2 exhibits superior evacuation performance at atmospheric pressure and in the region A close to atmospheric pressure and the low vacuum region B, each of the time required for reaching the low vacuum region B and the time required for reaching the medium vacuum region C is shorter, as compared to the vacuum evacuation device 101 according to Comparative Example 1. In addition, since the vacuum evacuation device 100 according to the first embodiment exhibits superior evacuation performance in the region A close to atmospheric pressure, the time required for reaching the low vacuum region B is shorter, as compared to the vacuum evacuation device 102 according to Comparative Example 2.

[0040] Therefore, among the vacuum evacuation device 100 according to the first embodiment, the vacuum evacuation device 101 according to Comparative Example 1 and the vacuum evacuation device 102 according to Comparative Example 2, the vacuum evacuation device 100 according to the first embodiment can reach the target degree of vacuum set in the medium vacuum region C within the shortest time period. Note that by using the vacuum evacuation device 102 according to Comparative Example 2, the target degree of vacuum can be reached within the shorter time period, as compared to the vacuum evacuation device 101 according to Comparative Example 1.

[0041] As described above, since the MBP1 having a higher power than that of the MBP11 in Comparative Example 1 is adopted in the vacuum evacuation device 100 according to the first embodiment, a higher pumping rate than that in the case of Comparative Example 1 can be achieved in the low vacuum region B and the region A close to atmospheric pressure. Moreover, by providing the check valve 3 and the branch pipe 70, a higher pumping rate than that of the vacuum evacuation device 102 according to Comparative Example 2 can be achieved in the region A close to atmospheric pressure.

[0042] Accordingly, in the vacuum evacuation device 100 according to the first embodiment, it can be said that the evacuation capacity of the MBP1 is satisfactorily attained in the low vacuum region B and the region A close to atmospheric pressure.

[0043] As described above, by using the vacuum evacuation device 100 according to the first embodiment, by increasing the power of the motor of the MBP1 and also providing the check valve 3 and the branch pipe 70, the pumping rate of the main pump will not be controlled by the pumping rate of the auxiliary pump even in the region close to atmospheric pressure, and thus the pumping rate in the region close to atmospheric pressure and the low vacuum region can be improved. For this reason, the evacuation performance in the region A close to atmospheric pressure and the low vacuum region B can be improved and, as a result, the LC20 can reach the target degree of vacuum within a short time period, while suppressing the level of alteration to the constitutions of the MBP1 and the DRP2 to a minimum level.

[0044] It should be noted that in the above-mentioned first embodiment, it is also possible to configure so that the branch pipe 70 is prepared as an individual exhaust pipe rather than to terminate the branch pipe 70 with the exhaust pipe 60 of the DRP2.

<Second embodiment>

[0045] FIG. 5 is a schematic diagram for explaining the constitution of a vacuum evacuation device according to a second embodiment, and the same component as that in FIG. 1 will be provided with the same reference symbol. A vacuum evacuation device 200 according to the second embodiment includes a main pump 21, in which two pumps (MBPs) 21a and 21b are arranged in parallel, an auxiliary pump 2 and a check valve 3. In other words, the vacuum evacuation device 200 according to the second embodiment has a constitution, which is different from that of the vacuum evacuation device 100 (refer to FIG. 1) according to the first embodiment in that the main pump 1 is constituted of two MBPs 21a and 21b, which are arranged in parallel, rather than a single MBP.

[0046] In the vacuum evacuation device 200, since the main pump is configured by arranging a plurality of pumps in parallel, the capacity of the main pump as a whole can be increased even if a high power motor is not employed in the individual pumps that constitute the main pump.

[0047] That is, in the second embodiment, a high power main pump 21 is achieved by arranging two MBPs in parallel, so that the ratio of the maximum power (unit: W) of the motor to the maximum pumping rate of two MBPs when added together will be equal to or more than 5 W/(m^3/h), even though the ratio of individual MBP is less than 5 W/(m^3/h).

[0048] As described above, by using by using the vacuum evacuation device 200 according to the second embodiment, by adopting the high power main pump 21, in which a plurality of MBPs are arranged in parallel, the evacuation performance in the region A close to atmospheric pressure and the low vacuum region B can be improved as in the first embodiment and, as a result, the LC20 can reach the target degree of vacuum within a short time period.

[0049] It should be noted that it is also possible to configure the main pump by using 3 or more pumps arranged in parallel, arranging a plurality of auxiliary pumps in parallel, or arranging a plurality of main pumps and a plurality of auxiliary pumps, respectively, in parallel. In addition, it is also possible to provide a pipe and a gate valve, for each pump that constitutes the main pump, between the LC20 and the pump. Further, it is also possible to provide a check valve and a branch pipe for each pump that constitutes the main pump.

INDUSTRIAL APPLICABILITY

[0050] According to the present invention, a vacuum evacuation device capable of shortening the evacuation time required until the target degree of vacuum is achieved can be provided, while suppressing the level of alteration to the constitutions of the main pump and the auxiliary pump to a minimum level.

DESCRIPTION OF THE REFERENCE SYMBOLS

[0051]

1:	Main pump (MBP)
2:	Auxiliary pump (DRP)
3:	Check valve
20:	Chamber (LC)
21:	Main pump MBP
30:	Gate valve
40, 50, 60, 70:	Pipe
100, 200:	Vacuum evacuation device

Claims

1. A vacuum evacuation device comprising:

a main pump;
an auxiliary pump connected in series to the main pump; and
an inter-pump piping for interconnecting an outlet of the main pump and an inlet of the auxiliary pump, wherein
the main pump comprises a mechanical booster pump;
a ratio of the maximum power of a motor for the main pump to the maximum pumping rate of the

main pump is no less than 5 W/(m^3/h);
the inter-pump piping comprises a branch pipe branched from the middle of the inter-pump piping; and
a check valve for releasing gas in the inter-pump piping and preventing a back flow of the gas is provided in the middle of the branch pipe.

2. The vacuum evacuation device according to Claim 1, wherein the main pump comprises a plurality of the mechanical booster pumps which are arranged in parallel.

3. The vacuum evacuation device according to Claim 1, wherein the branch pipe is terminated with an exhaust pipe of the auxiliary pump.

4. The vacuum evacuation device according to any one of Claims 1 to 3,
wherein a pressure loss of a gas flow in the check valve is no more than 10,000 Pa when operating the main pump at atmospheric pressure.

FIG. 1

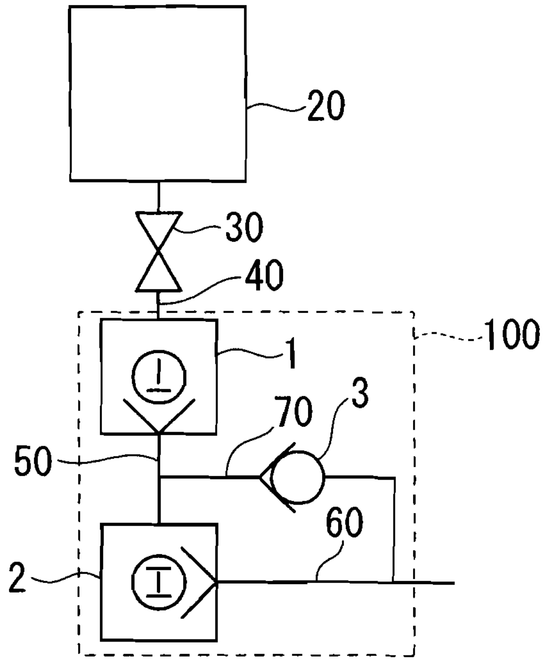


FIG. 2

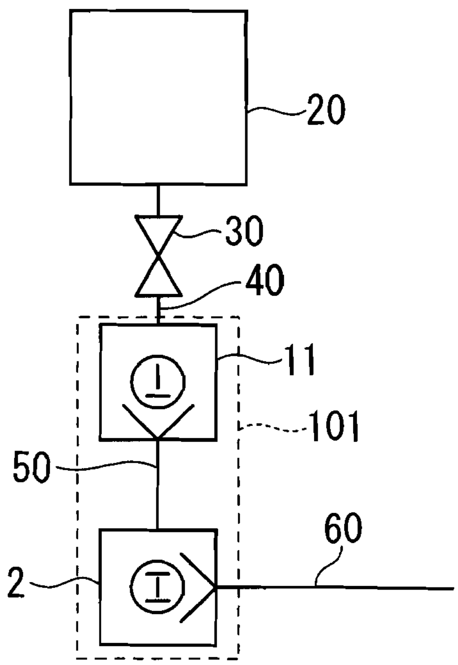


FIG. 3

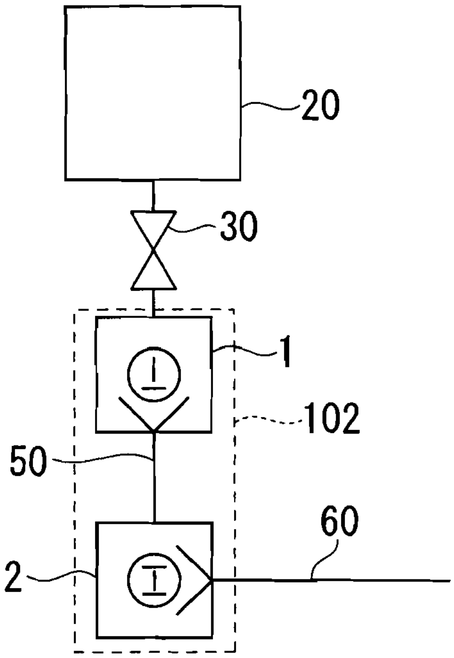


FIG. 4A

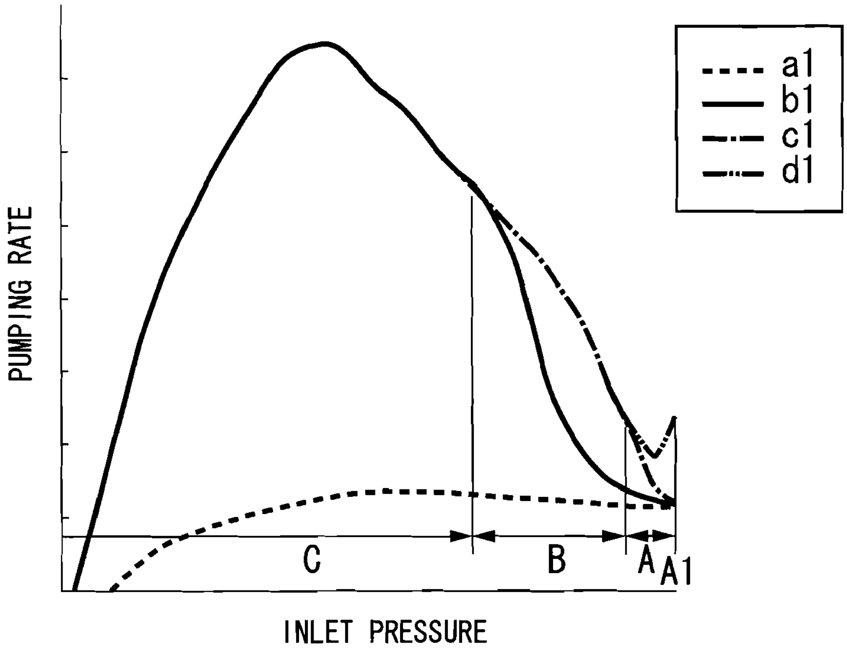

a1
b1
c1
d1
PUMPING RATE
C
B
A
A1
INLET PRESSURE

FIG. 4B

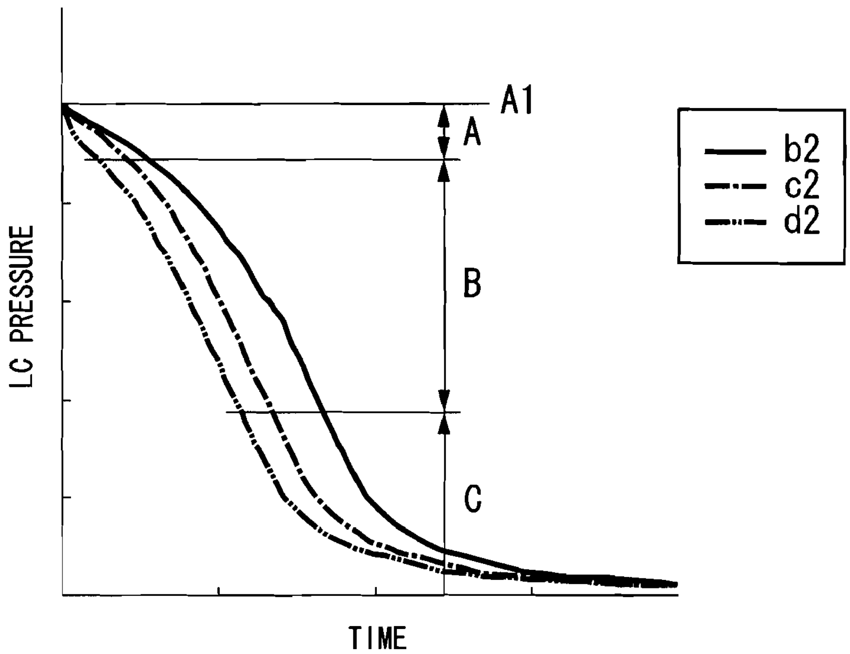
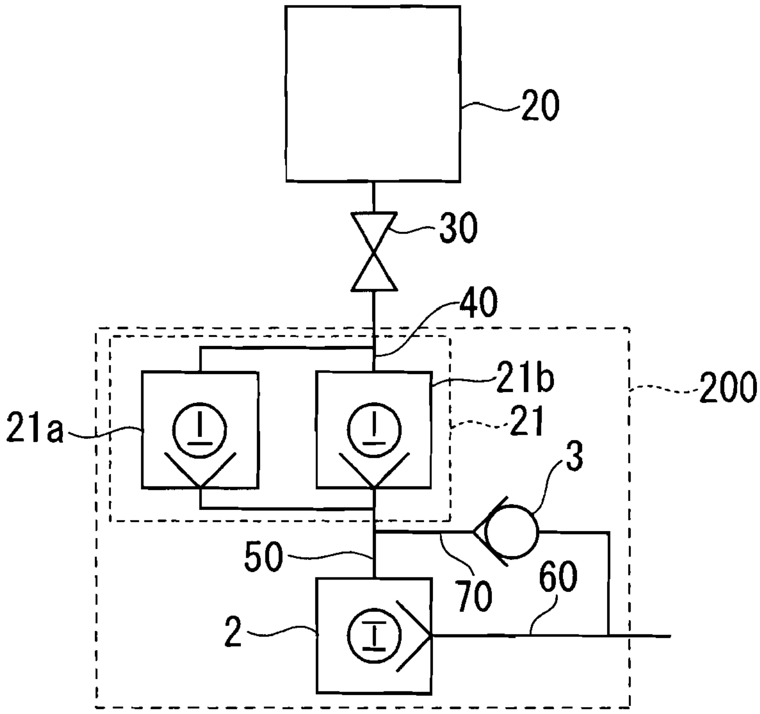

A1
A
B
C
b2
c2
d2
LC PRESSURE
TIME

FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004496

A. CLASSIFICATION OF SUBJECT MATTER
F04B37/16(2006.01)i, *F04B39/10*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04B37/16, F04B39/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2003-129957 A (Ulvac, Inc.), 08 May 2003 (08.05.2003), claims 1 to 8; fig. 1 & US 2004/0173312 A1 paragraph [0132]; fig. 11	1-4
Y	JP 2003-139080 A (Ulvac, Inc.), 14 May 2003 (14.05.2003), claims 1 to 2; fig. 1 & US 2004/0173312 A1 paragraph [0132]; fig. 11	1-4
Y	JP 2003-139056 A (Ulvac, Inc.), 14 May 2003 (14.05.2003), claims 1 to 3; fig. 7 & US 2004/0173312 A1 paragraph [0132]; fig. 11	1-4

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
26 October, 2009 (26.10.09)	10 November, 2009 (10.11.09)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/004496

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2007-231935 A (Ebara Densan Ltd.), 13 September 2007 (13.09.2007), paragraphs [0023] to [0026]; fig. 1 & WO 2007/088989 A1 page 8, line 21 to page 9, line 20; fig. 1	1-4

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2008232324 A **[0001]**
- JP 2007127048 A **[0007]**