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(71) Applicant: **TLV Co., Ltd.**
Kakogawa-shi
Hyogo 675-8511 (JP)

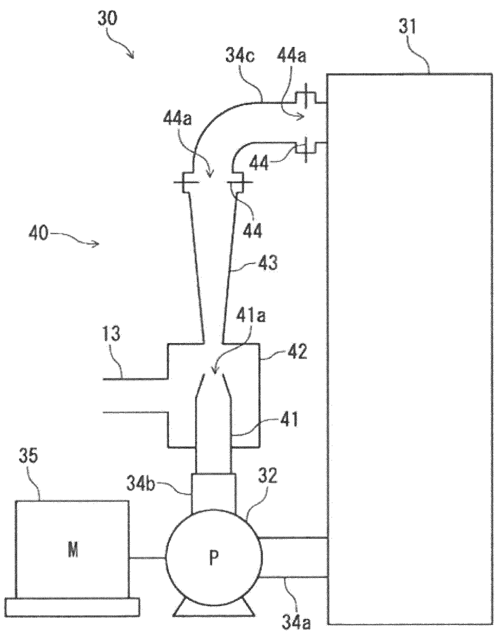
(72) Inventor: **KURODA, Junji**
Kakogawa-shi
Hyogo 675-8511 (JP)

(74) Representative: **Puschmann Borchert Bardehle Patentanwälte Partnerschaft mbB**
Bajuwarenring 21
82041 Oberhaching (DE)

(54) EJECTOR AND VACUUM GENERATION DEVICE WITH SAME

(57) An ejector (40) includes a nozzle (41) that ejects a first fluid, a suction chamber (42) that sucks a second fluid using a pressure decrease caused by ejection of the first fluid through the nozzle (41), a diffuser (43) that discharges the first fluid ejected through the nozzle (41) and the second fluid sucked into the suction chamber (42) while raising a pressure of the first fluid and the second fluid, and at least one orifice plate (44) located downstream from the diffuser (43).

FIG. 2



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Description

FIELD

[0001] The disclosure relates to an ejector and a vacuum generation device including the ejector.

BACKGROUND

[0002] An ejector and a vacuum generation device including the ejector are known. For example, a vacuum generation device described in Patent Literature 1 circulates a fluid stored in a tank through a pump and an ejector as a first fluid to allow the ejector to generate a suction force, which sucks a second fluid.

CITATION LIST

PATENT LITERATURE

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2014-156814

SUMMARY

TECHNICAL PROBLEM

[0004] The ejector includes a nozzle and a diffuser that are designed to suck the second fluid as intended.

[0005] However, the ejector including the nozzle and the diffuser designed as above may fail to suck the second fluid as intended if the ejector malfunctions. The ejector may malfunction when, for example, the pressure of the fluid passing through the diffuser is not raised sufficiently.

[0006] In response to the above issue, one or more aspects of the disclosure are directed to an ejector that functions properly.

SOLUTION TO PROBLEM

[0007] An ejector according to one aspect of the disclosure includes a nozzle that ejects a first fluid, a suction chamber that sucks a second fluid using a pressure decrease caused by ejection of the first fluid through the nozzle, a diffuser that discharges the first fluid ejected through the nozzle and the second fluid sucked into the suction chamber while raising a pressure of the first fluid and the second fluid, and at least one flow restrictor located downstream from the diffuser.

[0008] A vacuum generation device according to another aspect of the disclosure includes the ejector, a tank that stores the first fluid and the second fluid that have passed through the diffuser, and a pump connected to the tank. The pump pumps a fluid in the tank to the ejector as the first fluid. The pump and the ejector allow the fluid in the tank to circulate through them and suck the second fluid through the ejector.

ADVANTAGEOUS EFFECTS

[0009] The ejector according to the above aspect includes the flow restrictor located downstream from the diffuser to sufficiently raise the pressure of the fluid passing through the diffuser. The ejector can thus function properly.

[0010] The vacuum generation device according to the above aspect includes the flow restrictor located downstream from the diffuser to sufficiently raise the pressure of the fluid passing through the diffuser. The ejector can thus function properly. The vacuum generation device can suck the second fluid properly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

[FIG. 1] FIG. 1 is a schematic diagram of piping for a vacuum steam heating system according to one embodiment.

[FIG. 2] FIG. 2 is a schematic diagram of a vacuum generation device.

[FIG. 3] FIG. 3 is a graph showing the relationship between the aperture ratio of an orifice plate and the circulating water temperature in association with a vacuum failure.

[FIG. 4] FIG. 4 is a graph showing the relationship between the degree of vacuum and the amount of suction by an ejector.

DETAILED DESCRIPTION

[0012] Embodiments will be described by way of example with reference to the drawings. The embodiments described below are preferred examples, and do not limit the scope, applications, and uses of the present invention.

[0013] FIG. 1 is a schematic diagram of piping for a vacuum steam heating system 1 according to one embodiment.

[0014] The vacuum steam heating system (hereafter, the heating system) 1 includes a reaction tank 20, which heats an object with steam, a steam supply pipe 11, which supplies steam to the reaction tank 20 from a steam generator (not shown), a discharge pipe 13, which discharges a drain generated in the reaction tank 20, and a vacuum generation device 30, which sucks the drain through the discharge pipe 13. The heating system 1 includes a fluid circuit 10, which includes the steam supply pipe 11, the reaction tank 20, the discharge pipe 13, and the vacuum generation device 30. The heating system 1 heats an object placed in the reaction tank 20 with saturated steam at an atmospheric pressure or less.

[0015] The reaction tank 20 includes a tank body 21, in which an object is placed, and a jacket 22, which extends along substantially the entire periphery of the tank body 21. The steam supply pipe 11 is connected to the jacket 22. The steam supply pipe 11 includes a supply valve 14, which is an on-off valve. Steam generated in the steam generator is supplied to the jacket 22 through the steam supply pipe 11. The steam supplied to the jacket 22 indirectly exchanges heat with the object placed in the tank body 21 in the reaction tank 20 to condense (or liquefy) and heat the object in the tank body 21. More specifically, the object is heated with the condensed latent heat from the steam.

[0016] The discharge pipe 13 has one end (inlet end) connected to a lower end part of the jacket 22, and the other end (outlet end) connected to the vacuum generation device 30. The discharge pipe 13 discharges the drain (condensate) generated from the steam condensed in the jacket 22. The discharge pipe 13 includes a steam trap 15, which automatically discharges only the drain flowing into the steam trap 15.

[0017] The vacuum generation device 30 includes a drain tank 31, which stores the drain, a pump 32, which pumps the drain in the drain tank 31, and an ejector 40, which sucks the drain from the reaction tank 20 through the discharge pipe 13. The drain tank 31, the pump 32, and the ejector 40 are connected to one another with a pipe 34. This forms a circulation passage including the drain tank 31, the pump 32, and the ejector 40. The vacuum generation device 30 circulates the drain stored in the drain tank 31 through the pump 32 and the ejector 40 to cause the ejector 40 to generate a suction force, which then sucks the drain from the reaction tank 20.

[0018] FIG. 2 is a schematic diagram of the vacuum generation device 30. The pipe 34 includes a first pipe 34a connecting the drain tank 31 and the pump 32, a second pipe 34b connecting the pump 32 and the ejector 40, and a third pipe 34c connecting the ejector 40 and the drain tank 31. The drain tank 31 is an example of the tank. The pump 32 is driven by a motor 35.

[0019] The ejector 40 includes a nozzle 41 for ejecting a first fluid, a suction chamber 42, which uses a negative pressure generated by the first fluid ejected through the nozzle 41 to suck a second fluid, a diffuser 43, which discharges the first fluid ejected through the nozzle 41 and the second fluid sucked into the suction chamber 42 while raising their pressure, and two orifice plates 44 located downstream from the diffuser 43.

[0020] The nozzle 41 is connected to a downstream end of the second pipe 34b. The nozzle 41 has an injection hole 41a located at least inside the suction chamber 42.

[0021] The suction chamber 42 also contains at least an upstream end part of the diffuser 43. The discharge pipe 13 has the outlet end connected into the suction chamber 42. In the suction chamber 42, the second fluid is sucked from the discharge pipe 13 under a negative pressure (pressure decrease) caused by ejection of the first fluid through the nozzle 41. In the suction chamber 42, the negative pressure resulting from the jet pumping of the first fluid generates a suction force for sucking the second fluid.

[0022] The diffuser 43 defines a linear passage. The cross-sectional area of the passage defined in the diffuser 43 increases from upstream to downstream. A fluid passing through the diffuser 43 thus decelerates, and the pressure of the fluid increases the fluid flows from upstream to downstream. The third pipe 34c is connected to the downstream end of the diffuser 43.

[0023] The orifice plates 44 are disc-shaped, and each have a circular central opening 44a. The orifice plates 44 are an example of a flow restrictor. The orifice plates 44 are located inside the third pipe 34c. More specifically, the upstream orifice plate 44 is located on an upstream end of the third pipe 34c, or is located at a joint between the diffuser 43 and the third pipe 34c. The downstream orifice plate 44 is located on a downstream end of the third pipe 34c, or is located at a joint between the third pipe 34c and the drain tank 31. The diffuser 43 and the third pipe 34c are connected to each other at their flanges. The upstream orifice plate 44 is located between the flange of the diffuser 43 and the flange of the third pipe 34c. The third pipe 34c and the drain tank 31 are connected to each other at their flanges. The downstream orifice plate 44 is located between the flange of the third pipe 34c and the flange of the drain tank 31.

[0024] The opening 44a in the upstream orifice plate 44 has an area smaller than the cross-sectional area of a passage in the part of the third pipe 34c downstream from the orifice plate 44. In the same manner, the opening 44a in the downstream orifice plate 44 has an area smaller than the cross-sectional area of a passage in the part of the third pipe 34c upstream from the orifice plate 44. More specifically, the upstream and downstream orifice plates 44 function as chokes to narrow the cross-sectional area of the passage downstream from the diffuser 43.

[0025] The opening 44a in the upstream orifice plate 44 has the same area as the opening 44a in the downstream orifice plate 44. The cross-sectional area of the passage in the third pipe 34c is uniform from upstream to downstream. For the upstream orifice plate 44, the ratio of the area of the opening 44a to the cross-sectional area of the passage in the third pipe 34c (the area of the opening 44a/the cross-sectional area of the passage in the third pipe 34c, or hereafter the aperture ratio) is equal to the aperture ratio of the downstream orifice plate 44.

[0026] The vacuum generation device 30 with the structure described above supplies the drain inside the drain tank 31 with the pressure being raised by the pump 32 to the nozzle 41 in the ejector 40 as the first fluid. The drain is ejected through the nozzle 41 into the suction chamber 42 to generate a negative pressure around the nozzle 41, which then sucks the drain in the reaction tank 20 into the suction chamber 42 through the discharge pipe 13 as the second fluid. The drain ejected through the nozzle 41 and the drain sucked from the discharge pipe 13 mix in the suction chamber 42. The resultant drain is then discharged through the diffuser 43. In this state, the drain decelerates and the pressure of the drain increases when flowing downstream through the diffuser

43. The drain finally flows into the drain tank 41. The drain in the reaction tank 20 is collected into the drain tank 31.

[0027] The orifice plates 44 located downstream from the diffuser 43 allow the ejector 40 to function properly, and the drain to be properly sucked from the reaction tank 20.

[0028] More specifically, the orifice plates 44 located downstream from the diffuser 43 increase the flow resistance in the passage downstream from the diffuser 43 and increase the fluid pressure in the passage downstream from the diffuser 43. This sufficiently raises the pressure of the fluid passing through the diffuser 43. At a low fluid pressure downstream from the diffuser 43, the pressure of the fluid passing through the diffuser 43 may not be raised sufficiently. In the ejector 40, the nozzle 41 and the diffuser 43 are designed based on the pressure difference between the inlet of the nozzle 41 and the outlet of the diffuser 43. If this pressure difference is too small, the ejector 40 cannot have an intended negative pressure generated in the suction chamber 42. The orifice plates 44 located downstream from the diffuser 43 allow a sufficiently large increase in the pressure of the fluid passing through the diffuser 43. This generates an intended negative pressure in the suction chamber 42. The ejector 40 can thus function properly.

[0029] The diffuser 43 may or may not sufficiently raise the pressure of the fluid depending on the temperature of the drain circulating through the vacuum generation device 30 (hereafter, the circulating water temperature) in addition to the pressure downstream from the diffuser 43. As the circulating water temperature is higher, the drain has lower viscosity, and thus causes a smaller pressure increase (pressure recovery) in the drain passing through the diffuser 43. In other words, as the circulating water temperature is higher, an intended negative pressure is less likely to be generated in the suction chamber 42.

[0030] FIG. 3 is a graph showing the relationship between the aperture ratio of the orifice plate 44 and the circulating water temperature in association with a failure to generate an intended negative pressure in the suction chamber 42 (hereafter, a vacuum failure). A solid line in FIG. 3 indicates a threshold at which a vacuum failure occurs when a single orifice plate 44 is used. A vacuum failure can occur in an area defined above the threshold, or an area in which the circulating water temperature is higher than the threshold (a hatched area for the threshold indicated by the solid line in the figure). A broken line in FIG. 3 indicates a threshold at which a vacuum failure occurs when two orifice plates 44 are used.

[0031] With no orifice plate 44 being used (corresponding to the aperture ratio of 100%), the circulating water temperature at the threshold at which no vacuum failure occurs (hereafter, the threshold water temperature) is T1. As shown in FIG. 3, the threshold water temperature can be higher as the opening 44a in the orifice plate 44 is smaller. In other words, the circulating water temperature at which no vacuum failure occurs can be higher. With the two orifice plates 44 being used, instead of the single orifice plate 44, the threshold water temperature can be still higher (as indicated by the broken line), because the use of more orifice plates 44 raises the pressure more in the passage downstream from the diffuser 43.

[0032] However, the orifice plate 44 having a smaller aperture ratio may have a flow resistance that is too high. This may decrease the flow rate of the drain passing through the third pipe 34c, or the flow rate of the drain passing through the diffuser 43. This lowers the flow rate of the drain to be sucked from the reaction tank 20 through the discharge pipe 13.

[0033] In contrast, multiple orifice plates 44 may be used to increase the flow resistance while retaining the intended flow rate. FIG. 4 is a graph showing the relationship between the degree of vacuum and the amount of suction by the ejector. In FIG. 4, a solid line indicates the structure including a single orifice plate 44 with the aperture ratio of 60%, whereas a broken line indicates the structure including two orifice plates 44 with the aperture ratio of 75%. When the degree of vacuum is high (e.g., 100 kPaG), or specifically when the ejector 40 functions properly, the structure including the two orifice plates 44 with the aperture ratio of 75% has a larger amount of suction than the structure including the single orifice plate 44 with the aperture ratio of 60%. Although the structure including the single orifice plate 44 with the aperture ratio of 60% can sufficiently increase the threshold water temperature (refer to FIG. 3), the aperture ratio is small and the amount of suction decreases. In contrast, the structure including the two orifice plates 44 with the aperture ratio of 75% can retain the intended amount of suction, in addition to sufficiently increasing the threshold water temperature. In other words, the use of more orifice plates 44 increases the threshold water temperature, while retaining the intended amount of suction with a greater aperture ratio.

[0034] As described above, the ejector 40 includes the nozzle 41 that ejects the first fluid, the suction chamber 42 that sucks the second fluid using a pressure decrease caused by ejection of the first fluid through the nozzle 41, the diffuser 43 that discharges the first fluid ejected through the nozzle 41 and the second fluid sucked into the suction chamber 42 while raising the pressure of the first fluid and the second fluid, and at least one orifice plate 44 located downstream from the diffuser 43.

[0035] The structure including the orifice plate 44 located downstream from the diffuser 43 can raise the pressure of the passage downstream from the diffuser 43. This structure thus sufficiently raises the pressure of the fluid passing through the diffuser 43, and enables the ejector 40 to function properly.

[0036] For example, the pipe 34 (in particular, the third pipe 34c) may be short to downsize the ejector 40 and thus the vacuum generation device 30. In this case, the pressure downstream from the diffuser 43 tends to be lower. The pressure of the fluid passing through the diffuser 43 may not be raised sufficiently. The orifice plate 44 used in this structure can sufficiently raise the pressure of the fluid passing through the diffuser 43. In other words, the structure including the orifice plate 44 is particularly effective for the ejector 40 and the vacuum generation device 30 that are compact.

[0037] The orifice plate 44 narrows the cross-sectional area of the passage from its peripheral portion, and thus allows the fluid to have an appropriate pressure decrease without excessively disturbing the outwardly diverging flow of the fluid.

[0038] The at least one orifice plate 44 includes a plurality of orifice plates 44. This structure can raise the pressure in the passage downstream from the diffuser 43 without excessively reducing the flow rate of the fluid passing through the diffuser 43.

[0039] Further, the at least one orifice plate 44 has the opening 44a with a smaller cross-sectional area than passages upstream and downstream from the orifice plate 44 as the restrictor.

[0040] The orifice plate 44 narrows the passage to increase the flow resistance.

[0041] The vacuum generation device 30 includes the ejector 40, the drain tank 31 that stores the first fluid and the second fluid that have passed through the diffuser 43, and the pump 32 connected to the drain tank 31. The pump 32 pumps the fluid in the drain tank 31 to the ejector 40 as the first fluid. The pump 32 and the ejector 40 allow the fluid in the drain tank 31 to circulate through them and suck the second fluid through the ejector 40.

[0042] In this structure, the ejector 40 can function properly as described above, and the second fluid can be sucked through the ejector 40 properly.

[0043] The ejector 40 and the vacuum generation device 30 are usable for systems other than the vacuum steam heating system 1. For example, the ejector 40 and the vacuum generation device 30 may be used for a system that performs cooling in addition to heating with steam. The steam used in such systems may not be steam at an atmospheric pressure or less.

[0044] Although the ejector 40 circulates water in the above embodiments, the ejector 40 may not be a liquid ejector. The ejector 40 may circulate a gas.

[0045] Although the orifice plate is used as the flow restrictor in the above embodiments, the flow restrictor may have any structure that increases the flow resistance to higher than the resistance in parts upstream and downstream from the flow restrictor. For example, the flow restrictor may be a choke that gradually narrows the cross-sectional area of a passage, a valve that reduces the cross-sectional area of a passage, or may be a bellow tube.

[0046] Although the structure according to the above embodiments includes the two orifice plates 44 as flow restrictors, the structure may include a single flow restrictor or three or more flow restrictors.

INDUSTRIAL APPLICABILITY

[0047] The technique according to the disclosure is applicable to the ejector and the vacuum generation device including the ejector.

REFERENCE SIGNS LIST

[0048]

1 vacuum steam heating system

30 vacuum generation device
31 drain tank (tank)
32 pump
40 ejector
41 nozzle
42 suction chamber
43 diffuser
44 orifice (flow restrictor)

Claims

1. An ejector, comprising:

a nozzle configured to eject a first fluid;
a suction chamber configured to suck a second fluid using a pressure decrease caused by ejection of the first fluid through the nozzle;
a diffuser configured to discharge the first fluid ejected through the nozzle and the second fluid sucked into the suction chamber while raising a pressure of the first fluid and the second fluid; and
at least one flow restrictor located downstream from the diffuser.

2. The ejector according to claim 1, wherein the flow restrictor comprises a plurality of flow restrictors.

3. The ejector according to claim 1 or claim 2, wherein the flow restrictor has a passage with a smaller cross-sectional area than passages upstream and downstream from the flow restrictor.

4. The ejector according to any one of claims 1 to 3, wherein the flow restrictor includes an orifice plate.

5. A vacuum generation device, comprising:

the ejector according to any one of claims 1 to 4;
a tank configured to store the first fluid and the second fluid that have passed through the diffuser; and
a pump connected to the tank, the pump being

configured to pump a fluid in the tank to the ejector as the first fluid,
wherein the pump and the ejector allow the fluid in the tank to circulate therethrough and suck the second fluid through the ejector.

FIG. 1

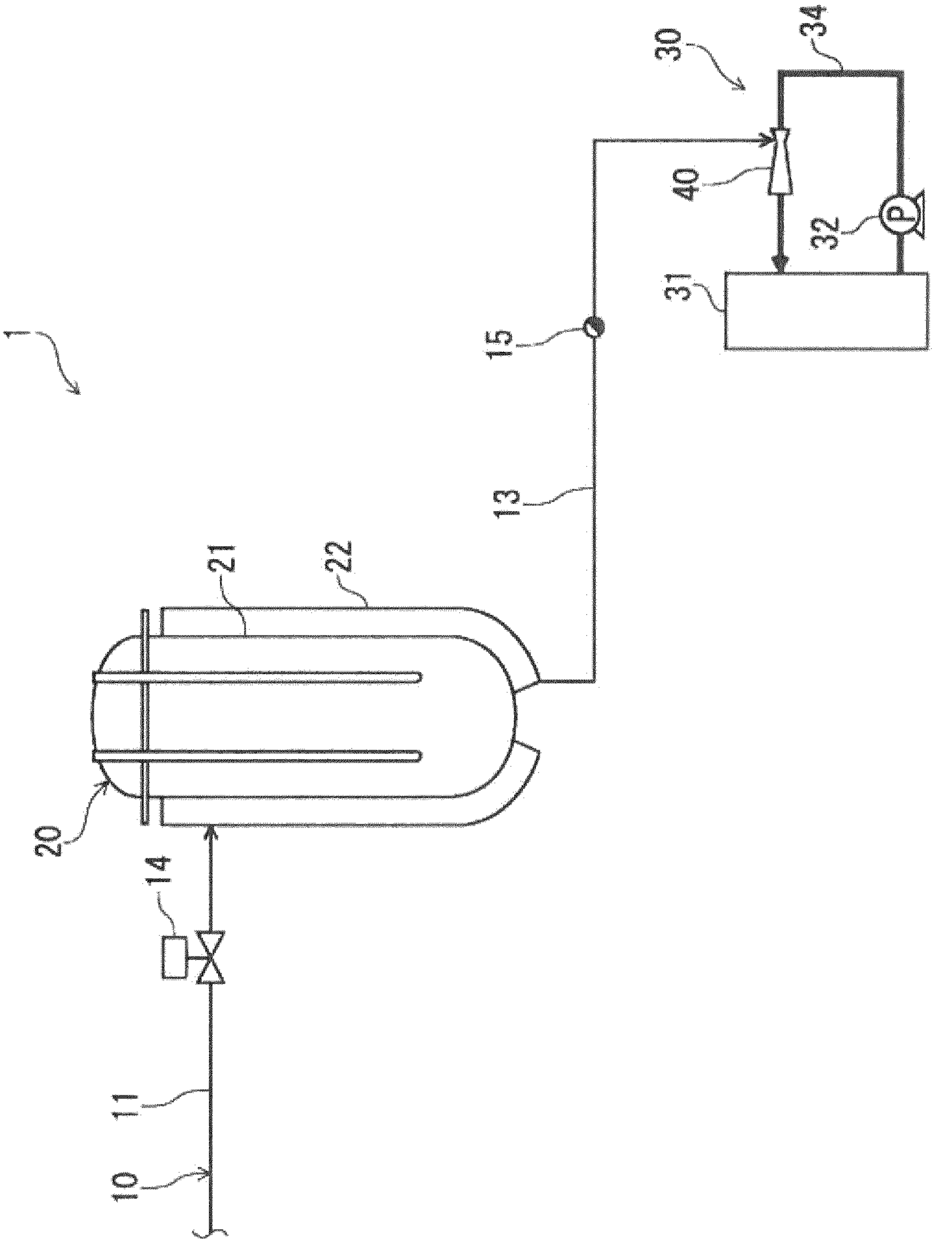


FIG. 2

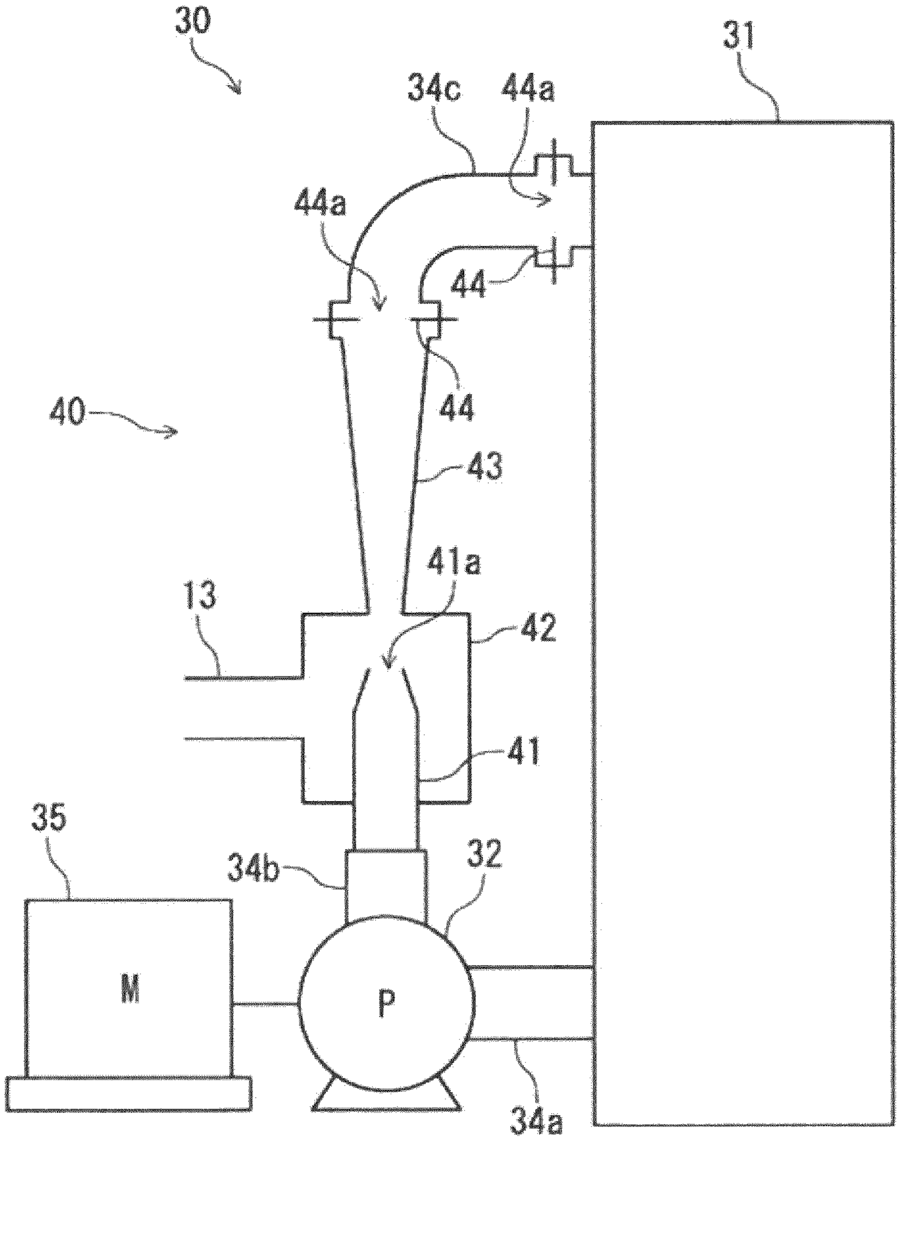


FIG. 3

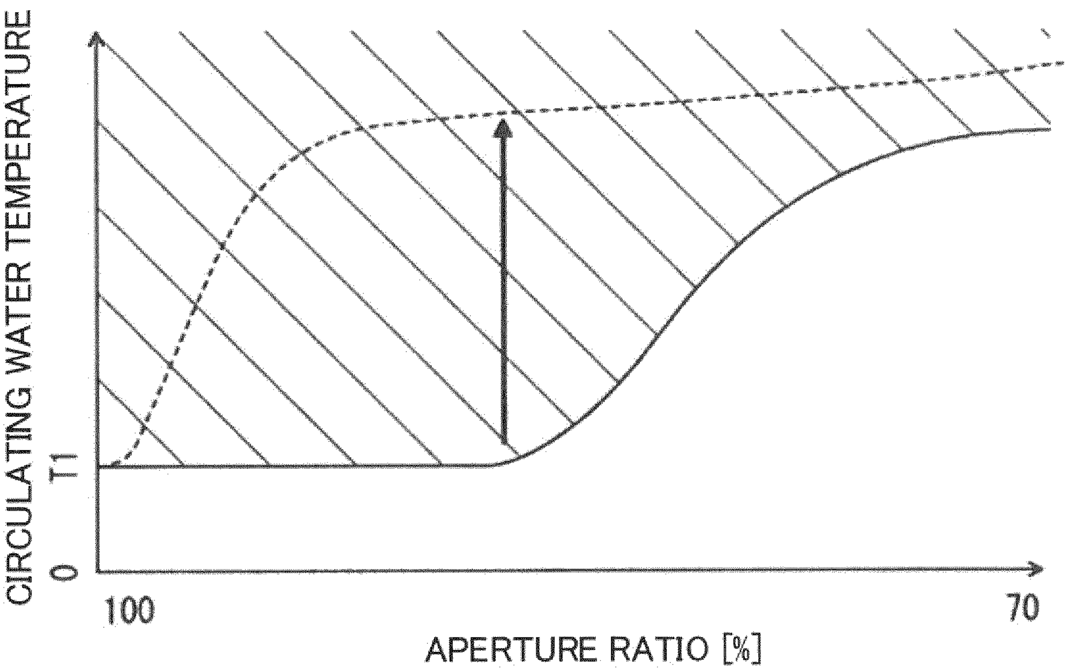
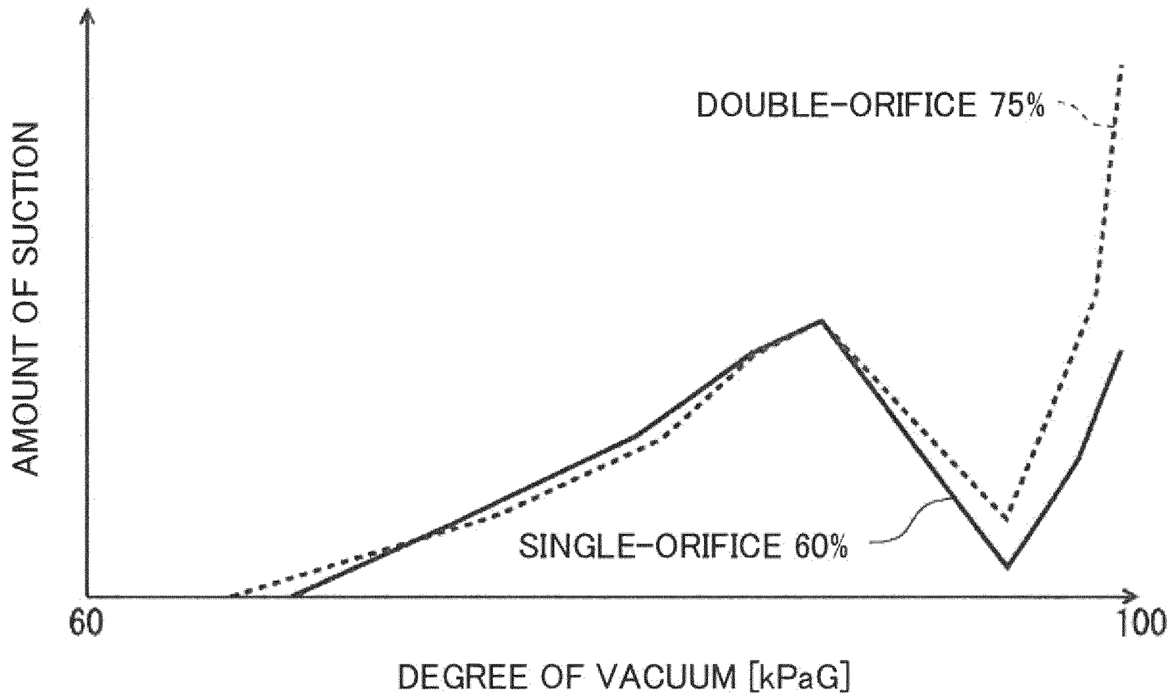


FIG. 4


DOUBLE-ORIFICE 75%
AMOUNT OF SUCTION
SINGLE-ORIFICE 60%
60
100
DEGREE OF VACUUM [kPaG]

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/075519

A. CLASSIFICATION OF SUBJECT MATTER
F04F5/44(2006.01)i, *F04F5/04*(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)
F04F5/44, F04F5/04

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	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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.
X Y A	WO 2012/132047 A1 (Koganei Corp.), 04 October 2012 (04.10.2012), paragraphs [0016] to [0043]; fig. 1 to 4 & US 2014/0014746 A1 paragraphs [0026] to [0053]; fig. 1 to 4 & JP 2012-215173 A & CN 103459855 A & KR 10-2014-0020944 A & TW 201239205 A	1,3-4 5 2
X Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 62498/1987(Laid-open No. 168300/1988) (Iwata Air Compressor Mfg. Co., Ltd.), 01 November 1988 (01.11.1988), specification, page 5, line 8 to page 7, line 19; fig. 1 (Family: none)	1,3 5 2,4

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 November 2016 (07.11.16)	15 November 2016 (15.11.16)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/075519

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 86535/1973(Laid-open No. 33310/1975) (Namio TAKAHASHI), 10 April 1975 (10.04.1975), specification, page 2, line 10 to page 5, line 5; fig. 2 (Family: none)	1,3 5 2,4
Y A	JP 2014-156814 A (TLV Co., Ltd.), 28 August 2014 (28.08.2014), paragraphs [0009] to [0013] (Family: none)	5 1-4
A	US 5896435 A (GAUTIER,Guy-Marie), 20 April 1999 (20.04.1999), entire text; all drawings & EP 798469 A1 & FR 2746484 A1	1-5

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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