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(71) Applicant: **Agilent Technologies, Inc.**
Santa Clara, CA 95051 (US)

(72) Inventors:
- **LEPORE, Andrea**
  SANTA CLARA (US)
- **DE PALMA, Giuseppe**
  SANTA CLARA (US)
- **IANNUCCI, Giovanni**
  SANTA CLARA (US)

(74) Representative: **Robba, Pierpaolo**
Interpatent S.R.L.
Via Caboto, 35
10129 Torino (IT)

(54) VACUUM PUMP PROVIDED WITH A GAS BALLAST ARRANGEMENT

(57) The present invention relates to a vacuum pump (1) provided with a gas ballast arrangement. Such gas ballast arrangement includes a gas ballast supply duct (29) opening into the pumping chamber (7) of the vacuum pump, which gas ballast supply duct is open during the compression phase of the vacuum pump working cycle and is closed at least during the exhaust phase of the vacuum pumping working cycle. Thanks to this gas ballast arrangement, condensation of liquids in the pumping chamber can be effectively prevented while avoiding, at the same time, increase in power consumption and in noise generated by the vacuum pump. In a preferred embodiment, the gas ballast supply duct (29) is connected to the exhaust duct (23) of the vacuum pump by a connecting pipe (35) and the gas ballast arrangement includes a valve assembly (37, 39) arranged in said connecting pipe, so that opening / closing of the gas ballast supply pipe can be controlled by the pressure in said exhaust duct (23).

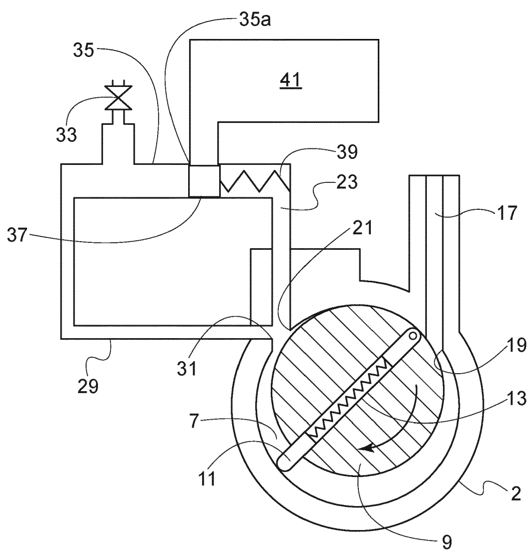

Fig. 3a

EP 4 174 316 A1

Description

Technical field of the invention

[0001] The present invention relates to a vacuum pump provided with a gas ballast arrangement. More particularly, the present invention relates to a rotary vane vacuum pump, in which oil is used as sealant and lubricant, provided with a gas ballast.

Prior art

[0002] Rotary vane vacuum pumps are well known in the art and they are generally used to obtain low vacuum conditions, that is a pressure range from atmospheric pressure to about 10^{-1} Pa.

[0003] In general, rotary vane vacuum pumps include a casing, having a suction port and an exhaust port, within which a stator is provided. Such stator defines a cylindrical pumping chamber inside which a circular rotor equipped with spring-loaded radial vanes is eccentrically arranged.

[0004] A suction duct connects the suction port to the pumping chamber and opens into the pumping chamber at a suction bore; analogously an exhaust duct connects the exhaust port to the pumping chamber and opens into the pumping chamber at an exhaust bore: during its rotation, the rotor pumps a fluid from the suction bore to the exhaust bore.

[0005] These pumps are immersed into an oil bath, which is used both for sealing the pumping chamber and for refrigerating and lubricating the pump.

[0006] Pumps of such kind are known for instance from documents EP 1 591 63 and US 2014/363319A1.

[0007] During operation of the pump, liquid, especially water, may enter the pumping chamber. This is the case, for instance, of moisture contained in a gas (air) pumped by the vacuum pump.

[0008] In this case, the liquid that is sucked by the vacuum pump is vaporized and enters the vacuum pump in the form of vapor.

[0009] A mixture of gas and vapor will be then sucked and compressed by the vacuum pump during the working cycle thereof.

[0010] As such mixture is compressed, the vapor will begin to condense and the remaining amount of gas will not be sufficient for quickly raising the pressure above the threshold value for causing the exhaust valve to open and the pumped mixture to be discharged from the pump.

[0011] When the remaining gas eventually reaches the pressure value required for opening the exhaust valve, the vapor will be almost completely condensed.

[0012] While the gas is discharged from the pump, the condensed liquid will fall back into the pumping chamber, thus mixing with oil.

[0013] This happens at each working cycle, so that after a number of working cycles as an overall effect oil will get emulsified. This will lead to a deterioration of sealing and lubricating properties of oil and, eventually, to malfunction of the vacuum pump and damages to its rotor.

[0014] In order to overcome this technical problem, rotary vane vacuum pumps provided with a so-called "gas ballast" arrangement have been developed.

[0015] Gas ballast is the introduction of a non-condensable gas into the pumping chamber of a vacuum pump during the compression phase in order to contribute to pressure increase, so that the threshold value allowing the exhaust valve to open is reached in an easier and faster way, namely before condensation of vapors in the pumping chamber.

[0016] In general, a gas ballast arrangement includes a gas ballast supply duct that opens into the chamber defined by the pump stator at a gas ballast bore, arranged at a position between the suction bore and the exhaust bore.

[0017] As long as the pressure in the chamber is above a given threshold, for instance above the atmospheric pressure, flow of gas through the gas ballast supply duct and into the pumping chamber is prevented.

[0018] As soon as the pressure drops below said threshold (i.e. below atmospheric pressure), gas is introduced into the pumping chamber through the gas ballast supply duct.

[0019] The gas ballast arrangement is equipped with some kind of valve assembly preventing the flow of oil from the pumping chamber into the gas ballast supply duct, while allowing the flow of gas into the pumping chamber.

[0020] It is evident that the gas ballast bore is arranged sufficiently far from the suction bore, so that flow of gas from the gas ballast supply duct into the vacuum chamber is prevented by the pump vane delimiting the pumping chamber.

[0021] Thanks to the introduction of the additional gas provided by the gas ballast, the pressure inside the pump rapidly increases, so that the exhaust valve is opened earlier than in a vacuum pump without a gas ballast arrangement, thus avoiding condensation of vapors inside the pump.

[0022] Although gas ballast allows to prevent the contamination of oil with condensed vapors and the consequent deterioration of oil properties, known gas ballast arrangements are not free from drawbacks.

[0023] More particularly, in known arrangement opening and closing of gas ballast supply duct is controlled by a manual valve, so that during vacuum pump operation the gas ballast supply duct is always open.

[0024] In other words, this duct is open during all phases of the pump working cycle, i.e. suction, expansion, compression and exhaust phases, even if introduction of gas is helpful during the compression phase only, in order to help raising pressure and making the exhaust valve open.

[0025] In the other phases of the pump working cycle, having the gas ballast supply duct open is useless and may involve a pressure decay, an increase of power consumption and an increase of noise generated by the vacuum pump as well.

[0026] The main object of the invention is therefore to overcome, or at least alleviate, the drawbacks and limitations of prior solutions.

[0027] This and other objects are achieved by the vacuum pump as claimed in the appended claims.

Summary of the invention

[0028] The present invention relates to a vacuum pump provided with a gas ballast arrangement including a gas ballast supply duct opening into the pumping chamber of the vacuum pump, in which this gas ballast supply duct is open during the compression phase of the vacuum pump working cycle and is closed at least during the exhaust phase of the vacuum pumping working cycle.

[0029] In embodiments of the invention, the vacuum pump includes a pumping chamber, a suction duct opening into said pumping chamber at a suction bore and an exhaust duct opening into said pumping chamber at an exhaust bore, as well as pumping means for pumping a fluid from said suction bore to said exhaust bore. The vacuum pump also includes a gas ballast arrangement including a gas ballast supply duct opening in the pumping chamber at a gas ballast bore. The vacuum pump further includes a valve assembly that can be driven from a first configuration, in which flow through the gas ballast supply duct and into the pumping chamber is allowed and flow out of the pumping chamber and through the exhaust duct is prevented, to a second configuration, in which flow through the gas ballast supply duct and into the pumping chamber is prevented and flow out of the pumping chamber and through the exhaust duct and is allowed, and vice versa.

[0030] In other words, in the first above-mentioned configuration the valve assembly leaves the ballast gas supply duct open and closes the exhaust duct, while in the second configuration the valve assembly closes the ballast gas supply duct and leaves the exhaust duct open. Accordingly, the gas ballast duct is open during the compression phase (i.e. when gas ballast is useful), while it is closed during exhaust phase.

[0031] This allows to reduce power consumption of the vacuum pump as well as noise generated by the vacuum pump. In addition, this allows to avoid loss of performance of the vacuum pump in terms of pressure ratio.

[0032] Although the valve assembly can be manually driven, in a preferred embodiment of the invention, the valve assembly is arranged at least in part in the exhaust duct or in a space in fluid communication with the exhaust duct, so that it can be driven from the first configuration to the second configuration, and vice versa, according to the pressure prevailing in the exhaust duct, therefore in the pumping chamber.

[0033] According to this preferred embodiment of the invention the valve assembly comprises valve means and driving means, wherein said driving means keep the valve means in the first configuration if the pressure in the exhaust duct is below a given threshold value, and wherein said driving means move the valve means to the second configuration if the pressure in the exhaust duct reaches said threshold value.

[0034] The gas ballast supply duct and the exhaust duct could be separate and independent ducts, and the valve assembly could comprise first valve means for opening / closing the gas ballast supply duct and second valve means for opening / closing the exhaust duct, said first and second valve means being controlled in a synchronized way.

[0035] In a preferred embodiment invention, the gas ballast supply duct and the exhaust duct are connected to each other through a connecting pipe, and the valve assembly comprises a single valve element arranged to travel along said connecting pipe move from a first position at a first end of said connecting pipe, in which it leaves the ballast gas supply duct open and closes the exhaust duct, to a second position at a second, opposite end of said connecting pipe, in which closes the ballast gas supply duct and leaves the exhaust duct open, and vice versa.

[0036] In embodiments of the invention, the gas ballast bore and the exhaust bore are separate ports, arranged at different location in the pumping chamber.

[0037] This allows to properly and independently select the location of each of said bores, thus increasing the degrees of freedom in designing the vacuum pump and optimizing the performance thereof.

Brief description of the drawings

[0038] Further features and advantages of the invention will be evident from the following detailed description of a preferred embodiment thereof, given by way of non-limiting example with reference to the accompanying drawings, in which:

Figure 1 is a perspective schematic view of an exemplary rotary vane vacuum pump;

Figure 2 is a schematic cross-sectional view of the vacuum pump shown in Fig. 1;

Figure 3a illustrates, in a cross-sectional view similar to Figure 2, a rotary vane vacuum pump provided with a gas ballast arrangement according to the invention, shown in a first configuration;

Figure 3b illustrates, in a cross-sectional view similar to Figure 2, a rotary vane vacuum pump provided with a gas ballast arrangement according to the invention, shown in a second configuration.

Description of a preferred embodiment of the invention

[0039] Referring to Figures 1 and 2, a rotary vane vacuum pump 1 comprises an external casing 3 in which a stator 5, defining a cylindrical pumping chamber 7, is tightly arranged. The chamber defined by the stator 5 houses a cylindrical rotor 9, driven into rotation by a motor 2 connected to the vacuum pump 1. The rotor 9 has an axis parallel to the axis of said cylindrical chamber 7, but eccentrically located relative to the chamber axis. One or more radially movable radial vanes 11 (two vanes in the embodiment shown) are mounted onto said rotor 9 and are kept against the wall of said chamber 7 by means of springs 13. Fluid is sucked through suction port 15 and travels through a suction duct 17, which opens into the pumping chamber 7 at a suction bore 19, thus entering the pumping chamber 7 at said suction bore 19.

[0040] Due to rotation of the rotor 9, the fluid is pushed by the rotor vane 11 from the suction bore 19 along the pumping chamber 7.

[0041] Due to the eccentric arrangement of the rotor 9, the fluid is initially expanded and then compressed. Finally, it is released through an exhaust duct 23, opening into the pumping chamber 7 at an exhaust bore 21 and ending at an exhaust port 25 of the external casing 1 at its opposite end.

[0042] Therefore, in a working cycle of the vacuum pump 1, four different phases can be identified:

- suction
- expansion
- compression
- exhaust.

[0043] In the shown embodiment, in which the rotor 9 has two vanes 11, one revolution of the rotor 9 corresponds to two working cycles.

[0044] The external casing 1 is filled with a suitable amount of oil, such that the stator 3 is immersed into an oil bath 27 acting as cooling and lubricating fluid. Furthermore, the rotary vane vacuum pump 1 is manufactured so that a certain amount of oil can penetrate into the pumping chamber 7 and form a thin film ensuring tightness between the vanes 11 of the rotor 9 and the wall of the pumping chamber 7.

[0045] As mentioned above, liquid present in the chamber evacuated by the vacuum pump (e.g., moisture) may be sucked through the suction port 15 and enter the pumping chamber 7 in the form of vapor.

[0046] In order to prevent condensation of such vapor inside the pumping chamber 7 before it is discharged through the exhaust duct 23, the rotary vacuum pump 1 is provided with a gas ballast arrangement, which is schematically shown in Figures 3a and 3b.

[0047] This gas ballast arrangement includes a gas ballast supply duct 29 which opens into the pumping chamber 7 at a gas ballast bore 31.

[0048] The gas ballast supply duct 29 can be in fluid communication with the outside environment, so that air at atmospheric pressure can be introduced into the pumping chamber.

[0049] As an alternative, the gas ballast supply duct 29 can be in fluid communication with a tank containing another suitable inert, non-condensable gas at a desired pressure.

[0050] Introduction of air or inert gas into the pumping chamber through the gas ballast supply duct 23 will promote the pressure raise in the pumping chamber and allow the pumped fluid to be discharged from said chamber before the liquid contained in said fluid can condense.

[0051] Gas ballast is helpful during compression phase of the vacuum pump working cycle only. It is not useful during the other phases of the working cycle; instead, especially during the exhaust phase, it can lead to an increase in power consumption and noise generated by the vacuum pump.

[0052] Accordingly, the gas ballast arrangement includes a valve assembly that can be driven from a first configuration (during compression phase), in which flow through the gas ballast supply duct 29 and into the pumping chamber 7 is allowed and flow out of the pumping chamber 7 and through the exhaust duct 23 is prevented, to a second configuration (during exhaust phase), in which flow through the gas ballast supply duct 29 and into the pumping chamber 7 is prevented and flow out of the pumping chamber 7 and through the exhaust duct 23 and is allowed, and vice versa.

[0053] Advantageously, in the shown embodiment, the gas ballast supply duct 29 is connected to the exhaust duct 23 by a connecting pipe 35 and the valve assembly includes a valve element 37 that can travel along the connecting pipe 35 from a first position at a first end 35a of such connecting pipe 35, to a second position at the second, opposite end 35b of said connecting pipe.

[0054] In said first position (Figure 3a), the valve element 37 blocks the exhaust duct 23, thus allowing flow through the gas ballast supply duct 29 and into the pumping chamber 7 and preventing flow out of the pumping chamber 7 and through the exhaust duct 23.

[0055] In said second position (Figure 3b), the valve element 37 blocks the gas ballast supply duct 29, thus preventing flow through the gas ballast supply duct 29 and into the pumping chamber 7 and allowing flow out of the pumping chamber 7 and through the exhaust duct 23.

[0056] As shown in Figure 3b, since some oil is drawn by the pumped fluid, the exhaust duct 23 leads to a tank 41, in which oil can be recovered.

[0057] The valve assembly further comprises driving means 39, which keep the valve element 37 at its first position as long as the pressure in the exhaust duct is below a given threshold value (Figure 3a), and move the valve element 37 to its second position as soon as the pressure in the exhaust duct reaches said threshold value (Figure 3b).

[0058] Such driving means can be implemented, for instance, as a spring, a piston or a lever system, opposing a desired resistance to the pressure prevailing n the exhaust duct 23.

[0059] Accordingly, if the pressure in the exhaust duct is below the threshold value, such pressure will not be sufficient for overcoming the resistance of the driving means 39. Conversely, if the pressure in the exhaust duct reaches the threshold value, it will overcome the resistance of the driving means 39, causing the valve element 37 to move to its second position.

[0060] It will be evident to the person skilled in the art that the disclosed gas ballast arrangement allows to automatically stop the gas ballast supply during the exhaust phase, while gas ballast will be allowed during compression phase.

[0061] As shown in Figures 3a and 3b, besides the valve element 37 of the valve assembly, the gas ballast arrangement may further include a further valve 33, such as for instance a manually operated valve 33 for allowing a user to permanently close the gas ballast supply pipe 29.

[0062] Always with reference with Figures 3a and 3b, it is to be noted that the gas ballast supply duct 29 and the exhaust duct 23 open into the pumping chamber 7 at gas ballast bore 31 and at exhaust bore 21, respectively, which are separate and distinct bores in the wall of said pumping chamber.

[0063] This advantageously allows to design the vacuum pump by independently arrange each of said bores at an optimum position for enhancing the vacuum pump operation and performance.

[0064] In general, it can be advantageous to arrange the gas ballast bore 31 close to the exhaust bore 21, as shown in Figures 3a and 3b: this allows, among others, to make the gas ballast arrangement as compact as possible.

[0065] It will be evident that the above description of a preferred embodiment has benne given by way of non-limiting example only, and several variants and modification within the reach of the person skilled in the art are possible without departing from the scope of the invention as defined by the appended claims.

Claims

1. Vacuum pump (1), comprising a stator (3) and a rotor (9), which define together a pumping chamber (7), wherein said vacuum pump comprises a suction duct (17) opening into said pumping chamber (7) and an exhaust duct (23) opening into said pumping chamber, wherein said vacuum pump further comprises a gas ballast arrangement including a gas ballast supply duct (29) opening in said pumping chamber (7), **characterized in that** said gas ballast arrangement includes a valve assembly (37, 39) that can be driven from a first configuration, in which flow through said gas ballast supply duct (29) and into said pumping chamber (7) is allowed and flow out of said pumping chamber (7) and through said exhaust duct (23) is prevented, to a second configuration, in which flow through said gas ballast supply duct (29) and into said pumping chamber (7) is prevented and flow out of said pumping chamber (7) and through said exhaust duct (23) and is allowed, and vice versa.

2. Vacuum pump (1) according to claim 1, wherein said valve assembly (37, 39) is kept in said first configuration as long as the pressure in said pressure chamber (7) is below a predetermined threshold value, and is driven to said second configuration as soon as the pressure in said pressure chamber (7) reaches said predetermined threshold value.

3. Vacuum pump (1) according to claim 1 or 2, wherein said valve assembly (37, 39) is arranged at least in part in said exhaust duct (23) or in a space in fluid communication with said exhaust duct (23).

4. Vacuum pump (1) according to any of the preceding claim, wherein said gas ballast supply duct (29) is connected to said exhaust duct (23) by a connecting pipe (35).

5. Vacuum pump (1) according to claim 4, wherein said valve assembly includes a valve element (37) arranged to travel along said connecting pipe (35) from a first position at a first end (35a) of said connecting pipe (35), in which it prevents fluid communication between said exhaust duct (23) and said pumping chamber (7) and allows fluid communication between said gas ballast supply duct (29) and said pumping chamber (7), to a second position at the second, opposite end (35b) of said connecting pipe (35), in which it allows fluid communication between said exhaust duct (23) and said pumping chamber (7) and prevents fluid communication between said gas ballast supply duct (29) and said pumping chamber (7), and vice versa.

6. Vacuum pump according to claim 5, wherein said assembly further comprises driving means (39) for driving said valve element from said first position to said second position, and vice versa.

7. Vacuum pump according to claims 2 and 6, wherein said driving means (39) keep said valve element (37) at said first position as long as the pressure in said pressure chamber (7) is below said predetermined threshold value, and move said valve element (37) to said second position as soon as the pressure in said pressure chamber (7) reaches said predetermined threshold value.

8. Vacuum pump according to claims 6 or 7, wherein said driving means (39) are implemented as a spring, a piston or a lever system.

9. Vacuum pump (1) according to any of the preceding claim, wherein said gas ballast arrangement further includes a further valve (33), such as for instance a manually operated valve, for allowing a user to per-

manently close said gas ballast supply pipe (29).

10. Vacuum pump (1) according to any of the preceding claim, wherein said exhaust duct (23) opens into said pumping chamber at an exhaust bore (21) and said gas ballast supply duct (29) opens in said pumping chamber (7) at a gas ballast bore (31), and wherein said gas ballast bore (31) and said exhaust bore (21) are separate and distinct bores in the wall of said pumping chamber (7).

11. Vacuum pump (1) according to any of the preceding claim, wherein said gas ballast supply duct (29) is in fluid communication with the outside environment or with a tank containing an inert, non-condensable gas at a suitable pressure.

12. Vacuum pump (1) according to any of the preceding claim, wherein said vacuum pump is a rotary vane vacuum pump (1) comprising an external casing (3) in which a stator (5), defining a cylindrical pumping chamber (7), is arranged and wherein a cylindrical rotor (9) is housed in said pumping chamber, said rotor having an axis parallel to the axis of said chamber but eccentrically located relative to said axis of said chamber and being provided with one or more radially movable radial vanes (11).

13. Method for operating a vacuum pump (1), of the kind comprising a stator (3) and a rotor (9), which define together a pumping chamber (7), a suction duct (17) opening into said pumping chamber (7) and an exhaust duct (23) opening into said pumping chamber, and further comprising a gas ballast arrangement including a gas ballast supply duct (29) opening in said pumping chamber (7), said method comprising:

- a suction phase, in which a fluid is sucked into said pumping chamber (7) through said suction duct;
- an expansion phase, in which said fluid is expanded in said pumping chamber (7);
- a compression phase, in which said fluid is compressed in said pumping chamber (7);
- an exhaust phase, in which said fluid is discharged from said pumping chamber through said exhaust duct;

characterized in that said method further comprises

- allowing flow through said gas ballast supply duct (29) into said pumping chamber (7) during said compression phase; and
- preventing flow through said gas ballast supply duct (29) into said pumping chamber (7) during said exhaust phase.

14. Method according to claim 13, wherein flow through said gas ballast supply duct (29) into said pumping chamber (7) is allowed if pressure in said exhaust duct (23) is below a given threshold value and flow through said gas ballast supply duct (29) into said pumping chamber (7) is prevented if pressure in said exhaust duct (23) reaches said given threshold value.

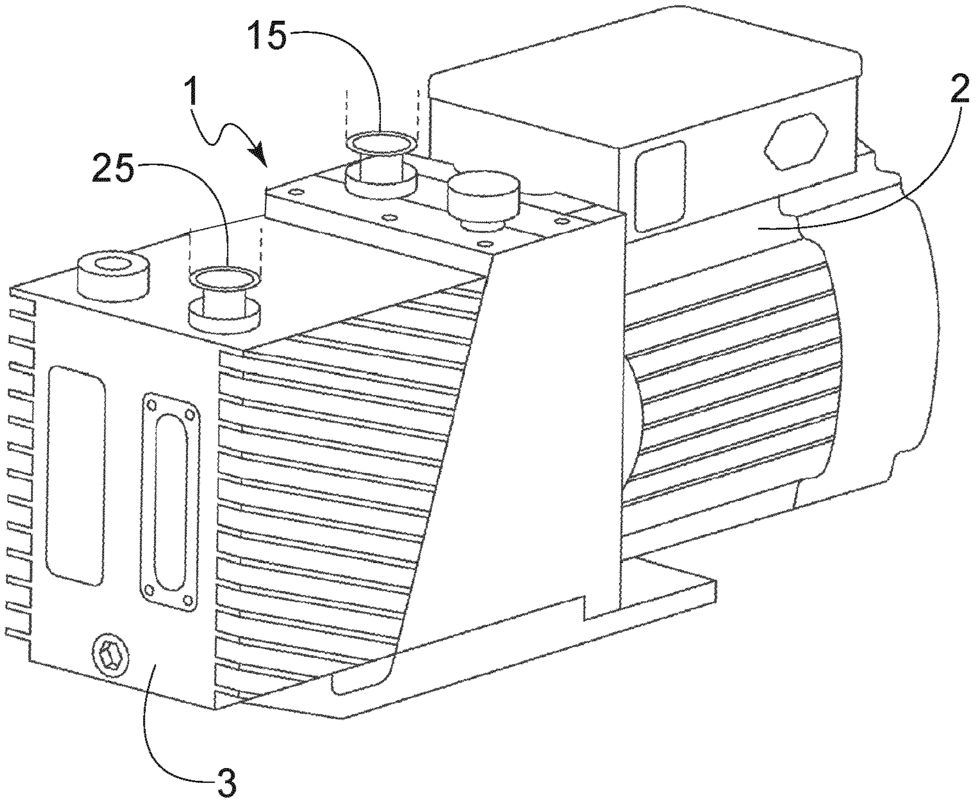

Fig. 1

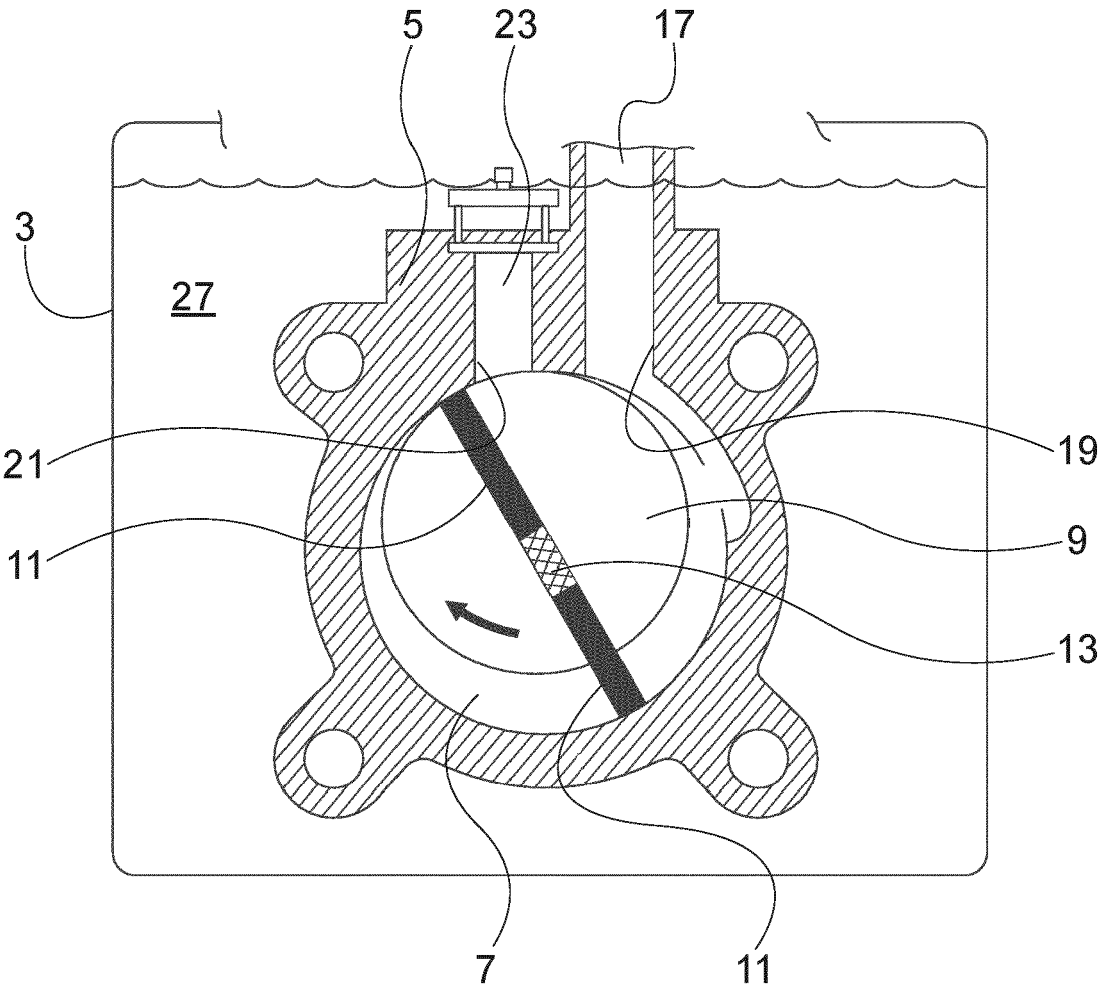

Fig. 2

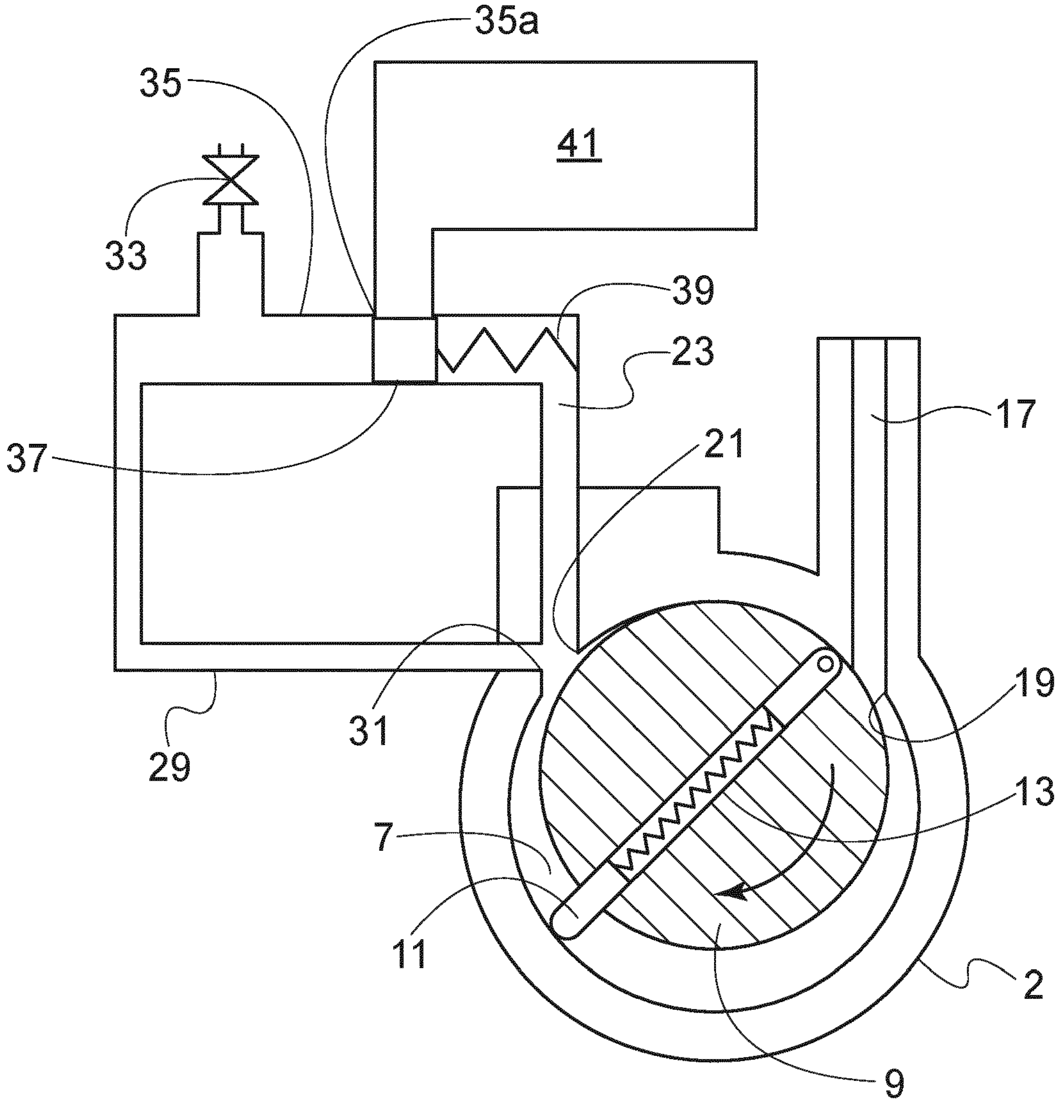

Fig. 3a

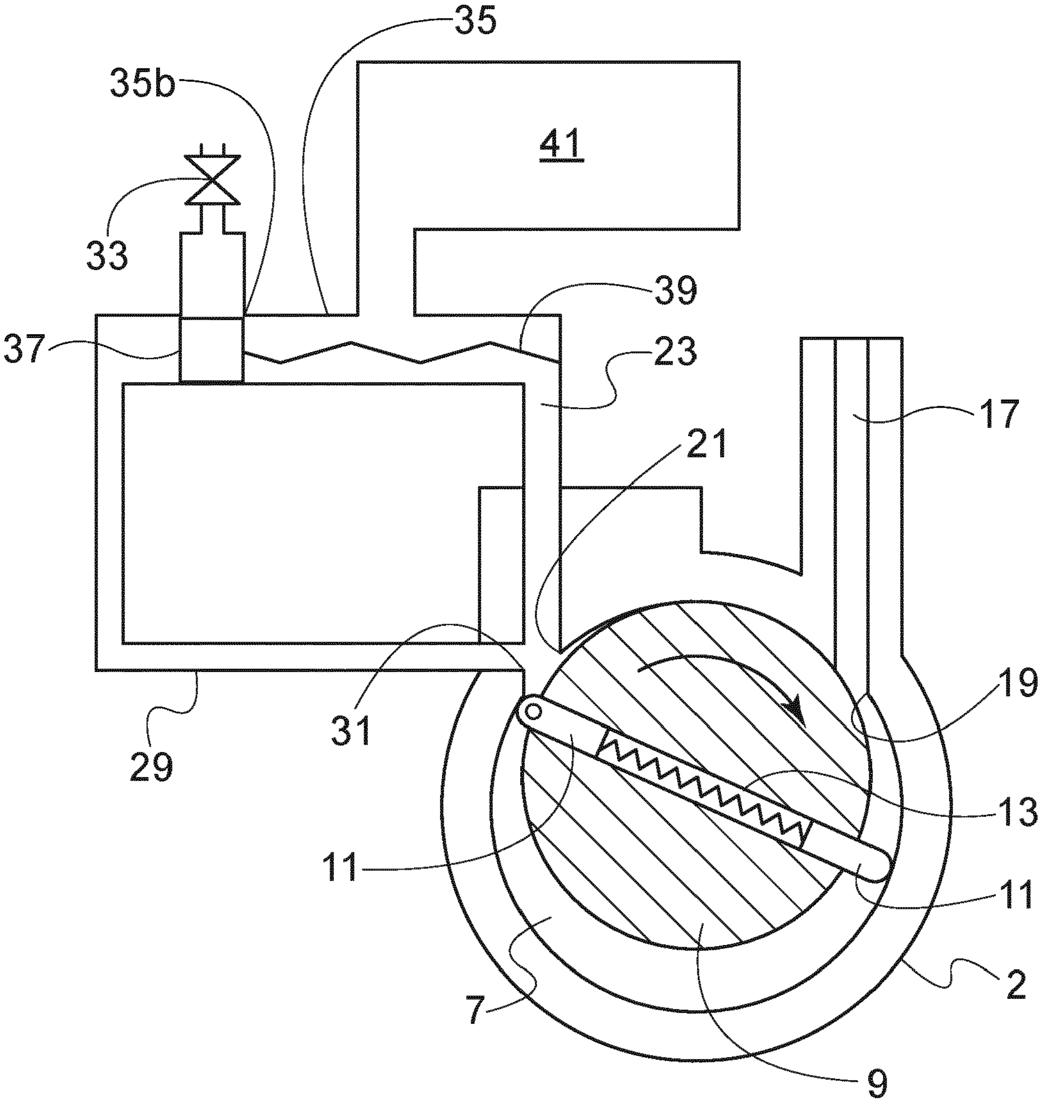

Fig. 3b

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EUROPEAN SEARCH REPORT

Application Number
EP 21 20 5596

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	GB 847 776 A (HERAEUS GMBH W C) 14 September 1960 (1960-09-14) * figures * * page 1, line 8 - line 9 * * page 1, line 70 - line 85 *	1-4,9-14 5-8	INV. F04C18/32 F04C25/02 F04C29/00
A	US 4 268 230 A (BASSAN BENJAMIN) 19 May 1981 (1981-05-19) * figures * * abstract *	1-14	
A	US 2 779 533 A (KLAUS ZIOCK) 29 January 1957 (1957-01-29) * figures * * column 1, line 71 - column 2, line 10 *	1-14	
A	EP 3 483 448 A1 (PFEIFFER VACUUM GMBH [DE]) 15 May 2019 (2019-05-15) * figures * * abstract *	1-14	

TECHNICAL FIELDS SEARCHED (IPC)

F04C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	27 April 2022	Durante, Andrea

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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- US 2014363319 A1 **[0006]**