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(54) Vacuum pump

(57) The invention relates to a vacuum pump to be operated in presence of corrosive gas, comprising a rotor group (1) and a rotatable unit (6, 12, 14) supporting said rotor group (1), wherein a first portion (8a) and a second portion (8b) are defined, both said portions being accessible to the gas and communicating between each other, and wherein disengageable sealing means (22) are provided for preventing the gas passage from said first portion to said second portion or viceversa when said sealing means (22) are engaged.

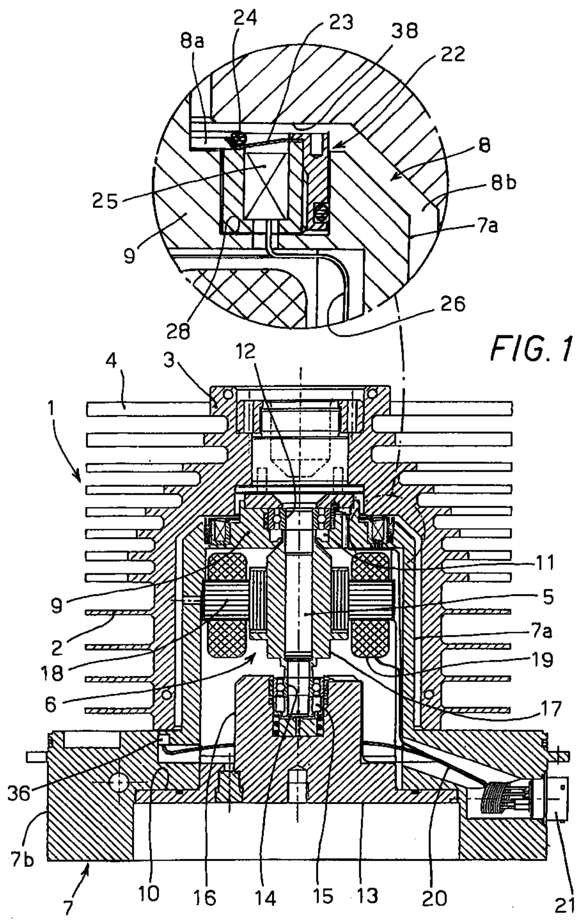

FIG. 1

EP 0 884 480 A2

Description

The present invention refers to a vacuum pump and more precisely to a turbomolecular vacuum pump adapted to be used in presence of corrosive gases.

An example of turbomolecular pump of improved design with pumping stages having a high compression ratio is disclosed in EP-A-0 445 855 in the name of the present applicant.

The above mentioned vacuum pumps of the turbomolecular type have been extensively used in the manufacturing of semiconductor circuits.

One of the main problems when using vacuum pumps in the semiconductor industry is due to the use of corrosive gaseous mixtures such as for example, HCl, HBr, Cl_2, Fl_2, etc... in the manufacturing steps, that can damage the pump components. The presence of the corrosive gases is moreover particularly detrimental when the pump is being stopped either for plant servicing or because of a sudden blackout of the electric power, or because of requirements of the working cycle.

Under these circumstances, that is when the pump is at rest, the corrosive gases present in the working environment can gather within the pump and reach, through the gaps existing between the rotating and the stationary parts, the pump electric motor and the mechanical bearings or the magnetic suspensions, when these latter are provided for.

Since the action of the corrosive gases can irreparably alter both the steel of the bearings, as well as the lubricant inside the bearings, with the risk of a seizure, special pumps resistant to the corrosion, known as "CP" (Corrosion Proof) pumps have been developed in the past to prevent the rapid damaging of the vacuum pumps operating in presence of corrosive gases.

In the "CP" type pumps a flow of inert gas is put into the space containing the bearings to form a barrier to the inlet of the corrosive gases used in processing semiconductor integrated circuits.

However, although a consistant amount of corrosive gases is prevented from reaching the most sensitive components in the pump, this solution still has a number of drawbacks.

The first of such drawbacks is that this solution requires to arrange a dedicated connecting circuit for the inlet of the inert gas, provided with valves, regulation means, and an outer apparatus comprising a distribution circuit, an inlet valve for admitting the inert gas, etc... which increase the complexity and the cost of the system.

Moreover the input of an inert gas into a vacuum pump operating in presence of a mixture of corrosive gases, on one hand can contaminate the gas mixture used in the pump operating cycle and on the other hand can lower the compression ratio of the vacuum pump.

An additional drawback of the above illustrated known solution is that it is necessary to provide a supply of the inert gas to be used as a barrier to the corrosive gases, which is preferably nitrogen.

It is therefore an object of the present invention to solve the problem of realizing a gas-tight or sealing arrangement capable of preventing the input of the corrosive gases when the vacuum pump is stopped, and that is free from the above discussed drawbacks of the prior art.

This object of the present invention is achieved through a vacuum pump as claimed in claim 1.

An appreciable drawback of the above mentioned known solution derives from the fact that in the absence of electric feed the system for injecting the inert gas can be shut down, thus allowing the inlet of corrosive gases into the pump.

A further object of the present invention is to solve the problem of realizing a seal adapted to prevent the inlet of corrosive gases when the vacuum pump is stopped, such seal being operative without requiring an electric feed.

This further object of the present invention is achieved through a vacuum pump as claimed by claim 9.

Additional objects of the present invention are accomplished through a vacuum pump as claimed in the dependent claims.

The present invention will now be disclosed in details with reference to the attached Figures in which:

Figure 1 is a cross section view of a vacuum pump according to a first embodiment of the invention;
Figure 2 is a cross section view of the sealing means of Figure 1;
Figure 3 is a cross section view of the sealing means in accordance with a second embodiment;
Figure 4 is a scrap cross section view of the sealing means in accordance with a third embodiment;
Figure 5 is a cross section view of the sealing means in accordance with a fourth embodiment.

With reference to drawings, Figure 1 illustrates a monolithic hollow rotor group 1 of a turbomolecular vacuum pump comprising a first plurality of smooth rotor disks 2 and a second plurality of rotor disks 3 provided with peripheral radial blades 4.

Such monolithic rotor 1 is supported by a rotatable shaft 5 driven by an electric motor 6 located inside a cylindrical casing 7.

In the example shown in Figure 1, said cylindrical casing 7 is substantially coaxial with the monolithic rotor 1 and comprises a first portion 7a of a smaller cross section that extends axially inside a cavity defined in the monolithic hollow rotor 1 and a second portion 7b of larger cross section secured to a casing (not shown) of the vacuum pump and located ouside said monolithic hollow rotor 1.

The cylindrical casing 7 is further provided with a closed base 9 in correspondence of that free end of the portion 7a that is adjacent to the rotor 1, and with an open base 10 at the opposed free end of the portion 7b.

The closed base 9 of said first portion 7a is further provided with an axial central hole 11 for receiving a first ball bearing 12 rotatably supporting the shaft 5.

At the opposed end of said cylindrical casing 7, a circular cover 13 closes the open base 10.

A second ball bearing 14 rotatably supporting the free end of the rotatable shaft 5 that is opposed with respect to the monolithic rotor 1, is disposed in a central cavity 15 of an axial projection 16 of said circular cover 13, such projection extending internally to the portion 7a of cylindrical casing 7.

The rotor 17 of the electric motor 6 is located between said first ball bearing 12 and said second ball bearing 14, and is fastened to the rotatable shaft 5.

The stator 18 of the electric motor 6 is located between said rotor 17 and the inner wall of said cylindrical casing 7, and secured to said inner wall. Such stator 18 comprises windings 19 fed through electric leads 20 from an electric connector 21 fitted in the portion 7b of the cylindrical casing 7 and accessible outside of the vacuum pump.

A gap 8 is provided between the rotor 1 and the portion 7a of the casing 7 for allowing an unimpeded rotation of the rotor 1 with respect to the casing 7.

Through said gap 8 the gas present in the vacuum pump could easily reach the inner space of the casing 7 where the bearings 12, 14 and the motore 6 of the pump are located.

To prevent the corrosive gases from reaching said components of the pump, disengageable sealing means 22 are provided in the gap 8, in correspondence of the closed base 9, around said rotatable shaft 5, said means comprising an electromagnet 25 and an annular flexible cap or washer 23 of a ferromagnetic material, to which it is secured an elastic ring 24, for example formed of Viton (TM).

Thus said disengageable sealing means separates the gap 8 into two portions - i.e. an inner portion 8a and an outer portion 8b - with respect to said means of seal 22.

The electromagnet 25 is fed by the electric leads 26 from the electric connector 21 and comprises a solenoid with an axis substantially orthogonal to said (annular) washer 23.

Because of the magnetic field generated by the electromagnet 25, the flexible washer 23 is actracted towards the electromagnet 25 assuming a disengaged position and the gas can flow unimpeded between the two portions of gap 8a and 8b and viceversa, and the rotor 1 is free to rotate.

On the contrary, in the absence of a magnetic field the washer 23 assumes an engaged position, better shown in Figure 2, with the sealing ring 24 pressed against the inner wall 38 of the rotor 1 due to pressure applied by the washer 23.

Therefore the passage of gas between the gap portions 8a and 8b is prevented, and more particularly the gas is prevented from entering into the inner space of the cylindrical casing 7 through the aperture 11 and the bearing 12.

Advantageously, as illustrated in Figure 2, the washer 23 comprises an inner folded edge 27 in correspondence of which said elastic ring 24 is fastened by vulcanisation or bonding.

The outer circumferential periphery of said annular washer 23 is blocked between the outer circumferential rim 31 of a first U-shaped inner ring nut 29 of a ferromagnetic material in which the elettromagnet 25 is fastened by an epoxy resin, and an L-shaped rim directed towards the inner part 32 of a second outer ring nut 30.

Said ring nuts 29 and 30 are further preferably joined together thanks tothreadings formed on the outer circumferential surface of the inner ring nut 29 and on the inner circumferential surface of the outer ring nut 30, respectively.

An annular channel 28, shown in Figure 1, is provided in the base 9 of the first portion 7a of said cylindrical casing 7 aroud the rotatable shaft 5 for housing the ring nuts 29 and 30.

A sealing ring 34, partially contained in an annular groove 37 on the outer circumferential surface of said ring nut 30, ensures the sealing between the second ring nut 30 and the channel 28.

For making easier the screwing of said second ring nut 30 onto the first ring nut 29 there are further provided axial holes 35 for inserting a suitable tool (not shown).

Both the channel 28 and the ring nut 29 are further provided with an axial hole for the passage of the leads 26 for feeding said electromagnet 25. A radial screw 33 is further provided for firmly securing the ring nut 30, and therefore the sealing means 22, in the channel 28.

Figure 3 illustrates a second embodiment of the invention in which the sealing means 22' comprises a washer 23' having a circumferential periphery with an L-folded portion 23'a, while the opposed end has an inner edge 27' folded in the opposite direction with respect to said portion 23'a.

Said portion 23'a is further firmly blocked inside the annular channel 28 provided in the base 9 of said first portion 7a of the cylindrical casing 7, around the shaft 5, between the wall of the channel 28 and a ring nut 29' housing the electromagnet 25.

The outer circumferential surface of said ring nut 29' has a portion 29'a with a smaller diameter for housing said portion 23'a of the washer 23'.

On the larger diameter portion of said ring nut 29' there is is provided an annular groove 37' partially housing a sealing ring 34 preventing the passage of gas radially through the channel 28.

Still with reference to Figure 1, a system for determining the relative speed of the rotor with respect to the pump body, for example constituted by a movement sensor 36, can be advantageously provided for controlling a feeding unit (not shown) of the electromagnet 25 only when the relative speed between the rotor 1 and the casing 7 is (or is at least approaching to) zero.

Thus the engagement of the sealing means 22 is prevented when the rotor 1 is still rotating, thus preventing the sealing ring 24 to be worn out by the friction generated by the scraping against the wall 38 of the rotor 1.

In a turbomolecular pump having a rotor diameter of about 260 mm and a diameter of the sealing ring 24 of about 100 mm, it has been experimentally found that the speed of rotation of the rotor 1 must not be higher than 100 rpm to prevent the risk of an excessive wear of the ring 24 when the sealing means 22 are engaged.

Moreover, since the braking couple the sealing ring 24 applies to the rotor 1 is proportional to the radius of the ring 24, it is preferable to provide a sealing ring with the maximum possible diameter, depending on the geometry of the vacuum pump.

Figure 4 illustrates a third embodiment of the invention in which the sealing means 22" comprises an annulus 39 of a ferromagnetic material with a elastic ring 24 partially contained in a circular groove 40 of the surface facing the rotor 1 of the pump.

Said annulus 39 is located adjacent an electromagnet 25 that innturn is blocked in a U-shaped ring nut 41 of a ferromagnetic material housed in the annular channel 28 provided in the base 9 of the first portion 7a of cylindrical casing 7.

Between said ring nut 41 and said annulus there is further provided a plurality of coil springs 42 adapted to repel said annulus 39 with respect to the ring nut 41 when the magnetic field generated by the electromagnet 25 is not present.

Said springs 42 are partially housed in as many axial holes 43 of the inner wall of the ring nut 41.

Thanks to the cooperation between the electromagnet 25 and the plurality of coil springs 42, said annulus 39 is therefore movable between an engaged position where the elastic ring 24 - pressing the surface of the rotor due to the repulsive force exerted by the springs over the annulus 39 - prevents the gas from flowing between the zone located ouside the circumference of the ring 24 and the zone located inside such circumference, and viceversa, and a disengaged position where the rotor, thanks to the actraction force generated by the magnetic field over the annulus 39 is free to rotate with respect to said elastic ring 24 and thus the gas can flow.

A second annular ring nut 44 is provided that is screwed over the outer circumferential surface of said ring nut 41 and axially extends outside the channel 28 for preventing radial displacements of the annulus and its misalignement with respect to the magnetic field generated by the electromagnet 25.

Between said second ring nut 44 and the wall adjacent of the channel 28 there is provided a sealing ring 34 adapted to prevent the gas passage radially through the channel 28.

The portion of said second ring nut 44 axially extending outside the channel 28 is further provided with a radial edge 45 folded towards the inside and adapted to limit the axial movement of the annulus 39 and preventing its outcoming.

Advantageously, the annulus 39 has a thickness of at least 2 mm for avoiding an excessive limitation of the electromagnet attraction force and ensuring a good axial guide surface.

A plurality of axial holes 46 are further provided for making easier the screwing of said second ring nut 44 on the first ring nut 41 for inserting a suitable tool (not shown).

In Figure 5 there is illustrated a fourth embodiment of the invention in which the sealing means 22"' are formed as an annular L-shaped member 50 of a ferromagnetic material housing an elastic ring 24 in a circular groove 51 of the surface facing the rotor 1 of the pump.

Such annular member 50 comprises a first portion 50a adjacent to an electromagnet 25 that in turn is secured in a U-shaped ring nut 52 of a ferromagnetic material, with this ring nut being housed in the annular channel 28 provided in the base 9 of the first portion 7a of the cylindrical casing 7, and a second portion 50b slidably disposed between said ring nut 52 and the annular channel 28.

A radial outer projection 52a having a plurality of holes for the passage of screws 53 for fastening the ring nut 52 to the base of the channel 28 is provided at the base of the ring nut 52.

Coil springs 54 resting on the radial projection 52a are further provided for driving back said member 50 with respect to the ring nut 52 when the magnetic field of the electromagnet 25 ceases.

The coil springs 54 are partially housed in as many axial holes 55 provided in portion 50b of the annular member 50.

Because of the cooperation between the electromagnet 25 and the plurality of coil springs 54, said annular member 50 is movable between a first engaged position in which the elastic ring 24 is urged against the rotor surface by the repulsion force of the springs 54 and prevents the gas from flowing from the zone outside the circumference of the ring 24 to the zone inside such circumference and viceversa, and a second disengaged position in which the rotor 1 of the vacuum pump - thanks to the attractive force of the magnetic field acting on member 50 - can freely rotate with respect to said elastic ring 24 and the gas can freely flow.

A series of threaded axial pins 56 are screwed in the inner wall of the ring nut 52 and pass through as many holes provided in the portion 50a of the annular member 50 to prevent the annular member 50 from coming out of the seat defined between the ring nut 52 and the channel 28.

Advantageously, the annular member 50 has a thickness of at least 2 mm to prevent excessive limitations to the attraction force of the electromagnet.

Between the portion 50b of said annular member

50 and the adjacent wall of the channel 28 there is provided a sealing ring 34 partially housed in an annular groove 57 for preventing the gas passage radially through the channel 28.

From what has been described and illustrated with reference to the Figures 4 and 5, it is clear that the axial stopping action achieved by the threaded pins 56 can also be accomplished through a ring nut similar to that indicated by reference 44 in Figure 4, internally mounted with respect to the ring nut 52 housing the electromagnet 25.

Advantageously, the vacuum pump according to the invention can further comprise a feeding unit comprising a device for converting the kinetic energy stored by the rotor 1 into electric energy when the rotor 1 decelerates.

This way electric energy can be advantageously used for feeding the electromagnet 25 even in the absence of external feed, thus preventing the sealing means 22 from being abruptly engaged in case of a shutting off of the mains power and when the relative speed between said rotor group 1 and said casing 7 is high.

Further, the use of said converting device has the advantage of progressively braking the rotation of the rotor for the whole time in which the energy conversion takes place.

In another embodiment of the invention there is further provided an external feeding battery either in combination or as an alternative to the energy conversion device.

The feeding battery provides the additional advantage that it can be mounted, if required, on board of the pump, thus feeding the electromagnet until the rotor speed is at least near to zero even in case the cables from an external feed unit for feeding the pump are interrupted or have been disconnected from the connector 21.

From what has been described and illustrated it is further clear that the sealing means 22 can be advantageously located even outside the rotor 1, for example between the outer wall of said casing 7 and the adjacent wall of the disk rotor 2 that is nearest to said casing 7.

If necessary, and if the ring 24 is of a suitable material, the sealing means 22 can be further advantageously used as braking devices for the rotor 1 during the working of the pump.

Claims

1. A vacuum pump to be operated in presence of corrosive gas, comprising a rotor group (1) and a rotatable unit (6, 12, 14) supporting said rotor group (1), in which a first portion (8a) and a second portion (8b) are defined, both said portions being accessible to the gas and communicating between each other, wherein disengageable sealing means (22, 22', 22", 22"') are provided for preventing the gas passage from said first portion to said second portion or viceversa when said sealing means are engaged.

2. A vacuum pump as claimed in claim 1, wherein a gap (8) is provided between said rotor group (1) and a casing (7) containing said rotatable supporting unit (6, 12, 14), said sealing means (22, 22', 22", 22"') being disposed in said gap (8) in such a manner as to prevent the gas from entering into said casing (7) containing said rotatable supporting unit (6, 12, 14).

3. A vacuum pump as claimed in claim 2, wherein said rotor group (1) comprises an axial inner cavity, and said gap (8) is defined between said axial inner cavity and casing (7).

4. A vacuum pump as claimed in claim 2, wherein said rotor group (1) comprises a plurality of parallel rotor disks (2, 3) and said gap (8) is defined between said casing (7) and the disk rotor that is nearest to said casing (7).

5. A vacuum pump as claimed in claim 3 or 4, wherein said rotatable supporting unit (6, 12, 14) comprises at least one bearing and an electric motor having the rotor (17) fastened to a rotatable shaft (5) supported by said at least one bearing, said rotatable shaft (5) projecting outside said casing (7) through an opening (11) provided thereon and being fastened outside said rotor group (1).

6. A vacuum pump as claimed in claim 5, wherein said sealing means (22) are located in said gap (8) near said opening (11), around said rotatable shaft (5).

7. A vacuum pump as claimed in claim 6, wherein said sealing means comprise a flexible annular cap or washer (23; 23') on which an elastic sealing ring (24) is fitted, said annular washer (23; 23') being movable from an engaged configuration in which said sealing means (22) prevents the gas from entering into said casing (7) of said rotatable supporting unit (6, 12, 14), to a disengaged configuration in which the gas entrance is not prevented.

8. A vacuum pump as claimed in claim 7, wherein the inner edge (27; 27') of said annular washer (23; 23') is folded back and wherein said elastic ring (24) is fastened in correspondence of said folded rim (27; 27') by vulcanisation.

9. A vacuum pump as claimed in claim 7, wherein said washer (23; 23') is of a ferromagnetic material, and wherein the passage of said washer (23; 23') from the engaged configuration to the disengaged configuration, or viceversa, is caused by the magnetic

field generated by an electromagnet (25) adjacent said washer (23; 23').

10. A vacuum pump as claimed in claim 9, wherein said electromagnet (25) is housed inside an annular channel (28) provided in the base (9) of said casing (7) adjacent said rotor group (1).

11. A vacuum pump as claimed in claim 10 wherein the outer circumferential periphery of said annular washer (23; 23') is clamped between a first ring nut (29; 29') and a second ring nut (30), said ring nuts being partially housed inside said annular channel (28), with said electromagnet (25) being housed in said first ring nut (29;29').

12. A vacuum pump as claimed in claim 10, wherein the outer circumferential periphery of said washer (23; 23') has a portion (23'a) that is L-folded in the opposite direction with respect of said inner folded edge (27; 27'), said portion (23'a) being clamped between a ring nut (29; 29') and the wall of said annular channel (28), with said electromagnet (25) being housed in said ring nut (29; 29').

13. A vacuum pump as claimed in claim 6, wherein said sealing means comprises an annulus (39) supported by elastic means provided with an elastic ring (24) on the surface facing the rotor (1) of the pump, said annulus (39) being movable from an engaged configuration in which said sealing means prevents the gas from entering into the casing (7) of said rotatable supporting unit (6, 12, 14), to a disengaged configuration in which the gas entrance is not prevented.

14. A vacuum pump as claimed in claim 13, wherein said annulus (39) is made of a ferromagnetic material and wherein the passage of said annulus (39) from the engaged configuration to the disengaged configuration, or viceversa, is caused by the magnetic field generated by an electromagnet (25) adjacent said annulus (39).

15. A vacuum pump as claimed in claim 14, wherein said elastic means comprises a plurality of coil springs (42) adapted to repel said annulus (39) with respect to the electromagnet (25) in the absence of the magnetic field generated by said electromagnet (25).

16. A vacuum pump as claimed in claim 14, wherein said elastic ring (24) is secured in correspondence of a groove (40) provided in said annulus (39) by vulcanisation.

17. A vacuum pump as claimed in claims 13 to 16, wherein said annulus (39) is radially blocked by a ring nut (44) partially housed inside an annular channel (28) provided in the base (9) of said casing (7) adjacent said rotor group (1) housing the electromagnet (25), said ring nut (44) comprising an inwardly extending radial edge (45) for limiting the axial movement of the annulus (39).

18. A vacuum pump as claimed in claim 6, wherein said sealing means comprises an L-shaped annular member (50) supported by elastic means provided with an elastic ring (24) on the surface facing the rotor (1) of the vacuum pump.

19. A vacuum pump as claimed in claim 18, wherein said annular member (50) is made of a ferromagnetic material and wherein the passage of said annular member (50) from the engaged configuration to the disengaged configuration, or viceversa, is caused by the magnetic field generated by an electromagnet (25) adjacent said annular member (50).

20. A vacuum pump as claimed in claim 19, wherein said annular member (50) comprises a first portion (50a) adjacent said electromagnet (25) and a second portion (50b) slidably housed inside an annular channel (28) provided in the base (9) of said casing (7) adjacent said rotor group (1) housing the electromagnet (25).

21. A vacuum pump as claimed in claim 20, wherein said elastic means comprises a plurality of coil springs (54) adapted to repel said annular member (50) with respect to the electromagnet (25) in the absence of the magnetic field generated by said electromagnet (25), said coil springs (54) being housed in said annular channel (28).

22. A vacuum pump as claimed in claim 20, wherein said elastic ring (24) is secured in correspondence of a groove (51) provided in said annular member (50) by vulcanisation.

23. A vacuum pump as claimed in claims 18 to 22, wherein said annular member (50) is axially fastened by a series of axial threaded pins (56) passing through as many holes provided in the portion (50a) of the annular member (50).

24. A vacuum pump as claimed in claim 9 or 14 or 19, wherein in the absence of magnetic field generated by said electromagnet (25), said sealing means assumes and retains the engaged configuration, and wherein, in presence of a magnetic field generated by said electromagnet (25), said sealing means assumes and retains the disengaged configuration.

25. A vacuum pump as claimed in claim 9, wherein said electromagnet comprises a solenoid the axis of which is substantially orthogonal to said elastic ring (24), said electromagnet (25) being housed in an annular channel (28) provided in the base (9) of said casing (7) adjacent said rotor group (1).

26. A vacuum pump as claimed in claim 25 provided with a unit for electrically feeding said electromagnet (25), said unit comprising means for controlling said feeding unit when the relative speed between said rotor group (1) and said casing (7) is at least near to zero.

27. A vacuum pump as claimed in claim 26, wherein said means comprises a movement sensor (36).

28. A vacuum pump as claimed in claim 27, wherein said feeding unit further comprises a kinetic/electric energy conversion device for converting the stored kinetic energy into electric energy when the rotor group (1) decelerates, said electric energy being adapted to generate an electric current capable of feeding said electromagnet (25) thus preventing said washer (23; 23') from abruptly assuming the engaged configuration if the mains electric feeding is interrupted when the relative speed between said rotor group (1) and said casing (7) is still high.

29. A vacuum pump as claimed in claim 28, wherein a battery is further provided for feeding said electromagnet, said battery feeding the electromagnet until the rotor speed is at least near to zero.

30. A vacuum pump as claimed in any of the preceding claims wherein said pump is a turbomolecular pump.

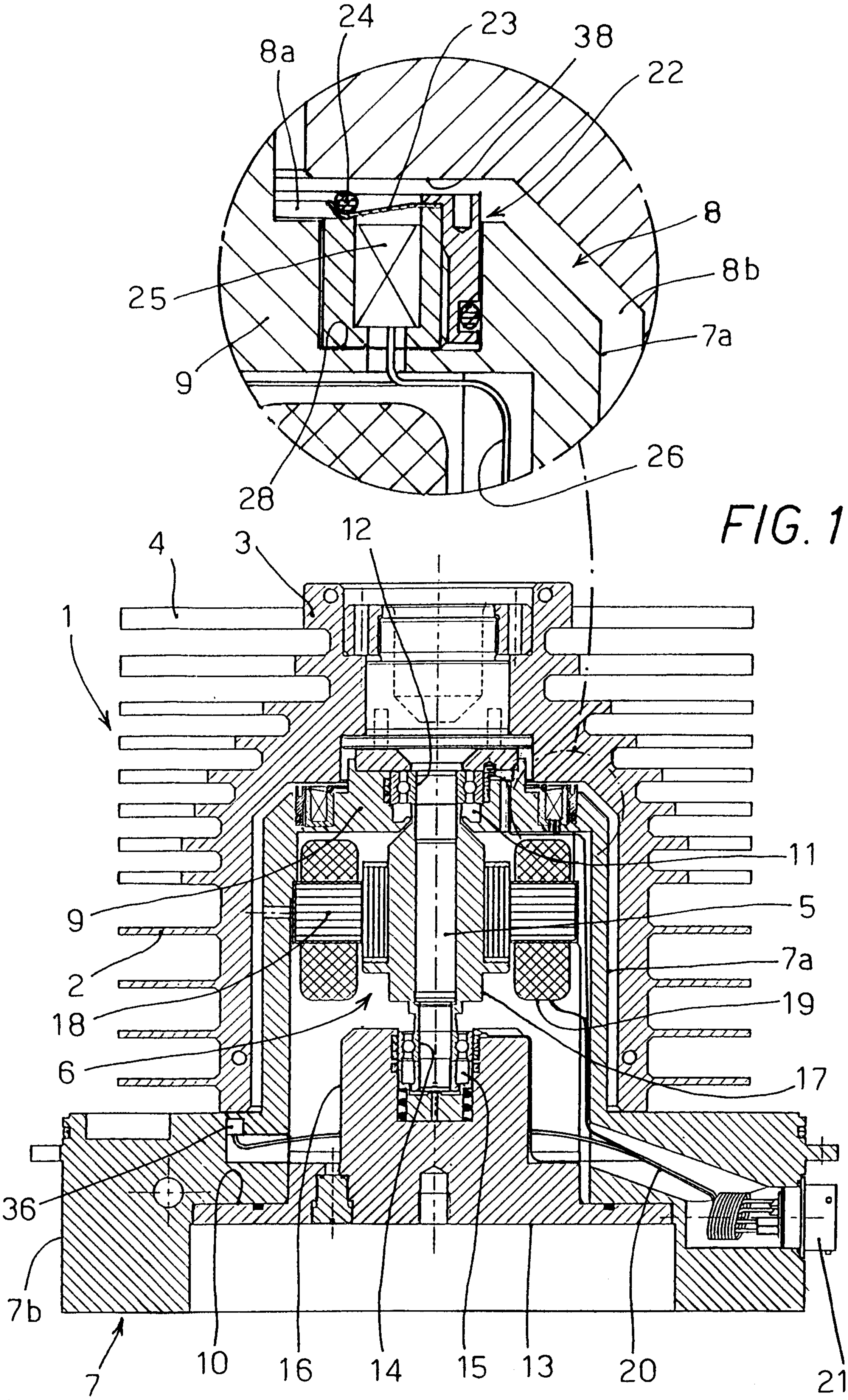
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FIG. 1

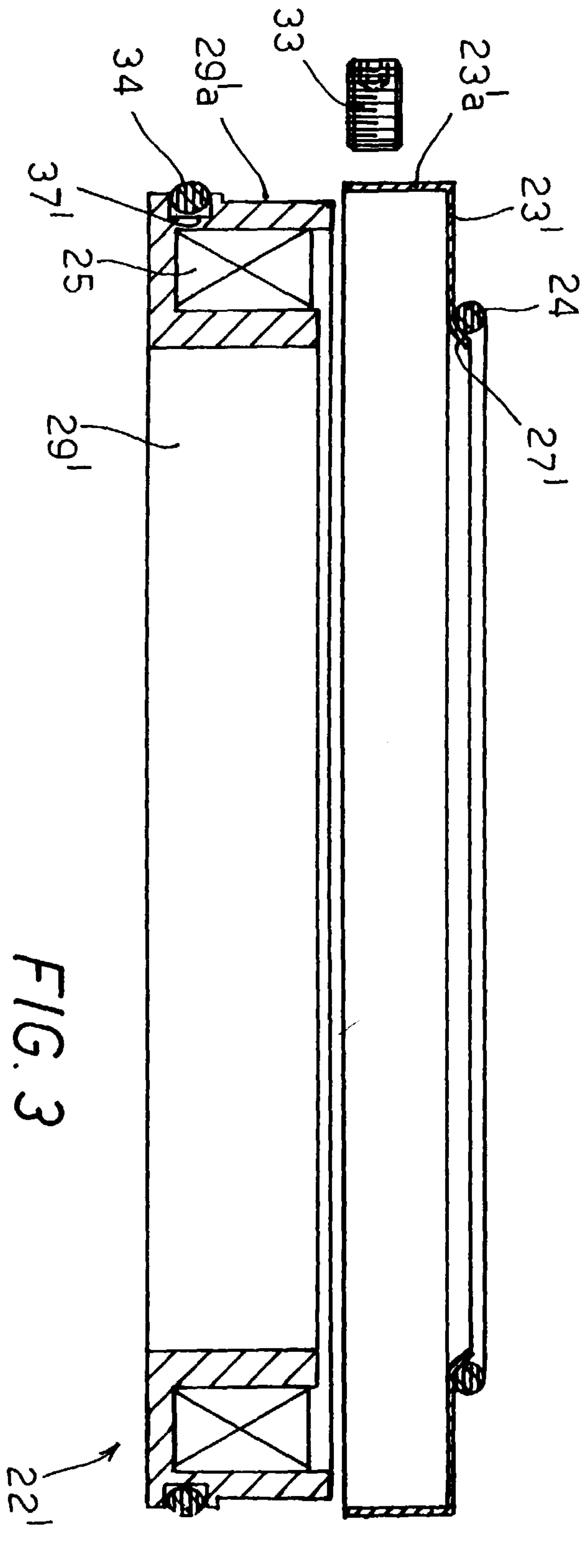
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FIG. 3

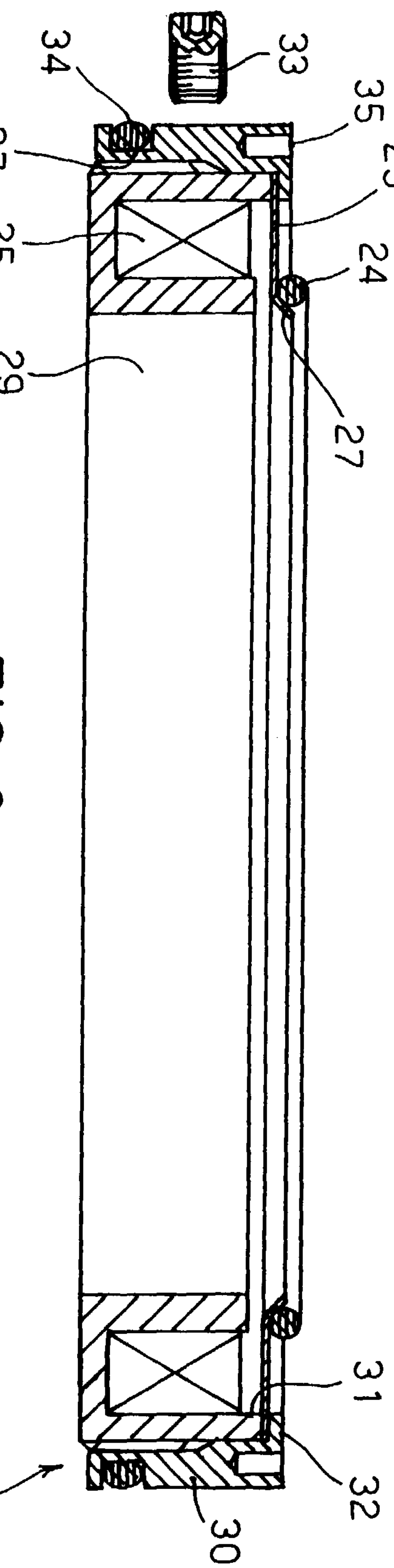
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FIG. 2

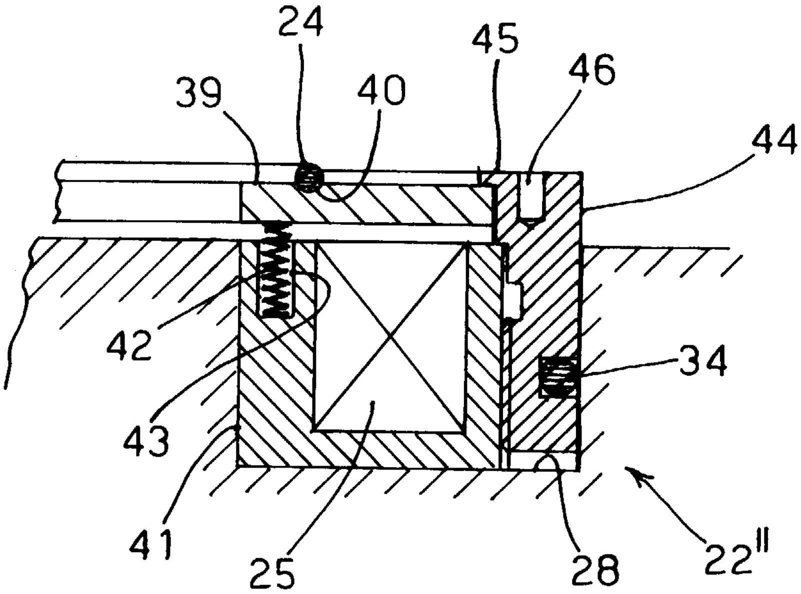
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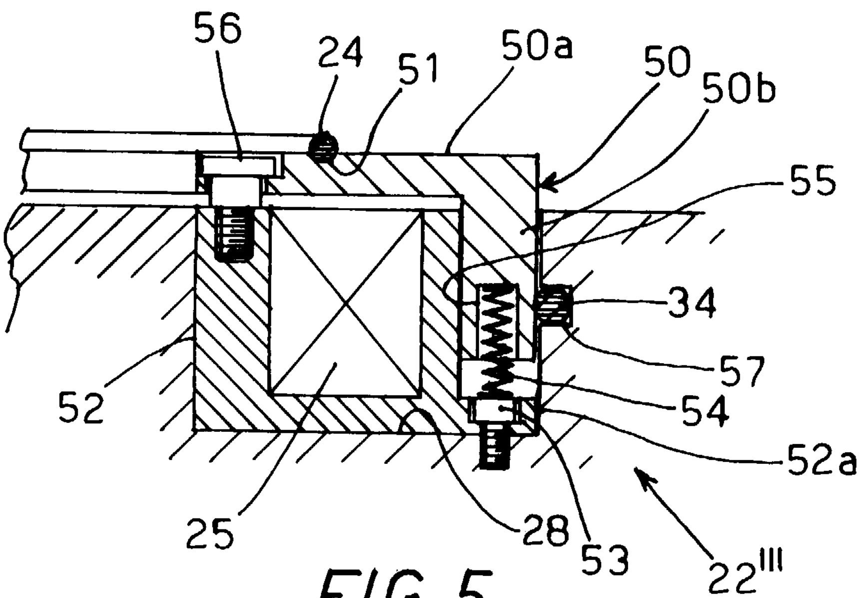
FIG. 4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53
22'''

FIG. 5