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(72) Inventor: **Grittner Gunter, Whirlpool Europe S.r.l.  
21025 Comerio (IT)**

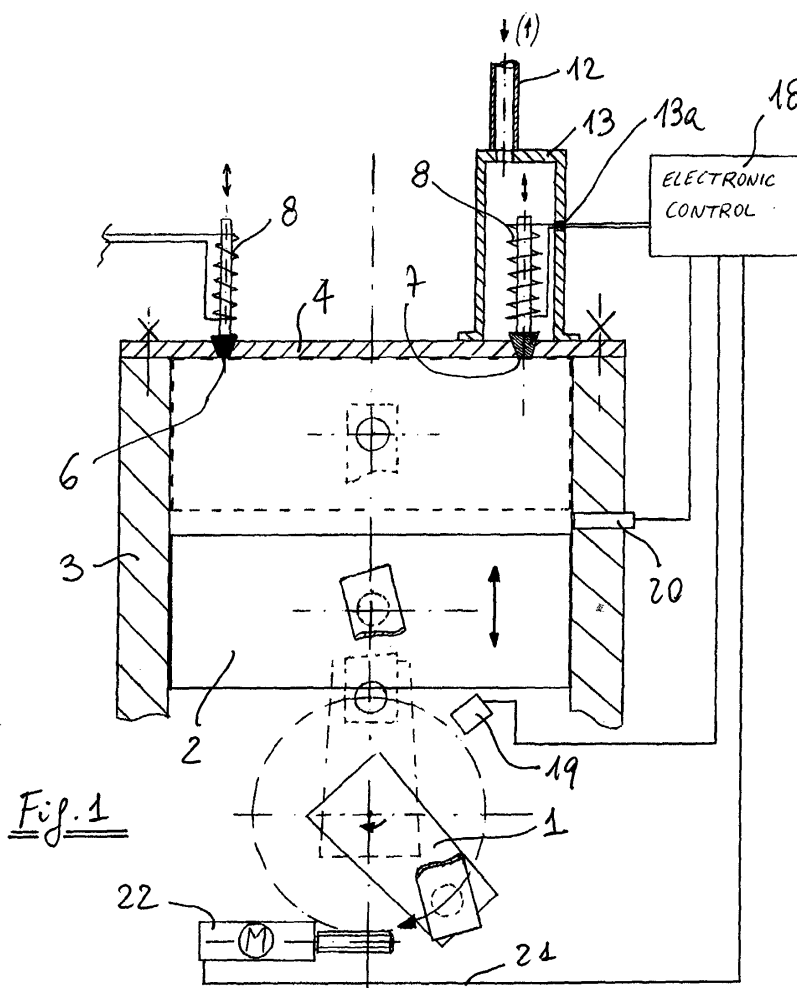
(74) Representative: **Guerici, Alessandro  
Whirlpool Europe S.r.l.  
Patent Department  
Viale G. Borghi 27  
21025 Comerio (VA) (IT)**

(71) Applicant: **WHIRLPOOL CORPORATION  
Benton Harbor Michigan 49022 (US)**

(54) **Reciprocating pump, particularly for vacuum insulated domestic refrigerators**

(57) A reciprocating-motion type vacuum pump for use in domestic refrigerators or freezers having vacuum insulated walls comprises valves which are electrically

or electronically driven and are controlled by an electronic control unit in order to optimise the pump performances.



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## Description

**[0001]** The present invention relates to a reciprocating-motion type pump comprising inlet and outlet valves. The present invention refers particularly to vacuum pumps used in vacuum insulated domestic refrigerators, in which a double wall of the appliance is maintained in a vacuum condition for decreasing the overall energy consumption of the appliance.

**[0002]** Vacuum pumps have -although built in many different ways- at least one valve for the flow of the gas. These valves can be of different types, but have all the same function: to open a channel where the gas can pass only in certain moments of the working cycle, and to prevent the passage of gas during other phases of the working cycle. Most important characteristics of the valves are leak rates, reliability, cost and energetic loss. Energetic loss happens when fluids pass a valve that creates resistance to the fluid flow, by the amount of energy necessary to activate the valve, and through residual volumes where fluids are compressed/decompressed more than once, thus creating additional losses.

**[0003]** In order to achieve low levels of vacuum (1mbar and below), residual volumes of valves have to be reduced as much as possible, because the volume of 'pressurised' fluid remaining at the end of the expulsion inside the pump volume limits the minimum pressure that can be reached during the suction phase (in fact, the suction pressure depends significantly on the ratio of 'residual volume' to 'maximum volume').

**[0004]** Most existing valves, especially the economic 'flap' valves made from rubber, metal and the like, are opened or closed by a gas pressure difference when such difference on both sides of the valve plate is larger than a threshold pressure and therefore inherently create a residual pressure difference and/or residual volume in the pump. Other executions need expensive mechanisms and/or gasket systems to allow and/or create movements that avoid residual volumes and reduce residual pressure differences.

**[0005]** The present invention overcomes the above-mentioned problem by an electronically activated element that opens and closes the channel for the gas at the right moment and improves the pump characteristics by reducing both residual pressure difference and residual volume. Such reduction of the residual pressure difference is obtained by an electrical or electronic drive of the valve. Preferably, in order to further decrease the residual volume, the vacuum pump presents valve plates which are substantially flush with the head of the cylinder.

**[0006]** The vacuum pump according to the invention is mechanically simple and therefore it has a reduced cost that renders it suitable for the application in domestic appliances, particular domestic refrigerators and freezer.

**[0007]** The foregoing and other features of the inven-

tion are hereinafter more fully described with reference to the appended drawings in which:

- Figure 1 is a schematic sectional view of a pump according to the invention,
- Figure 2 is an enlarged view of a detail of Figure 1, showing how the valve can work without residual volume in the cylinder, and
- Figure 3 is a schematic diagram showing an example of electric signal for driving the valve.

**[0008]** With reference to the drawings, in Figure 1 a piston-type pump system is shown, that can either be used as compressor or as vacuum pump.

**[0009]** A rotational movement of a crankshaft 1 is translated into a reciprocating movement of a piston 2, moving back and forth in a cylinder 3. The cylinder is closed by a cylinder head plate 4, that closes the working volume of the pump together with the piston 2 and the cylinder 3.

**[0010]** The cylinder head plate has two holes 6 and 7, which are the outlet and the inlet of the pump respectively and have also the function of valve seats. A valve plate 10 is moved via a coil 8 that is attached to an electronic circuit 18 generating an electric signal 14 and it can close each hole. The electric signal (Figure 3) creates in a temporary controlled manner a magnetic field in the coil 8, that reacts on rod 9 made of ferromagnetic material and connected to the valve plate, thus moving such plate 10 to or from the holes 6, 7. In this way, the valve seats 6, 7 can be opened and closed in a controlled manner.

**[0011]** Each valve may be provided with a spring M for maintaining the holes 6 and 7 in a closed (or open) condition when the coil 8 or an alternative actuator is not energised.

**[0012]** A particular embodiment of the present invention is shown in Figure 2. The valve plate 10 is shaped (frusto conical) in such a way that its front surface 10a is substantially flush with the surface of the head 4 of the cylinder 3. Of course the valve seats 6 and 7 have a frusto conical shape which matches the shape of the valve plate 10. The valve plate 10 closes the holes 6 and 7 in a way that the cylinder head plate 4 creates a flat surface that allows the piston 2, when moved in its upper position with reference to Figures 1 and 2, to substantially touch the cylinder head plate without opening the valve constituted by the valve plate 10 and hole 6, 7. The valve plate 10, acting as a gasket, fits perfectly into the hole 6, 7 reducing to a minimum the space between the piston 2 in its upper position and the valve plate 10, thus eliminating the 'residual volume' of the valve combination.

**[0013]** To make best use of the pressure or vacuum produced by the here described pump with electronically controlled valve, an embodiment of the valve has a housing 13 around at least one of the valves, preferably the inlet valve. The housing 13 is connected to a con-

nection tube 12 that allows the easy connection to suction or working tube. The housing 13 is sealed to the cylinder head plate 4, and has a sealed passage 13a for the electric connection of the valve coil 8. In this embodiment low-cost components can be used for the valve, without the need of airtight mechanical devices.

**[0014]** The electric signal 14 for controlling the valve is generated by an electronic control unit 18 (in figure 1 it is shown the link of the valve closing the suction hole 7 to the electronic control unit 18, but it is clear that also the valve closing the hole 6 is linked to the same control unit 18). The control unit 18 may use signals taken from various possible sensors 19, 20, 21 to get information about the actual working condition of the pump (e.g. rpm, crankshaft and / or piston position, motor load etc.), or it may control both the valves and the motor 22 which drives the crankshaft of the pump, to assure a perfect synchronisation of the motor and valves.

**[0015]** The electric signal to the valves may work only with opening impulses 15 (when valves are kept closed by springs or the like, as in the embodiment shown in figure 2), and/or may use closing impulses 17 (shown in dotted lines in Figure 3) for a faster and more accurate control of the valves, as well. Special current/voltage pulse peaks 16, of which an example is shown in Figure 3, may further improve the control of the valve. According to another aspect of the invention, the electronic control unit 18 may keep under certain conditions one or more valves open or closed for extended periods (longer than the normal work cycle), in order to reduce temporarily the workload of the motor or to regulate pressure or flow rate.

**[0016]** A further embodiment of this invention allows to change the operating mode very easily by electronic commands, for example from vacuum pump mode to compressor mode. In this case, the control just changes the timing of the valves relative to the piston position and -movement.

**[0017]** Instead of using traditional coil/piston or coil/yoke type valves, where the piston or yoke are made from ferromagnetic material, the valves can be executed in silicone etching technology as well, thus reducing size and increasing in particular the operating speed (= opening/closing frequency).

**[0018]** Silicon-based valves may use different driving mechanisms as well, like thermal effects, electrostatic forces and other wellknown effects.

**[0019]** Another embodiment of the present invention works with piezo-ceramic material to drive the valves.

**[0020]** The vacuum pump according to the present invention is particularly useful for application to domestic refrigerators in which vacuum is used for decreasing the energy consumption of the appliance. To maintain vacuum condition in the double wall of the refrigerator cabinet for more than few years is not always possible, especially for refrigerators having liners made of polymeric material. In this case it is known to connect the double wall with a vacuum pump which can be activated periodically and/or when the pressure inside the double wall

is higher than a predetermined value. Up to now this solution has not been implemented mainly due to high cost of traditional vacuum pumps which are normally used in laboratories and which have high costs. The vacuum pump according to the invention has been specifically designed for assuring a low cost and, at the same time, high performances in term of degree of vacuum.

**[0021]** In order to combine the vacuum pump of the invention and a vacuum insulated refrigerator, it is only necessary to connect the suction tube 12 of the pump to the double wall of the refrigerator or freezer cabinet; moreover the electronic control unit 18 can be linked to the central processing unit of the refrigerator and/or to pressure sensors inside the double wall of the appliance.

**[0022]** The vacuum pump according to the invention may be also used in refrigerators having one or more vacuum compartment and/or containers for improving food conservation.

## Claims

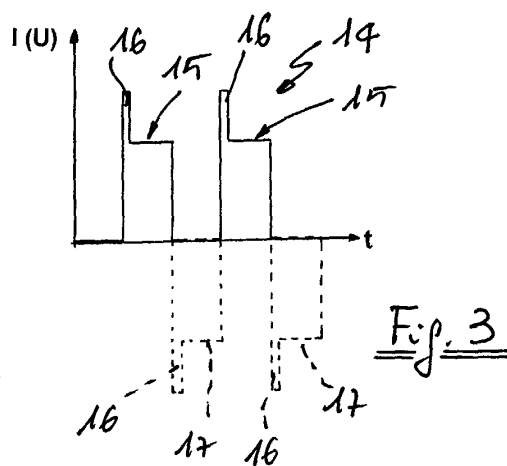
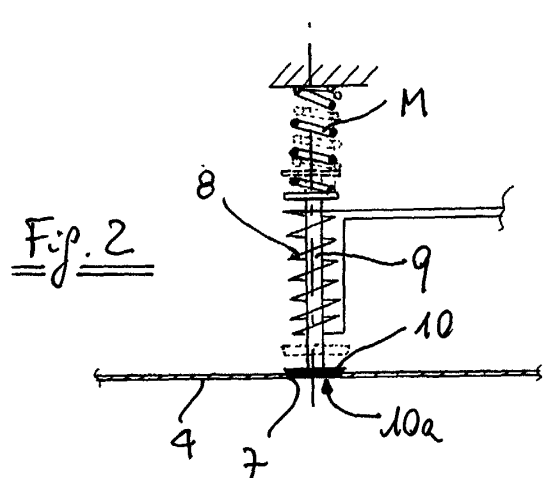
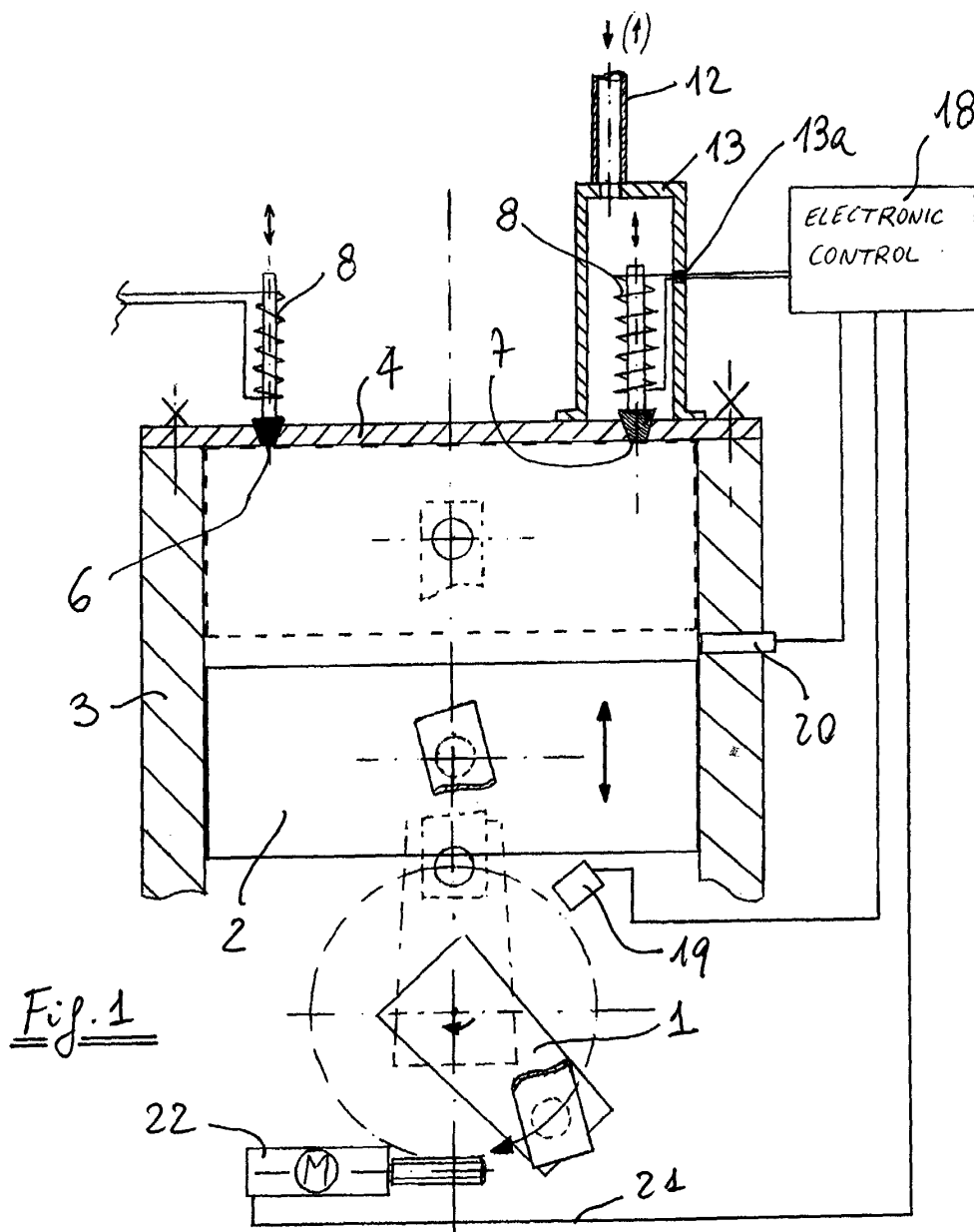
1. A reciprocating-motion type pump comprising valves, particularly a vacuum pump for use in domestic refrigerators or freezers having vacuum insulated walls, **characterised in that** at least one valve (6, 7, 8, 9, 10) is electrically or electronically driven.
2. A reciprocating-motion type pump according to claim 1, in which the valves are placed in a cylinder head (4), **characterised in that** at least one valve comprises a valve plate (10) which is substantially flush with the head (4) of the cylinder (3).
3. A reciprocating-motion type pump according to claim 1 or 2, **characterised in that** the valve is housed in an airtight housing (13) in which the electrical or electromechanical driving system (8, 9, M) of the valve is contained, such housing being connected to the inlet or outlet conduit (12).
4. A reciprocating-motion type pump according to any of claims 1 to 3, **characterised in that** it comprises an electronic control circuit (18, 19, 20) which is adapted to optimise the pump performance, in a way that the valve (9, 10) is opened and closed in co-ordination with the movement of a piston (2) inside the cylinder (3).
5. A reciprocating-motion type pump according to any of the preceding claims, **characterised in that** valves (9, 10) are made from silicon or similar material processed with semiconductor production technologies like etching and the like, to achieve cost-efficient production of fast moving elements.

6. A reciprocating-motion type pump according to any of the preceding claims, **characterised in that** the valves comprise actuators that are made from piezo-electric material. 5
7. A reciprocating-motion type pump according to claim 4, **characterised in that** the electronic control circuit (18) carries out an automatic adjustment of the valve opening timing depending on the pump working conditions. 10
8. A reciprocating-motion type pump according to claim 7, **characterised in that** the electronic control circuit (18) controls both the pump-motor speed and the movement of the valve or valves. 15
9. A reciprocating-motion type pump according to claim 7, **characterised in that** the electronic control circuit (18) is adapted to keep one or more valves open or closed for periods longer than the normal work cycle, in order to reduce temporarily the work load of the pump motor (22). 20
10. A reciprocating-motion type pump according to claim 7, **characterised in that** the electronic control circuit (18) is connected to at least one sensor (19, 20) adapted to detect the pump speed and/or position of the piston, in order to synchronise the valve movement with the pump cycle. 25 30
11. A reciprocating-motion type pump according to any of the preceding claims, **characterised in that** the electrically or electronically driven valves (9, 10) are adapted to switch between an operating mode in which the pump works as a vacuum pump and an operating mode in which the pump works as a compressor. 35
12. Domestic refrigerator or freezer, having a double-walled vacuum-insulating structure, **characterised in that** it comprises a pump according to one of the preceding claims. 40

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# EUROPEAN SEARCH REPORT

Application Number  
EP 02 00 4225

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		8 November 2002	Ingelbrecht, P
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

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Application Number  
EP 02 00 4225

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 8 November 2002	Examiner Ingelbrecht, P
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

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EP 02 00 4225

### CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- ☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):
- ☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

### LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- ☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.
- ☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.
- ☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:
- ☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:





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**LACK OF UNITY OF INVENTION  
SHEET B**

Application Number  
EP 02 00 4225

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claim : 2 with 1

A reciprocating pump comprising valves at least one of which is electronically driven characterised in that at least one valve comprises a valve plate which is substantially flush with the head of the cylinder

2. Claim : 5 with 1

A reciprocating pump comprising valves at least one of which is electronically driven characterised in that the valves are made from silicon or similar material processed with semiconductor production technologies

3. Claim : 7 with 1 and 4

A reciprocating pump comprising valves at least one of which is electronically driven with an electronic control circuit which is adapted to optimise the pump performance, in a way that the valve is opened and closed in co-ordination with the movement of a piston inside the cylinder characterised in that the electronic control circuit carries out an automatic adjustment of the valve opening timing depending on the pump working conditions.

4. Claim : 11 with 1

A reciprocating pump comprising valves at least one of which is electronically driven characterised in that the electronically driven valves are adapted to switch between an operating mode in which the pump works as a vacuum pump and an operating mode in which the pump works as a compressor.

**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 02 00 4225

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on  
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