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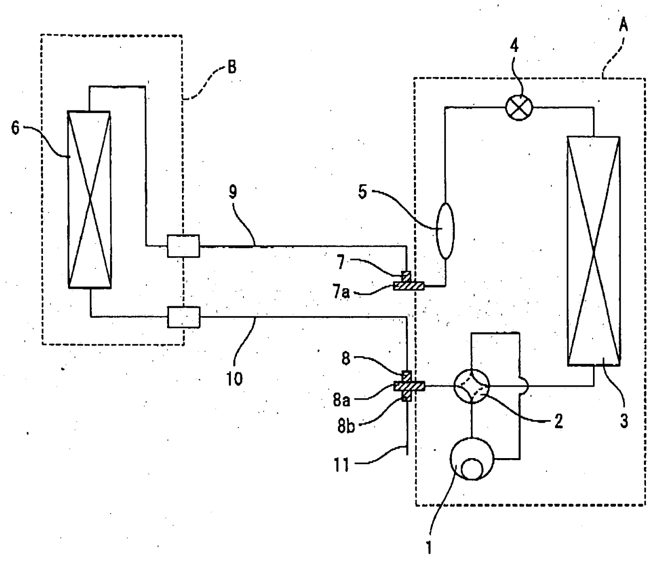
(54) **Vacuum pump and installation method for air conditioner**

(57) A vacuum pump and an installation method for an air conditioner are provided, whereby, the installation of an air conditioner can be performed readily in a short period of time, whilst restricting harmful effects on the environment. The interior of a cylinder (15) is divided into two chambers by a piston (16), and intake ports (20) and exhaust ports (19) are provided, these intake ports and exhaust ports having non-return valves installed respectively at the top dead center and the bottom dead center of these two chambers of the cylinder. When the piston (16) is caused to move in either direction, then if the respective exhaust ports (19) are connected together, the air inside the cylinder is exhausted, thereby causing the exhaust port (19) side in the cylinder to assume a pressurized state, and if the intake ports (20) are coupled, then the intake ports (20) in the cylinder are caused to assume a negative pressure state.

F I G. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a vacuum pump required when installing a separated unit-type air conditioner wherein an indoor unit and an outdoor unit are connected by connection pipes, and to a method of . installing an air conditioner using this vacuum pump.

2. Description of the Related Art

[0002] In a conventional method for installing an air conditioner, in order to exhaust the air in the indoor device and the air in the connection pipes after installation, refrigerant gas is previously filled into the main body of the outdoor unit to a volume in excess-of the specified volume required to display an air conditioning function, for the purpose of purging the air, this refrigerant gas is introduced into the connection pipes and indoor unit via a liquid-side two-way valve provided in the. outdoor unit, and thereupon, the air and refrigerant gas in the connection pipes and inside the indoor unit is exhausted into the atmosphere by means of a valve known as a gas-side three-way service port, which is provided in the outdoor unit.

[0003] On the other hand, with increasing restrictions relating to the environment in recent years, due to the destruction of the ozone layer, global warming, and the like, the expulsion of refrigerant gas, which has a high ozone layer destruction coefficient and a high global warming coefficient, into the atmosphere during installation of air conditioners has become a problem and it is recommended that an electric vacuum pump is used. By connecting this electric type vacuum pump to a valve known as a gas-side three-way service port on the outdoor unit, supplying electric power and then activating the electric vacuum pump, the air in the connection pipes and inside the indoor unit is sucked out and removed to create a sufficient vacuum state, whereupon the refrigerant gas is introduced via a liquid-side two-way valve into the connection pipes and indoor unit.

[0004] However, it becomes relatively difficult to use an electric vacuum pump of this kind in conditions where the installation position is troublesome, such as on the roof, or the like. Moreover, using the vacuum pump method, installation takes a long time compared to a method where refrigerant gas inside the outdoor unit is used.

[0005] Furthermore, the present inventors have also proposed a manual vacuum pump in order to supplement the electric vacuum pump, but with either a manual or an electric vacuum pump, the degree of vacuum reached in the connection- pipes and the interior of the indoor unit is managed by means Of the operating time for which the pump is operated, along with a Bourdon tube pressure gauge.

[0006] However, a Bourdon tube pressure gauge is very susceptible to shocks, and in many cases, the zero point is disturbed due to a slight operational mistake by the operator. Moreover, the smallest graduation on the vacuum gauge is generally large, and rather than indicating the actual level of vacuum reached, it merely serves as a general measure for management purposes.

SUMMARY OF THE INVENTION

[0007] The present invention was devised with the foregoing problems of the prior art in view, an object thereof being to provide a vacuum pump which enables easy installation of an air conditioner whilst considering the effects on the environment, and an installation method for an air conditioner using the vacuum pump.

[0008] In order to achieve the aforementioned object, the present invention provides a vacuum pump, and an installation method for an air conditioner using the vacuum pump, wherein an intake port with a non-return valve and an exhaust port with a non-return valve are provided respectively at the top dead center and the bottom dead center of a cylinder divided into two chambers, an upper chamber and a lower chamber, by means of a position. When the piston is caused to move in either direction, then if the respective exhaust ports are coupled together, gas inside the cylinder is exhausted, thereby causing the exhaust port side to assume a pressurized state, and if the intake ports are coupled, the intake port side of the cylinder is caused to assume a negative pressure state.

[0009] By means of the present invention, in an installation procedure for an air conditioner, after coupling an indoor unit to an outdoor unit by means of connection pipes, firstly, the pump can be used as a pressurizing pump by coupling together the exhaust ports, and leakage inspection for the pipe connection region can be performed at an applied atmospheric pressure of up to approximately 5 kg/cm^2. Compared to a conventional leakage inspection method using refrigerant filled into the outdoor unit, it is possible to achieve a leakage inspection method which is less harmful to the environment. Thereupon, by coupling the intake ports together and using the pump as a conventional pressure reducing vacuum pump, it is possible to reduce the pressure of the air inside the indoor unit and the connection pipes, which must be exhausted from the viewpoint of the reliability of the refrigerating cycle, to a suitable level. This series of tasks can be performed manually, without having to use electrical power.

[0010] Furthermore, the present invention is a vacuum pump wherein the intake ports are connected together by a connecting portion port section, and when the piston moves in either direction, the intake port side is caused to assume a negative pressure state, the vacuum pump being provided with a sensor which is capable of counting the reciprocal movements of the piston.

[0011] According to the present invention, since the number of reciprocal movements of the piston can be counted reliably, then if a database is previously prepared to indicate the capacity of the vacuum pump with respect to the internal volume, based on a.visual estimate of the length of the piping in the indoor unit and the connection pipes, then it is possible for the operator readily to estimate the level of vacuum attained, simply by controlling the number of reciprocal movements of the piston.

[0012] Moreover, the present invention is a vacuum pump and an installation method for an-air conditioner using same, wherein an intake port provided with a non-return valve and coupled to the air conditioner, and an exhaust port provided with a non-return valve and connected to the atmosphere, are installed respectively at the top dead center of a cylinder which is divided into two chambers, an upper and lower chamber, by a piston which moves upwards and downwards by means of a handle, and an open port which is open to the atmosphere and is capable of taking in or exhausting air is provided at the bottom dead center.

[0013] According to the present invention, after causing the upper chamber to assume a negative pressure state by moving the piston downwards, the piston is induced to return in the upward direction, of its own accord, due to an intake action via the open port, so as to correct the pressure differential between the upper chamber and the lower chamber, and consequently, virtually no force is required in the upward action of the piston and hence the piston is easy to operate.

[0014] Furthermore, the embodiments of the present invention are described in detail as follows.

[0015] In order to achieve the aforementioned object, the vacuum pump according to the present invention is a vacuum pump, wherein the interior of a cylinder is divided into two chambers by a piston, intake ports and exhaust ports including non-return valves being provided respectively at the top dead center and the bottom dead center of the cylinder divided into two chambers, and when the piston is caused to move in either direction, then if the respective exhaust ports are coupled together, gas inside the cylinder is exhaused, thereby causing the exhaust port side of the cylinder to assume a pressurized state, and if the intake ports are coupled, the intake port side of the cylinder is caused to assume a negative pressure state. By using this vacuum pump, in an installation procedure for..an air conditioner, after connecting the indoor unit to the. outdoor unit by connection pipes, firstly, the pump is used as a pressurizing pump by coupling the exhaust ports together, and leakage inspection for the pipe connection region can be performed at an applied atmospheric pressure of up to approximately 5 kg/cm^2. Compared to a conventional leakage inspection method using refrigerant filled into the outdoor unit, it is possible to achieve a leakage inspection method which is less harmful to the environment. Thereupon, by coupling the intake ports together and using the pump as a conventional pressure reducing vacuum pump, it is possible to reduce the pressure of the air inside the indoor unit and the connection pipes, which must be exhausted from the viewpoint of the reliability of the refrigerating cycle, to a suitable level. This series of tasks can be performed manually, without having to use electrical power.

[0016] Moreover, a compression coil spring is provided inside the non-return valves installed in the intake ports, the spring constant of the compression coil spring being 0.01 - 0.04 N/mm. Thereby, it is possible to provide a non-return valve having a sufficiently small minimum operating pressure differential.

[0017] Furthermore, the installation method for an air conditioner according to the present invention is an installation method for the installation of an air conditioner comprising an indoor unit and an outdoor unit connected by connection pipes, wherein the vacuum pump comprises a cylinder, the interior of which is divided into two chambers by a piston, intake ports and exhaust ports including non-return valves being provided respectively at the top dead center and the bottom dead center of the cylinder divided into two chambers, and the installation method comprises, at the least: a first step, wherein the respective exhaust ports are coupled together and if the piston is caused to move in either direction, then the gas inside the cylinder is exhausted, thereby causing the interior of the indoor unit and the connection pipes to assume a pressurized state; and a second step, wherein the intake ports are coupled together, and the interior of the indoor unit and the connection pipes are caused to assume a negative pressure state.

[0018] According to this method, using the exhaust port side of the vacuum pump as a pressurizing pump, it is possible to perform leakage inspection on the connections at a pressure of approximately 5 kgf/cm^2, after coupling the indoor unit to the outdoor unit by connection pipes. Compared to a conventional leakage inspection method using the refrigerant filled into the outdoor unit, it is possible to achieve a leakage inspection method which is less harmful to the environment. Moreover, by subsequently using the intake port side as a pressure reducing vacuum pump, it is possible to set the interior of the indoor unit and the connection pipes to a sufficient negative pressure state. In this way, it is possible to install an air conditioner by making effective use of both the exhaust port side and the intake port side of the vacuum pump.

[0019] Moreover, the method of present invention is an installation method for an air conditioner, comprising the provision of: a first coupling section for coupling together the exhaust ports; a second coupling section for coupling together the intake ports; a connecting section for connecting the first coupling section to the exhaust ports; and a connecting section for connecting the second coupling section to the intake ports. Moreover, in the installation method for an air conditioner, the connecting sections are detachable. Thereby, by providing readily detachable connecting sections on the intake ports and exhaust ports, in the installation of an air conditioner, firstly, the exhaust port side can be used as a pressurizing pump for performing-leakage inspection of the connection section, and then the exhaust port side can be used as a conventional pressure reducing vacuum pump. By providing readily attachable and detachable connecting sections in this way, it is possible to divide the mechanical function of the vacuum pump according to the present invention between a pressurizing device and a pressure reducing device.

[0020] Furthermore, the present invention is a vacuum pump, wherein the interior of a cylinder is divided into two chambers by a piston, the vacuum pump comprises intake ports and exhaust ports including non-return valves being provided respectively at the top dead center and the bottom dead center of the cylinder divided into two chambers, the respective intake ports are coupled together by means of a coupling port section, the pressure differential between the two chambers is gradually reduced from an initial presuure differential, as the intake port side is caused to assume a negative pressure state, by movement of the piston in either direction, and a sensor is provided for counting the number of reciprocal movements of the piston. By this means, when installing an air conditioner, it is possible, for example, to reduce the pressure inside the connection pipes and the indoor unit, thereby drawing in refrigerant gas from the outdoor unit, via the service port of the gas-side three-way valve in the outdoor unit. Moreover, since the sensor counts the reciprocal movements of the piston, the level of vacuum attained on the intake port side can be estimated. For example, if a database is previously prepared to indicate the capacity of the vacuum pump with respect to the internal volume, based on a visual estimate of the length of the piping in the indoor unit and the connection pipes, then it is possible for the operator readily to estimate the level of vacuum-attained, by controlling the number of reciprocal movements of the piston. Furthermore, there is no requirement for special caution in handling the vacuum pump, and the piston can be operated manually.

[0021] Moreover, in the vacuum pump of the present invention, the sensor is an acceleration sensor and the response sensitivity thereof is 1 to 5 G. Since an acceleration sensor having a response sensitivity of 1 to 5 G is used as the sensor for counting the reciprocal movements of the piston, then it is possible to count only the accelerations G caused when the piston impacts with the inner wall of the cylinder. Thereby, by using an acceleration sensor capable of responding to an acceleration of 1 to 5 G, it is possible to count accurately only the accelerations G caused when the piston impacts with the inner wall of the cylinder, thus providing a sensor which does not provide an inaccurate count, such as double counting or missed counting of the stroke movements of the piston.

[0022] Furthermore, in the vacuum pump, the sensor has a construction using a wire spring or an arm held by a cantilever, and the wire spring or arm can be made to respond accurately to the accelerations G having a uniform direction caused by reciprocal movements of the piston. In this way, since the acceleration G is received by means of a wire spring or a cantilevered arm, it is possible to provide an acceleration sensor which is able to respond accurately to accelerations G having a uniform direction, such as the reciprocal movements. in the stroke action of the piston.

[0023] Furthermore, the acceleration sensor is a mechanical sensor, the mechanism thereof being a pressure contact system, a reed switch system or a conductive contact system, and by adopting a mechanical sensor based on a pressure contact system, a reed switch system or a conductive contact system, it is possible to achieve a relatively simple structure. In this way, by a adopting a mechanical system and using a pressure contact system, a reed switch system or a conductive contact system for the mechanism thereof, it is possible to count the acceleration G accurately, by means of a relatively simple mechanical structure, for example, a wire spring, a pendulum or electrical contacts.

[0024] Moreover, in order to achieve the aforementioned object, the present invention is a vacuum pump, wherein the interior of a cylinder is divided into an upper chamber and a lower chamber by a piston, the piston being coupled to a handle which causes the piston to move by means of a supporting shaft provided on the upper chamber side thereof, an intake port including a non-return valve and an exhaust port including a non-return valve each being provided at the top dead center of the upper chamber, an open port provided in the lower chamber of the cylinder and being capable of taking in or exhausting air, the upper chamber being caused to assume a negative pressure state by movement of the piston in the downward direction, and furthermore, the piston being moved in the upward direction by the intake action via the open port. For example, when installing an air conditioner, if the indoor unit is connected to the outdoor unit by connection pipes and the intake port and exhaust port are used as a pressure vacuum pump, then when the upper chamber has been caused to assume a negative pressure state by moving the piston downwards, the piston will then be induced to return in an upward direction, of its own accord, due to an intake action via the open port, so as to correct the pressure differential between the upper chamber and the lower chamber. Consequently, whilst a uniform force is required to move the piston in a downward direction, virtually no force is required to move it in the upward direction, and hence a light operation is achieved. For example, it is possible to reduce the pressure of the oxygen in the air, which must be exhausted from the viewpoint of the reliability of the refrigerating cycle, to a suitable level, in addition to which, the operation of the piston can be performed manually, without having to use electrical power, which is a great merit.

[0025] Furthermore, the present invention is an installation method for an air conditioner when using a vacuum pump to install an air conditioner comprising an indoor unit and an outdoor unit connected by connection pipes, wherein the vacuum pump comprises a cylinder, the interior of which is divided into an upper chamber and a lower cylinder by a piston, the piston being coupled to a handle which causes the piston to move by means of a supporting shaft provided on the upper chamber side thereof, an intake port and an exhaust port including non-return valves and provided at the top dead center of the upper chamber, and an open port provided in the lower chamber of the cylinder and being capable of taking in or exhausting air; the relationship between A, which is the total volume of the internal spatial volume of the upper chamber formed when the piston is at the bottom dead center and the internal volume of the space from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve, and B, which is the total volume of the cylinder internal dead space formed when the piston is at the top dead center, and the internal volume of the space from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve; is $V1a/V1b \geq 20$; and after the upper chamber has been caused to assume a negative pressure state by moving the piston in a downward direction, the piston is induced to move in the upward direction by the intake action via the open port, whilst the interior of the indoor unit and the connection pipes is caused to assume a negative pressure state.

[0026] Furthermore, the present invention is an installation method for an air conditioner when using a vacuum pump to install an air conditioner comprising an indoor unit and an outdoor unit connected by connection pipes, wherein the vacuum pump comprises a cylinder, the interior of which is divided into an upper chamber and a lower cylinder by a piston, the piston being coupled to a handle which causes the piston to move by means of a supporting shaft provided on the upper chamber side thereof, an intake port and an exhaust port including non-return valves and provided at the top dead center of the upper chamber, and an open port provided in the lower chamber of the cylinder and being capable of taking in or exhausting air; the relationship between A, which is the total volume of the internal spatial volume of the upper chamber formed when the piston is at the bottom dead center and the internal volume of the space from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve, and B, which is the total volume of the cylinder internal dead space formed when the piston is at the top dead center, and the internal volume of the space from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve, is $V1a/V1b \geq 20$, and more desirably, $V1a/V1b \geq 40$; and after the upper chamber has been caused to assume a negative pressure state by moving the piston in a downward direction, the piston is induced to move in the upward direction by the intake action via the open port, whilst the interior of the indoor unit and the connection pipes is caused to assume a negative pressure state. Therefore, in the installation procedure for the air conditioner, it is possible to reduce the oxygen in the air, which must be eliminated from the viewpoint of the reliability of the refrigerating cycle, to a suitable level, and hence the installation of the air conditioner can be completed in a short period of time.

[0027] Furthermore, the present invention is an installation method for an air conditioner wherein, in the installation process, the interior of the indoor unit and the connection pipes are caused to assume a negative pressure state, after a specific gas has been introduced into the indoor unit and the connection pipes and the air inside the indoor unit and the connection pipes has been substituted by the specific gas. By means of this method, since the vacuum pump is used after the air in the indoor unit and the connection pipes has been substituted with a gas which will not be detrimental to the refrigerating cycle, even if it is left during the installation process, such as carbon dioxide gas, then it is possible to a reliable installation process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028]

Fig. 1 is a block diagram of an air conditioner according to the present invention;

Fig. 2 is a diagram showing a construction of a vacuum pump main body and a pressure-resistant hose connection path according to the present invention;

Fig. 3 is an enlarged diagram of an essential part á of the vacuum pump shown in Fig. 2;

Fig. 4 is a schematic diagram of an acceleration sensor provided in a handle of the vacuum pump according to the present invention;

Fig. 5 is a schematic diagram of a non-return valve provided in an air exhaust port according to the present invention;

Fig. 6 is a sectional view along a face A - A' in the non-return valve in Fig. 5;

Fig. 7 is a schematic diagram of a non-return valve provided in an air intake port according to the present invention;

Fig. 8 is an enlarged diagram of the principal section β of the vacuum-pump shown in Fig. 2;

Fig. 9 is a schematic diagram of a filter section according to the present invention;

Fig. 10 is a concrete view showing a dead space when the piston is at the bottom dead center, in the principal section γ of the vacuum pump shown in Fig. 2;

Fig. 11 graph of the relationship between the number of strokes and the internal pressure in a vacuum pump according to the present invention;

Fig. 12 is a diagram showing the construction of the main body of a vacuum pump according to the present invention, and the connection path of the pressure-resistant hoses connected to the exhaust port side;
Fig. 13 is a diagram showing the construction of the main body of a vacuum pump according to the present invention, and the connection path of the pressure-resistant hoses connected to the intake port side;
Fig. 14 is a graph of the relationship between the number of strokes and the internal pressure in a vacuum pump according to the present invention;
Fig. 15 is a diagram showing the construction of the main body of a vacuum pump according to the present invention, and the connection path of the pressure-resistant hoses connected to the exhaust port side;
Fig. 16 is a diagram showing the construction of the main body of a vacuum pump according to the present invention, and the connection path of the pressure-resistant hoses connected to the intake port side;
Fig. 17 is a schematic diagram showing the air flow on the intake port side of the filter section according to the present invention;
Fig. 18 is a schematic diagram showing the air flow on the exhaust port side of the filter section according to the present invention;
Fig. 19 is a schematic diagram of a one-touch pipe joint provided on the main body of the vacuum pump according to the present invention;
Fig. 20 is a concrete view showing a dead space when. the piston is at the bottom dead center, in the principal section δ of the vacuum pump shown in Fig. 14;
Fig. 21 is a graph of the relationship between the number of strokes and the internal pressure of a vacuum pump according to the present invention;
Fig. 22 is a flowchart of the procedure until an acceleration sensor of the vacuum pump according to the present invention displays a count;
Fig. 23 is a schematic schematic diagram showing an acceleration sensor installed on the handle of a vacuum pump according to the present invention;
Fig. 24 is a schematic diagram showing a strain gauge of an acceleration sensor of a vacuum pump according to the present invention;
Fig. 25 is a detection circuit diagram of a strain gauge of an acceleration sensor in a vacuum pump according to the present invention;
Fig. 26 is a graph of the relationship between the number of strokes and the internal pressure of a vacuum pump according to the present invention;
Fig. 27 is a schematic diagram showing a counter built into an acceleration sensor provided in the handle of a vacuum pump according to the present invention;
Fig. 28 is a schematic diagram showing the mechanism of an acceleration sensor in a vacuum pump according to the present invention;
Fig. 29 is a schematic diagram showing a counter built into an acceleration sensor provided in the handle of a vacuum pump according to the present invention;
Fig. 30 is a schematic diagram showing the mechanism of an acceleration sensor in a vacuum pump according to the present invention;
Fig. 31 is a schematic diagram showing a counter built into an acceleration sensor provided in the handle of a vacuum pump according to the present invention;
Fig. 32 is a schematic diagram showing the mechanism of an acceleration sensor in a vacuum pump according to the present invention;
Fig. 33 is a refrigerant cycle diagram showing an air conditioner installed using the vacuum pump of the present invention;
Fig. 34 is a diagram showing the construction of a vacuum pump according to the present invention and the connection path of a pressure-resistant hose;
Fig. 35 is a detailed schematic diagram of a case where the piston shown in Fig. 2 of the vacuum pump according to the present invention is situated at the top dead center; and
Fig. 36 is a diagram showing the construction of the vacuum pump according to the present invention and the connection path of a pressure-resistant hose.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] Below, embodiments of the present invention are described with reference to the drawings.

(First embodiment)

[0030] Fig. 1 is a schematic diagram of a refrigeration cycle of an air conditioner described in the embodiment. The refrigeration cycle comprises, as typical components: a compressor 1, a four-way valve 2, an outdoor, heat exchanger 3, an aperture device 4, a drier 5, and an indoor heat exchanger 6. The compressor 1, four-way valve 2, outdoor heat exchanger 3, aperture device 4, and drier 5 are situated in an outdoor unit A, and the indoor heat exchanger 6 is situated in an indoor unit B.

[0031] A liquid side two-way valve 7 and a gas-side three-way valve 8 are provided in the outdoor unit A. Connection pipes 9, 10 for connecting the outdoor unit A and the indoor unit B are respectively connected via the liquid-side two-way valve 7 and the gas-side three-way valve 8. The liquid-side two-way valve has a screw section 7a, and by opening this screw section 7a, the pipe of the outdoor unit A and the connection pipe 9 are coupled. Moreover, the gas-side three-way valve 8 has a screw section 8a and a service port section 8b, and by opening the screw section 8a, the pipe of the outdoor unit A and the connection pipe 10 are coupled together.

[0032] The outdoor unit A and indoor unit B are connected by indoor/outdoor connection pipes 9, 10, a central port 12a of a gauge manifold 12 being coupled via a pressure-resistant hose 11 to the service port section 8b of the gas-side three-way valve 8 on the outdoor unit A, and a low-pressure side port 12b of a gauge manifold 12 being coupled to a pressure-resistant hose 13 forming a coupling section which couples the two suction ports into a single port. A filter section 14 is provided in the path of the hose 13.

[0033] Fig. 2 shows a schematic diagram for giving a detailed description of the construction of the vacuum pump main unit and the connection paths of the pressure-resistant hoses.

[0034] The structure of the vacuum pump comprises an aluminium piston 16 disposed inside an aluminium cylinder main body 15 in such a manner that it divides the interior of the cylinder into two chambers, the piston 16 being coupled via a stainless steel supporting shaft 17 to an aluminium handle 18. An acceleration sensor 181 and a primary electric cell 182 are built into the handle 18, and a display 183 is provided on the surface of the upper portion of the handle 18, in such a manner that a signal from the acceleration sensor 181 can be displayed on the display 183.

[0035] Fig. 3 shows a schematic diagram of the construction of a handle 18, and Fig. 4 shows a schematic diagram of an acceleration sensor 181.

[0036] The acceleration sensor 181 comprises a thinly formed sensor section consisting of a semiconductor and a weight section having a large surface area. In operation, when the stroke movement of the handle 18 halts and an acceleration of G is generated, the weight section receives this and the sensor section distorts. Due to this distortion, the electrical resistance of the diffused layer formed on the upper part of the sensor section changes. The stress caused by the distortion of the sensor section due to this acceleration is detected by a piezo effect of the sensor section, and is converted to a voltage output by means of a bridge circuit. The total weight of the vacuum pump main body is approximately 1 kg.

[0037] A construction is adopted wherein non-return valves 19a, 19b, 20a, 20b connect directly to the main wall of the cylinder in the regions where the piston 16 forms a top dead center face and a bottom dead center face when it moves inside the cylinder 15. In this case, a structure as illustrated in Fig. 5 and Fig. 6 is used for the exhaust port non-return valves 19a, 19b, and a structure as illustrated in Fig. 7 is used for the intake port non-return valves 20a, 20b. The copper tube 191 of the exhaust port non-return valves 19a, 19b is processed with roll grooves at two points, and a brass valve seating member 192 is fixed in groove section 191a. A nylon valve member 193 impacts with the valve seating member 192, and the movement thereof is halted by a contact face with the valve seating member 192 in a section having an oblique face. Moreover, in the opposite direction, the movement of the valve member is halted by the groove section 191b. Therefore, a non-return valve structure is obtained wherein air only flows in the direction of the arrow. The copper tube 201 of the intake non-return valves 20a, 20b is processed with roll grooves at two points, and a brass valve seating member 202 is fixed to the groove section 201a. A compression coil spring member 203 is connected to a film plate 204 and under the force of the compression coil spring, the nylon film plate 204 is caused to impact with a brass valve seating member 205, the fluid path being sealed by the contact between the respective faces of the seating member 205 and the film plate 202, thereby achieving a non-return valve structure wherein air is only able to flow in the direction of the arrow. Using a spring made from SUS 304 steel with a spring constant of 0.04 N/mm for the compression coil spring member 203, it was possible to achieve a minimum operating pressure differential of 10 torr. A brass valve seating member 205 is fixed by the groove section 201b, and it is provided with a tapered section, with the object of slightly increasing the pressure differential required to operate the valve by reducing the suction flow path surface area in the flow path on the upstream side of the valve seating member 205.

[0038] Furthermore, shaft seals 21a, 21b are disposed in the region where the supporting shaft 17 meets the outer wall of the cylinder 15, as illustrated in Fig. 8, the seals being constituted by a dual O-rings made from HNBR. A shaft seal 22 consisting of an O-ring made from HNBR is also provided in the portion of the piston 16 where it contacts the inner wall of the cylinder 15.

[0039] Fig. 9 shows the internal construction of the filter section 14. The main body of the filter section 14 has a circular tubular shape, and air entering into the filter soon confronts a wall 141 and is caused to change direction to flow in an outward radial direction, then passing through a tubular pulp film 142 disposed in a fixed position inside the filter body, and being introduced into an internal passage, before finally being directed out of the filter. Consequently, when the air passes from the outer passage to the inner passage, dirt is trapped. Moreover, if the cylindrical tube 143 of the filter section 14 is made from a transparent glass or resin, then the state of the trapped dirt can be observed visually.

[0040] Next, the operation of the vacuum pump will be described. Firstly, when the handle 18 is pulled in direction a (towards the top dead center), the air inside the indoor unit B and the connection pipe 9 is drawn in from the service port section 8b and via the pressure-resistant hose 11, the gauge manifold 12, and the pressure-resistant hose 13, and into the cylinder interior section 14b via the non-return valve 20b at the intake port, whilst conversely, the air in the cylinder interior section 14a is exhausted into the atmosphere via the non-return valve 19a at the exhaust port. Thereupon, when the handle 18 is pushed in direction b (towards the bottom dead center), the air in the indoor unit B and the connection pipe 9 is drawn in from the service port section 8b and via the pressure-resistant hose 11, the gauge manifold 12, and the pressure-resistant hose 13, and into the cylinder interior section 14a via the non-return valve 20a at the intake port, whilst conversely, the air in the cylinder interior section 14b is exhausted into the atmosphere via the non-return valve 19b at the exhaust port. Thereupon, when reciprocal movement of the handle 18 is performed, whereby the handle 18 is again pulled in direction a (towards the top dead center), then the piston 16 performs synchronized movement. In this case, the interior of the cylinder constantly reduces in pressure, whether the piston moves in direction a or direction b, whilst the four non-return valves are switched alternately, and ultimately, a sufficient negative pressure state can be achieved. In strict terms, it is possible to continue the pressure reducing mechanism, as long as it is possible to generate a pressure differential between the interior of the pressure-resistant hose 13 and the interior of the cylinder 14a or 14b when performing reciprocal movement of the handle 18. Therefore, the non-return valves 20a and 20b provided at the intake ports are required to have a low minimum operating pressure differential. In the case of a non-return valve as in the present embodiment, the factor determining this minimum operating pressure differential is the spring constant of the compression coil spring member 203.

[0041] The series of reciprocal movements is detected by the acceleration sensor 181 and the number of stroke operations of the handle 18 can be displayed on the display 183. In the initial period of using the vacuum pump, a large pressure differential is created between the cylinder interior sections 14a and 14b, but by reciprocal movement of the piston, this differential pressure state is gradually attenuated. In this case, the shaft seals 21a and 21b ensure a sufficient differential pressure state between the negative pressure (30 torr or less) inside the cylinder 14, and the external air (760 torr), and in order to prevent any leakage of air, a dual O-ring structure is used for the seals. By adopting a dual-ring structure, it is possible to prevent foreign material, which is liable to adhere to and infiltrate inside the seal section when the supporting shaft is operated. Furthermore, the shaft seal 22 provides a sufficient guarantee of a differential pressure state created when the piston 16 is made to perform reciprocal movement, by means of a single O-ring.

[0042] A specific installation procedure is now described. The pressure-resistant hose 13 of the vacuum pump is connected to the low pressure port 12b of the gauge manifold 12, and then attached to the service port section 8b, thereby achieving a state where the interior of the pressure-resistant hose 11 is connected with the indoor unit B and the connection pipe 9. Moreover, the interior of the pressure-resistant hose 13 is connected by opening the low pressure side handle 12c of the gauge manifold 12. Thereupon, reciprocal movement of the handle 18 of the vacuum pump is performed, and by reading off the number of stroke operations thereof, from the display 183, the operator is able to estimate when the interior of the indoor unit B and the connection pipe 9 has reached a sufficient state of negative pressure. Furthermore, the sufficient negative pressure state is ultimately judged by the operator from the scale of the vacuum gauge 12d of the gauge manifold 12. Immediately, the low pressure side handle 12c of the gauge manifold 12 is closed, and after waiting for a short while, it is confirmed that there is no change in the reading of the vacuum gauge 12d. Here, if there is a change in the reading, then there is a point at which an air leak is occurring in the connection pipe section. Next, the screw section 7a of the liquid side two-way valve 7 is slightly loosened and refrigerant gas from the outdoor unit A is introduced, whereby the connection pipes 9, 10 and the interior of the pipes in the indoor unit B assume a slightly positive pressure state (approximately 0.2 kgf/cm^2). Thereupon, the pressure-resistant hose 11 is detached from the service port section 8b, the screw section 7a of the liquid-side two-way valve 7 is rotated by a further 1/4 turn, and the state of leakage of the connection pipe section is rechecked at an applied pressure of (3 - 6 kgf/cm^2). Finally, the screw section 7a of the liquid-side two-way valve 7 is opened fully, and the screw section 8a of the gas-side three-way valve 8 is opened fully, thereby completing the installation tasks relating to the installation of an air conditioner.

[0043] In the present embodiment, the internal volume of the piping of the indoor unit B including the indoor heat exchanger 6, and the connection pipes 9, 10, was 1.5 litres. In the vacuum pump, the internal volume of the cylinder space when the piston is at the top dead center was 150 ml (27 dia $\times$ 260 mm), and the total volume from the cylinder outlet formed when the piston is at the bottom dead center, to the intake port and exhaust port non-return valves; was 1.5 ml. These figures are taken to include the port flow path space arising in the cylinder wall. The cylinder internal dead space formed when the piston is at the bottom dead center was 2 ml. Taking Via to be the total volume of the internal volume of the cylinder space when the piston is at the top dead center, the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the non-return valves of the intake ports and exhaust ports, and taking V1b to be the total volume of the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the non-return valves of the intake ports and exhaust ports, the relationship between V1a and V1b is V1a/V1b.

[0044] Fig. 10 shows a concrete illustration of the V1b portion comprising the cylinder internal dead space and the total volume of the internal space from the cylinder outlet when the piston is at the bottom dead center to the intake port and exhaust port non-return valves. By adopting a structure wherein an intake port and exhaust port are embedded in the cylinder wall at positions corresponding to the top dead center face and the bottom dead center face of the cylinder main body, in such a manner that each pair of non-return valves are directly connected, a system structure design is achieved wherein the portion forming the dead space in the pressure-reducing mechanism is a minimum.

[0045] In this case, by following the aforementioned work procedure, it was possible to achieve 30 torr using the vacuum pump, by performing 40 strokes of reciprocal movement of the handle. Fig. 11 shows the progress of the state of pressure reduction, in the form of the relationship between the number of strokes and the internal pressure. The progress of pressure reduction was confirmed up to 50 strokes, but the vacuum level attained reached a state of equilibrium at 40 strokes and did not advance further thereafter. Consequently, it can be seen that when a vacuum pump according to the present embodiment is applied to a system having an internal volume of 1.5 litres, then 40 strokes is the general standard for the attained vacuum level. To obtain an accurate figure, the vacuum level was monitored separately using a digital pressure sensor.

(Second embodiment)

[0046] Fig. 12 is a schematic diagram giving a detailed illustration of a pressure-resistant hose connection path connecting the vacuum pump main mechanism with the exhaust port according to the present embodiment, and Fig. 13 is a schematic diagram of a pressure-resistant hose connection path connecting to the intake port side. In the present embodiment, a vacuum pump main body similar to the first embodiment is used, but a pressure-resistant hose 23 is provided which forms a coupling section for coupling the exhaust ports into one. The constitutional elements which are similar to the first embodiment are not described in detail here.

[0047] Next, the effects of the present embodiment are described in terms of the operational mechanism of the vacuum pump. Firstly, when the handle 18 is pulled in direction a (towards the top dead center), the air in the cylinder interior section 14a is drawn via the non-return valve 19a forming an exhaust port into the indoor unit B and connection pipe 9. Thereupon, when the handle 18 is pushed in direction b (towards the bottom dead center), the air in the cylinder interior section 14b is drawn via the non-return valve 19b forming an exhaust port into the indoor unit B and the connection pipe 9. Thereupon, the handle 18 is caused to perform reciprocal movement, in such a manner that the handle 18 is pulled again in direction a (towards the top dead center), and the piston 16 becomes synchronized. In this case, the interior of the cylinder can be used as a pressurizing pump, which constantly causes the indoor unit B and the interior of the connection pipe 9 to be in a pressurized state due to the atmosphere, whether the piston moves in direction a or direction b, whilst the four non-return valves are switched alternately. Since this operation is performed manually, there is a natural limit on the pressurization level, and anyone can readily achieve a level of approximate 5 kg/cm^2.

[0048] Now, a concrete installation procedure is described. An indoor unit B and outdoor unit A are connected by connection pipes, the exhaust port side pressure-resistant hose 23 of the vacuum pump is connected to the low pressure port 12b of the gauge manifold 12, and this is then attached to the service port section 8b, whereby the interior of the pressure-resistant hose 11 becomes connected to the interior of the indoor unit B and the connection pipe 9. Furthermore, the interior of the pressure-resistant hose 13 is connected by opening the low pressure side handle 12c of the gauge manifold 12. Thereupon, the handle 18 of the vacuum pump is caused to perform reciprocal movement, and when the pump has become difficult for the operator to work using his or her own strength, the low pressure side handle 12c is closed, thereby setting the interior of the indoor unit B and the connection pipe 9 to a pressurized state at an atmosphere of approximately 5 kg/cm^2. By waiting for a short while whilst confirming the pressure level using a vacuum gauge 12d, it is possible to check for leaks relating to the connection pipe sections. Thereupon, the pressure-resistant hose 23 is detached from the lower pressure side port 12b of the gauge manifold 12 and the low pressure side handle 12c is opened, thereby allowing the pressurized air to escape externally, and returning the interior to a normal pressure state. Next, the pressure-resistant hose 13 of the vacuum pump is connected to the low pressure port 12b of the gauge manifold 12. Here, the low pressure side handle 12c of the gauge manifold 12 is open, and hence the indoor unit B and the connection pipe 9 are in a connected state. When the handle 18 of the vacuum pump is caused to perform reciprocal movement, the pressure can gradually be reduced, and by reading the number of strokes of reciprocal movement from the display 183, the operator is able to estimate when the interior of the indoor unit B and the connection pipe 9 has reached a sufficient negative pressure state. Furthermore, the sufficient negative pressure state is ultimately judged by the operator from the scale of the vacuum gauge 12d of the gauge manifold 12. Immediately, the low pressure side handle 12c of the gauge manifold 12 is closed. Next, the screw section 7a of the liquid side two-way valve 7 is loosened and refrigerant gas from the outdoor unit A is introduced, whereby the connection pipes 9, 10 and the interior of the pipes in the indoor unit B assume a slightly positive pressure state (approximately 0.2 kgf/cm^2). Thereupon, the pressure-resistant hose 11 is detached-from the service port section 8b, and the screw section 7a of the liquid-side two-way valve 7 is opened fully, and the screw section 8a of the gas-side three-way valve 8 is opened fully, thereby completing the installation tasks relating to the installation of an air conditioner.

[0049] In the present embodiment, the internal volume of the indoor unit B piping including the indoor heat exchanger 6, and the connection pipes 9, 10, was 1.5 litres. In the vacuum pump, the internal volume of the cylinder space when the piston is at the top dead center was 250 ml (27 dia. × 440 mm), and the total internal volume from the cylinder outlet formed when the piston is at the bottom dead center, to the intake port and exhaust port non-return valves, was 1.5 ml. These figures are taken to include the port flow path space arising in the cylinder wall. The cylinder internal dead space formed when the piston is at the bottom dead center was 2 ml. The relationship between V1a and V1b determined in a similar manner to the first embodiment is V1a/V1b = 72.

[0050] Here, using the vacuum pump in accordance with the work procedure described above, it was possible to achieve 18 torr by performing 40 strokes of reciprocal movement of the handle. Fig. 14 shows the progress of the state of pressure reduction, in the form of the relationship between the number of strokes and the internal pressure. After 25 strokes, the pressure was 30 torr or less, and the progress of pressure reduction was confirmed up to 50 strokes, but the vacuum level attained reached a state of equilibrium at 40 strokes and did not advance further thereafter. Consequently, it can be seen that when a vacuum pump according to the present embodiment is applied to a system having an internal volume of 1.5 litres, then 40 strokes is the general standard for the attained vacuum level. To obtain an accurate figure, the vacuum level was monitored separately using a digital pressure sensor.

[0051] In the present embodiment, by using the exhaust port side of a vacuum pump as a pressurizing pump, it was possible to perform adequate leak inspection associated with the installation work. In the prior art, the only method available was to use the refrigerant in the leak inspection of the connection pipes and indoor unit, but here, it is possible to provide an installation method for an air conditioner which is not harmful to the environment, by using pressurized air to perform a leak inspection.

(Third embodiment)

[0052] In this embodiment, no gauge manifold 12 is interposed in the path from the service port to the vacuum pump. Fig. 15 shows a schematic diagram which gives a detailed illustration of a pressure-resistant hose connection path connecting a vacuum pump main body and an exhaust port side according to the present embodiment, and Fig. 16 is a schematic diagram of a pressure-resistant hose connection path connected to the intake port side. The structure of the vacuum pump comprises an aluminium piston 27 which is disposed inside an aluminium cylinder main body 15 in such a manner that it divides the interior of the cylinder into two chambers, the piston 27 being coupled via a stainless steel supporting shaft 17 to an aluminium handle 18. An acceleration sensor is built into the handle 18, similarly to the first embodiment, in such a manner that signals from the acceleration sensor are displayed on a display. In the present embodiment, a construction is adopted wherein non-return valves 30a, 30b, 31a, 31b connect directly to the main wall of the cylinder in the regions where the piston 27 forms a top dead center face and a bottom dead center face when it moves inside the cylinder 15. The non-return valves 30a, 30b used for the exhaust ports and the non-return valves 31a, 31b used for the intake ports are similar to those used in the first embodiment. Moreover, shaft seals similar to those of the first embodiment are provided in the region where the supporting shaft 17 meets the cylinder wall, and a shaft seal 22 is also provided on the portion of the piston 27 which contacts the inner wall of the cylinder 15.

[0053] Figs. 17 and 18 illustrate the internal construction of a filter section 14 and the flow of air therein. The main body of the filter section 14 has a circular tubular shape, and when the filter section 14 is used on the intake port side, in other words, as illustrated in Fig. 17, then air entering into the filter immediately confronts a wall 25 and is caused to change direction to flow towards an outer flow path 252, and it then passes through a tubular pulp film 253 provided in a fixed position inside the filter and into an inner passage 254, before finally being directed out of the filter. Furthermore, if used on the exhaust port side, in other words, as illustrated in Fig. 18, then air exiting from the internal passage 254 to the outer side of the tubular pulp film 253 confronts a tubular pulp fibreless cloth 255 provided on the inner wall of the tubular main body of the filter section 14, and is exhausted out of the filter via the outer passage 252. Consequently, a construction is achieved wherein, when the filter is used on the intake port side, dirt is trapped by the tubular pulp film 253 which has a relatively small mesh size, whereas when the filter is used on the exhaust port side, dirt is trapped by a tubular fibreless cloth 255 having a relatively large mesh size.

[0054] The exhaust port non-return valves 30a, 30b used have a similar structure to that in the first embodiment illustrated in Fig. 5 and Fig. 6, and the intake port non-return valves 31a, 31b used have a similar structure to that in the first embodiment illustrated in Fig. 7.

[0055] One-touch pipe joints 34a, 34b are provided respectively at the exhaust port non-return valves 30a, 30b, via joint sections 33a, 33b. Furthermore, one-touch pipe joints 36a, 36b are provided respectively at the intake port non-return valves 31a, 31b, via joint sections 35a, 35b. The structure of the one-touch pipe joints 34a, 34b, 36a, 36b is virtually the same, and Fig. 19 illustrates schematically the construction taking the one-touch pipe joint 34a as a typical example. The concrete construction is described below. A release bush 341 is provided around the pressure-resistant hose, and the release bush 341 is fixed by providing a guide 343 and collet 344 on the main body 342. A chuck 345 is disposed between the release bush 341 and collet 344, and the chuck 345 is caused to fit into the pressure-resistant hose, thereby preventing detachment of the pressure-resistant hose, by pushing the chuck 345 in the direction of the pressure-resistant hose by means of a CR rubber lip seal 346. Furthermore, since the pressure of of the chuck 345 can be released by pushing the release bush 341 towards the inner side along the pressure-resistant hose, the pressure-resistant hose can be detached readily. Provided that the lip seal 346 is functioning sufficiently, it is possible to prevent air leakage.

[0056] Now, a concrete installation procedure will be described. After connecting the indoor unit B and the outdoor unit A by means of connection pipes, a pressure-resistant hose 13 forming a connection port is coupled in order to couple the two exhaust ports to the exhaust port side of the vacuum pump. More specifically, a pressure-resistant hose 13 which is branched by means of a filter 14 is connected respectively to one-touch pipe joints 34a and 34b. Furthermore, the pressure-resistant hose 13 is also connected to the service port section 8b. Next, the handle 18 of the vacuum pump is caused to perform reciprocal movement, and when the pump has become difficult to work under the operator's own strength and the operation is halted, it can be estimated that the interior of the indoor unit B and the connection pipe 9 has reached a pressurized state of approximately 5 kg/cm^2. This judgement is sufficiently easy to make after a little experience of the installation work. Thereupon, it is possible to perform a leak inspection relating to the connection pipe work, using soapy water, or the like. After leak inspection, the interior of the indoor unit B and the connection pipe 9 are returned again to atmospheric pressure by releasing the one-touch pipe joints 34a, 34b. Next, the respective branches of the pressure-resistant hose 13 are connected to the one-touch pipe joints 36a and 36b. If the handle 18 of the vacuum pump is caused to perform reciprocal movement, the pressure can be gradually reduced, and by means of the operator reading the number of stroke movements from the display, it is possible to estimate when the interior of the indoor unit B and the connection pipe 9 has reached a sufficient negative pressure state. In other words, provided that the operator previously knows the relationship between the length of the connection pipe 9 and the number of strokes of the vacuum pump, from experience or from reference data, then he or she is able to judge a sufficient negative pressure state inside the indoor unit B and connection pipe 9, by confirming the number of strokes by means of the acceleration sensor.

[0057] Thereupon, by loosening the screw section 7a of the liquid-side two-way valve 7 and introducing refrigerant gas from the outdoor unit A, the interior of the connection pipes 9, 10 and the indoor unit B pipes are made to assume a slightly positive pressure state (approximately 0.2 kgf/cm^2). The pressure-resistant hose 13 is detached from the service port section 8b, and the screw section 7a of the liquid-side two-way valve 7 is then fully opened. Finally, the screw section 8a of the gas-side three-way valve 8 is fully opened, thereby completing the installation work relating to the installation of the air conditioner.

[0058] In the present embodiment, the internal volume of the indoor unit B piping including the indoor heat exchanger 6, and the connection pipes 9, 10 was 2.5 litres. In the vacuum pump, the internal volume of the cylinder space when the piston is at the top dead center was 250 ml (27 dia. $\times$ 440 mm), and the total internal volume from the cylinder outlet formed when the piston is at the bottom dead center, to the intake port and exhaust port non-return valves, was 1.5 ml. These figures are taken to include the port flow path space arising between the interior space of the cylinder and the cylinder wall. The cylinder internal dead space formed when the piston is at the bottom dead center was 3 ml. The relationship between V1a and V1b determined in a similar manner to the first embodiment is V1a/V1b = 57. Fig. 20 shows a concrete illustration of the V1b portion comprising the cylinder internal dead space and the total volume of the internal space from the cylinder outlet when the piston is at the bottom dead center to the intake port and exhaust port non-return valves. By adopting a structure wherein an intake port and exhaust port are embedded in the cylinder side wall at positions corresponding to the top dead center face and the bottom dead center face of the cylinder main body, in such a manner that each pair of non-return valves are directly connected, a design is achieved wherein the portion forming the dead space in the pressure-reducing mechanism is a minimum, and furthermore, by providing the non-return valves in the side wall of the cylinder, it possible to perform reciprocal movement of the piston in a state where the under face of the cylinder 15 of the vacuum pump is positioned on the ground, or the like. As a result, it is possible to improve the operability of the vacuum pump for the operator.

[0059] In this case, by following the aforementioned work procedure, it was possible to achieve 22 torr using the vacuum pump, by performing 70 stroke's of reciprocal movement of the handle. Fig. 21 shows the progress of the state of pressure reduction, in the form of the relationship between the number of strokes and the internal pressure. After 60 strokes, the pressure was 30 torr or less, and although the progress of pressure reduction was confirmed up to 80 strokes, the vacuum level attained reached a state of equilibrium at 70 strokes and did not advance further thereafter. Consequently, it can be seen that when a vacuum pump according to the present embodiment is applied to a system having an internal volume of 2.5 litres, then 70 strokes is the general standard for the attained vacuum level. To obtain an accurate figure, the vacuum level was monitored separately using a digital pressure sensor.

[0060] In the present embodiment, by initially using the exhaust port side of the vacuum pump having a readily detachable connection device, as a pressurizing pump, it is possible to perform satisfactory leakage inspection accompanying installation work. Thereupon, by attaching pressure-resistant hoses to the intake port side, it is possible to use the pump as a conventional pressure reducing vacuum pump. In this way, by simply changing the installation of the pressure-resistant hose section forming a coupling section for the respective exhaust ports or intake ports, between the exhaust port side or the intake port side, it is possible to use separate active functions of the vacuum pump. Moreover, since only one pressure-resistant hose is required, it is possible to achieve a system that is more compact than that described in the second embodiment.

[0061] In the present embodiment, one-touch joints as illustrated in Fig. 19 were used for the readily attachable and detachable connection devices, but the readily attachable and detachable connection devices which can be used in the present invention are not limited to this. In addition to this, it is also possible to use a tube coupler, or the like, which does not comprise a self-sealing mechanism.

[0062] Installation was completed according to the procedures of the first, second and third embodiments, for an air conditioner using R410A as the refrigerant and an ester oil as the cooling unit oil, and reliability testing was carried out for 5000 hours, by setting the output temperature of the compressor to an overload condition of 115°C, and setting both the indoor unit and the outdoor unit to high-temperature cooling conditions of 40°C. No particular irregularities were observed as a result of this testing.

[0063] In the pressure reducing mechanism of a vacuum pump according to the present invention, the interior of the cylinder can be maintained constantly at a reduced pressure state by operating the piston, but the cylinder internal dead space formed when the piston is at the bottom dead center and the spatial volume from the cylinder outlet to the non-return valves on the intake port side and the exhaust port side create a dead space. The cylinder internal dead space comprises the small gap formed when the piston meets the plane of the bottom dead center of the cylinder, and the intake port and exhaust port flow paths formed inside the cylinder wall. Therefore, in terms of the attained vacuum level, the relationship between via, which is the total volume of the internal volume of the cylinder space, the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, and V1b which is the total of the cylinder internal dead-space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, is very important. Moreover, if the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, is clearly greater than the aforementioned dead space, then at the top dead center of the piston, rather than functioning as a vacuum pump, the system conversely reduces the negative pressure level, and therefore, desirably, the dead space formed at the top dead center and the bottom dead center should be approximately equal. In other words, the reason why the dead space formed at the bottom dead center of the piston is a more crucial element in the level of vacuum attained than that formed at the top dead center, is because the volume of the cylinder space is reduced by the volume occupied by the supporting shaft.

[0064] It was observed that, if a design is adopted whereby the relationship between V1a, which is the total volume of the internal volume of the cylinder space formed when the piston is at the top dead center, the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, and V1b which is the total of the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, is $V1a/V1b \geq 40$, and if the leakage at the non-return valves is controlled to some extent, then it is possible to achieve a pressure of 30 torr or less, satisfactorily, by performing reciprocal movement of the handle of the vacuum pump. In view of the long-term reliability of the refrigeration cycle, even if there is no leaking of the airtightness in the design, a relationship of $V1a/V1b \geq 40$ is required. If the relationship V1a/V1b is too large, then although there will be no impediment to the level of vacuum attained, the vacuum pump will be become bulky and heavy and portability of the device will be impaired. Moreover, the operation for performing reciprocal movement of the handle will be impaired.

[0065] It can be seen that the number of strokes of the vacuum pump required in the installation of an air conditioner according to the present invention is determined by the relationship between the internal volume of the piping of the indoor unit and the connection pipes, and the internal volume of the cylinder space. If the internal volume of the indoor unit piping and the connection pipes is 1.5 litres, and the internal volume of the cylinder space is 150 or 250 ml, then a state of equilibrium is reached after performing approximately 40 strokes of reciprocal movement, and if the internal volume of the indoor unit and the connection pipes is 2.5 litres, and the internal volume of the cylinder space is 250 ml, then a state of equilibrium is reached after performing approximately 70 strokes of reciprocal movement. Therefore, by establishing these relationships in a database, it is possible for an operator to estimate and deduce the general state of the vacuum level attained, by controlling the number of strokes of the vacuum pump.

[0066] The shaft seal used in the present invention is an elastomer with a hardness of approximately 60 - 90 in a spring-type hardness test (type A). More specifically, it is also suitable to use CR, EPDM, NBR, or the like, in addition to HNBR. Moreover, in the present embodiment, the shaft seals had a dual O-ring structure and formed a contact with the supporting shaft at two points, and in this case, the contact point on the outer side has the action of removing dust adhering to the supporting shaft when the supporting shaft is outside the cylinder. Moreover, even in the case of sudden movements of the supporting shaft, since there are two or more contact points with the seals, then even if an air leakage occurs on one side, this can be sealed off by the contact point on the other side.

[0067] As a non-return valve structure for the exhaust port side used in the present invention, in addition to the construction described in the embodiments, it is also possible to use an opening and closing valve structure by moving a movable member consisting of a small and lightweight metal ball inside a pipe. For the resin, in addition to nylon, it is also possible to fluorine based resins, such as PFA, PVDF, or the like, or PPS. In the non-return valves used in the present invention, the minimum operating pressure differential is more important on the intake port side than on the exhaust port side. In other words, the exhaust port side gradually moves towards a greater pressure differential as the vacuum pump is operated, but on the intake port side, conversely, the pressure differential between the indoor unit and connection pipes and the interior of the cylinder becomes smaller. Therefore, it is desirable that the non-return valves on the intake port side should close and seal even at a small pressure differential, and more specifically, that the minimum operating pressure differential should be 10 torr or less. More desirably, the fluid leakage volume at a pressure differential of 1 kgf/cm^2 should be 1 ml/min or less. This is because operability is impaired, in such a manner that as soon as the operator stops operating the handle of the vacuum pump, the vacuum level attained thus far drops suddenly. More specifically, it is desirable that the non-return valve shuts off the flow path by pressing a resin film against a valve seating member, by means of a compression coil spring such as that used in the present embodiment. In this case, the spring constant of the compression coil spring was 0.01 - 0.04 N/mm. If the spring constant is less than 0.01 N/mm, then depending on the direction of the vacuum pump during operation, the compression coil spring may be affected by gravity and may fail to function satisfactorily.

[0068] In the present embodiment, the vacuum pump was operated using a manual handle, but it is also possible to adopt a mechanical construction, wherein a pedal is provided and the operation of the piston is synchronized to the pedal. Taking the global environment into consideration, the fact that a satisfactory level of vacuum can be obtained by using a handle or a pedal, as opposed to an electric pump as in the prior art, brings significant benefits in terms of reducing the environment load when installing an air conditioner.

(Fourth embodiment)

[0069] The construction of the refrigerating cycle illustrating an air conditioner according to the fourth embodiment is the same as that shown in Fig. 1, which is a refrigerating cycle diagram relating to the first embodiment.

[0070] In the separate type air conditioner of the present embodiment the outdoor unit A and the indoor unit B are connected in a ring configuration by connection pipes 9, 10, a quantity of refrigerant gas required in order to display a prescribed cooling effect is previously filled into the pipes of the outdoor unit A, and a screw section 7a of a liquid-side two-way valve 7 and a screw section 8a of a gas-side three-way valve 8 are closed. After installation for connecting the indoor unit B to the outdoor unit A by means of connection pipes 9, 10, the vacuum pump P according to the present invention as illustrated in Fig. 16 is used to perform a vacuum process in order to reduce the oxygen in air, which must be evacuated from the respective interiors of the indoor unit B and the connection pipes 9, 10, from the viewpoint of the reliability of the refrigerating cycle, to a satisfactory level.

[0071] In other words, the connection pipes 9, 10 connected to the indoor unit B are connected to the liquid-side two-way valve 7 and gas-side three-way valve 8 of the outdoor unit A, whereupon the vacuum pump P is coupled to a service port section 8b of the gas-side three-way valve 8 of the outdoor unit A by means of a pressure-resistant hose 13 which forms a coupling port section for coupling the two exhaust ports 31 into one. The pressure-resistant hose 13 is provided with a filter section 14 at an intermediate position therein.

[0072] Fig. 16 is a schematic diagram which gives a detailed illustration of the construction of the vacuum pump P and the connection path of the pressure-resistant hose according to the present invention. As the handle 18 is operated upwards and downwards and travels in either the a direction or the b direction, the pressure difference between the two chambers gradually declines from the initial differential, and the intake port side 31 is set to a negative pressure state.

[0073] An acceleration sensor 181 and primary electric cell 182 as illustrated in Fig. 3 and Fig. 4 are built into the handle 18 to serve as a sensor which counts (detects) each stroke of the piston 27 in the a direction and b direction, and allows the operator to estimate the negative pressure state on the intake port 31 side. Furthermore, a display 183 is provided on the upper surface of the handle 18 in such a manner that the negative pressure state on the intake port 31 side can be displayed on the display 183 on the basis of detection signals from the acceleration sensor 181. Moreover, the intake ports 31 and exhaust ports 30 are disposed respectively in positions bordering the top dead center and bottom dead center of the two chambers 26a, 26b of the cylinder 15, and the total weight of the vacuum pump P is -approximately 1 kg.

[0074] Fig. 3 is a schematic view showing the principal part of the construction of the handle 18, and Fig. 4 is a schematic constitutional view of the acceleration sensor 181. The acceleration sensor 181 is composed of a thinly formed sensor section 41 consisting of a silicon semiconductor 40, and a weight section 42 having a large surface area. In the operation of the acceleration sensor 181, when the piston 27 arrives at the top dead center or the bottom dead center of the cylinder 15 due to the manual operation thereof, it impacts with the wall of the cylinder 15 and the stroke movement of the handle 18 halts, at which time an acceleration G is generated by this impact and the weight section 42 receives this acceleration and the sensor section 41 is caused to distort.

[0075] This distortion in turn causes a change in the electrical resistance of the diffused layer 43 formed on the top of the sensor section 41. In other words, a construction is adopted wherein the acceleration sensor 181 detects the stress caused by distortion of the sensor section 41 due to the acceleration G, by means of a piezo effect of the sensor section 41, converting this into a voltage output by means of a bridge circuit, and if this output exceeds a certain prescribed value, then one stroke can be counted. In the diagram, 44 is an electrode, and 45 is a case comprising a base plate onto which the electrode 44 is fixed.

[0076] Fig. 22 is a flowchart of the procedure whereby the acceleration sensor 181 counts the reciprocal movements of the piston 27 and the estimated negative pressure state on the intake port 31 side is displayed. A signal output based on the piezo effect in the sensor section 41 is amplified by the amplifying section 50 and after unwanted components have been removed from the output by a filter section 51, the signal is passed through an A/D converter 52 for converting the output into a digital signal, whereupon the negative pressure state at the intake port 31 side is calculated by an operating unit 53, and finally, the count is displayed on a display section 183.

[0077] Thereupon, the operation of the vacuum pump P is described. Firstly, if the handle 18 is pulled in the a direction (towards the top dead center), then the air inside the connection pipe 9, the indoor unit B and the connection pipe 19 is drawn in from the service port section 8b, via the pressure-resistant hose 13 and filter section 14, and into chamber 26b inside the cylinder 15, by means of the intake non-return valve 31b of the intake port 31, whilst conversely, the air in the chamber 26a inside the cylinder 15 is exhausted into the atmosphere via the exhaust side non-return valve 30a.

[0078] Thereupon, when the handle 18 is pushed in the b direction (towards the bottom dead center), the air inside the connection pipe 9, the indoor unit and the connection pipe 10 is drawn in from the service port section 8b, via the pressure-resistant hose 13 and filter section 14, and into the chamber 26b inside the cylinder 15 by means of the intake side non-return valve 31a of the intake port, whilst conversely, the air in the chamber 26a inside the cylinder 15 is exhausted into the atmosphere via the exhaust non-return valve 30b of the exhaust port 30.

[0079] Thereupon, the reciprocal movement of the handle 18 is repeated in such a manner that the handle 18 is pulled again in the a direction (towards to the top dead center), and the piston 17 performs synchronized movement. In this case, the interior of the cylinder 15 constantly reduces in pressure, whether the piston moves in direction a or direction b, whilst the four non-return valves are switched alternately, and ultimately, a sufficient negative pressure state can be achieved. In strict terms, it is possible to continue the pressure reducing mechanism, as long as it is possible to generate a pressure differential between the interior of the pressure-resistant hose 13 and the chambers 26a or 26b inside the cylinder when performing reciprocal movement of the handle 18. Therefore, the non-return valves 31a and 31b provided at the intake ports 31 are required to have a low minimum operating pressure differential. In the case of a non-return valve as in the present embodiment, the factor determining this minimum operating pressure differential is the spring constant of the compression coil spring member 203.

[0080] when the vacuum pump P performs this series of reciprocal movements, the operator causes the piston 27 to impact respectively with the inner wall of the cylinder 15 at the top dead center and the bottom dead center, respectively, and in this case, the operator is able to cause an acceleration of 1 to 5 G. This acceleration G is transmitted to the handle 18 via the supporting shaft 17. Consequently, the acceleration sensor 181 detects the generated acceleration G and is able to display the number of strokes of reciprocal movement, on the display 183.

[0081] When it is used initially, the vacuum pump P generates a large pressure differential between the chambers 26a and 26b inside the cylinder 15, but as the piston 27 performs reciprocal movement, this pressure differential state is gradually attenuated. In this case, the shaft seals 21a, 21b provide a satisfactory guarantee of the pressure differential state between the negative pressure (30 torr or less) inside the cylinder 15 and the external atmosphere (760 torr), and in order to prevent leaking of airtightness, as far as possible, the seals are formed by dual O-rings. By adopting a dual structure in this way, it is possible to prevent foreign material which is liable to adhere to and infiltrate inside the seal section when the supporting shaft is operated. Furthermore, the shaft seal 22 provides a sufficient guarantee of a differential pressure state created when the piston 27 is made to perform reciprocal movement, by means of a single O-ring.

[0082] A specific installation procedure for an air conditioner is now described. Connection pipes 9 and 10 are connected to the indoor unit B and further connected to the liquid-side two-way valve 7 and gas-side three-way valve 8 of the outdoor unit A, whereupon the vacuum pump P is coupled by the pressure-resistant hose 13 to the service port section 8b of the gas-side three-way valve 8 of the outdoor unit A. In this way, by attaching the pressure-resistant hose 13 of the vacuum pump P to the service port section 8b, the interior of the pressure-resistant hose 13 becomes coupled to the indoor unit B and the interior of the connection pipes 9, 10.

[0083] Thereupon, the handle 18 of the vacuum pump P is caused to perform reciprocal movement, and the operator is able to estimate and determine that the interior of the indoor unit B and the connection pipe 9 has reached a sufficient negative pressure state by reading out the number of strokes of reciprocal movement performed from the display 183. Then, the screw section 7a of the liquid-side two-way valve 7 is loosened slightly, and refrigerant gas filled into the outdoor unit is introduced, thereby setting the interior of the connection pipes 9, 10 and the indoor unit side piping to a slight positive pressure state (approximately 0.2 kgf/cm^2). Subsequently, the pressure-resistant hose 13 is detached from the service port section 8b and the service port section 8b is automatically closed. The screw section 7a of the liquid-side two-way valve 7 is rotated by a further 1/4 turn, and a positive pressure state (approximately 3 - 6 kgf/cm^2) is applied again to recheck for leaking in the connection pipe regions. Finally, the screw section 7a of the liquid-side two-way valve 7 is opened completely, and the screw section 8a of the gas-side three-way valve 8 is opened fully, whereby the installation tasks for the installation of the air conditioner are completed.

[0084] In the present embodiment, the internal volume of the indoor unit piping, including the indoor heat exchanger 6, and the connection pipes 9, 10, was 2.5 litres. In the vacuum pump, the internal volume of the cylinder space when the piston is at the top dead center was 250 ml (27 mm diameter × 440 mm), and the total internal volume from the cylinder outlet at the exhaust port 30 formed when the piston is at the bottom dead center, to the two intake port side and exhaust port side non-return valves, was 1.5 ml. These figures are taken to include the port flow path space arising in the main wall of the cylinder 15.

[0085] The cylinder internal dead space formed when the piston 27 is at the bottom dead center was 3 ml. Taking Via to be the total volume of the internal volume of the cylinder space formed when the piston 27 is at the top dead center, the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, and taking V1b to be the total volume of the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, then the relationship between V1a and V1b is V1a/V1b = 57.

[0086] Fig. 20 is a concrete illustration of the V1b region comprising the cylinder internal dead space and the total internal volume of the space from the cylinder outlet when the piston 27 is at the bottom dead center to the two non-return valves on the intake port side and the exhaust port side. By adopting a system structure wherein intake ports 31 and exhaust ports 30 are embedded in the cylinder side wall at positions corresponding to the top dead center and the bottom dead center of the cylinder main body, in such a manner that the pair of exhaust non-return valves 30a, 30b and the pair of intake non-return valves 31a, 31b are directly, connected, respectively, a design is achieved wherein the portion forming the dead space in the pressure-reducing mechanism is a minimum, and furthermore, it possible to perform reciprocal movement of the piston 27 in a state where the under face of the cylinder 15 of the vacuum pump P is placed on the ground, or the like. As a result, it is possible to improve the operability of the vacuum pump for the operator, and it is also possible for the pump to handled in a normal way, without the need for special caution.

[0087] The vacuum pump P was able to achieve 22 torr by performing the operation according to the aforementioned procedure, and by performing 70 strokes of reciprocal movement of the handle 18. Fig. 21 shows the progress of the state of pressure reduction, in the form of the relationship between the number of strokes on the horizontal axis and the internal pressure on the vertical axis. The progress of pressure reduction was confirmed up to 80 strokes, but the vacuum level attained reached a state of equilibrium at 70 strokes and did not advance further thereafter. Consequently, it can be seen that when a vacuum pump according to the present embodiment is applied to a system having an internal volume of 2.5 litres, then 70 strokes is the general standard for the attained vacuum level.

[0088] The accurate figure of the vacuum level was monitored separately using a digital pressure sensor. The number of strokes can be counted by the operator is his or her head, but if the number of strokes can be counted by an acceleration sensor as in the present embodiment and displayed in a reliable manner, then this is very convenient in operational terms. For example, it makes it possible to prevent situations where someone starts to speak to the operator whilst he or she is counting, thereby making the operator lose count.

[0089] In the present embodiment, the acceleration sensor 181 is provided inside the handle 18, but the invention is not limited to this. In other words, since the piston 27 which impacts with the cylinder 15 is fixed to the supporting shaft 17, and the supporting shaft 17is fixed to the handle 18, then it is possible to achieve the initial object by providing the sensor on either the piston, the supporting shaft or the handle.

(Fifth embodiment)

[0090] Fig. 23 is a schematic constitutional view showing an acceleration sensor provided on the handle of a vacuum pump according to a fifth embodiment of the present invention. The present embodiment uses a distortion resistance mechanism for the acceleration sensor method, and with the exception of this, the construction of the vacuum pump is the same as that of the fourth embodiment, and hence detailed description thereof is omitted here and only the different parts are explained.

[0091] A construction is adopted wherein a supporting pillar 132 is provided inside a case 131, and a weight 133 is provided at the front end of the supporting pillar 132 and is held by an arm 134 in a cantilever fashion. Components forming strain gauges 135 are attached to the front and rear sides of the surface of the arm 134. Fig. 24 shows the construction of this strain gauge 135. An aluminium metal foil 152 of 3 μm thickness is adhered onto a polyimide insulating film 151, and after patterning by hot etching in order to obtain a required shape and resistance values, it is covered with a protective film. Numerals 153 denote lead wires.

[0092] Fig. 25 is a diagram of a detection circuit using a strain gauge of the acceleration sensor in a vacuum pump according to the present invention. Taking ΔR to be the change in resistance when a load (acceleration G) is applied to the free end of the cantilever arm 134, and taking Va and Vb to be the voltages at point a and point b of the bridge circuit, and Vo to be the output voltage, the respective voltage are expressed by the following equations. The signal:output is then amplified and processed, and a count is displayed on the display in a similar method to that in the fourth embodiment.

$$Va = V \cdot R1 / (R1 + RG1 + \Delta R)$$

$$Vb = V \cdot R2 / (R2 + RG2 + \Delta R)$$

$$Vo = 1Va - Vb1$$

[0093] In the present embodiment, the internal volume of the indoor unit piping, including the indoor heat exchanger 6, and the connection pipes 9, 10, was 1.5 litres. In the vacuum pump, the internal volume of the cylinder space when the piston 27 was at the top dead center was 200 ml (27 mm diameter × 350 mm), the total internal volume of the space from the cylinder outlet formed when the piston is at the bottom dead center to the two non-return valves on the intake port side and exhaust port side was 1.5 ml, and the cylinder internal dead space formed when the piston is at the bottom dead center was 3 ml. This is taken to include the port flow path space arising in the main wall of the cylinder 13. If the relationship between the total internal volume V1a and the total internal volume V1b is determined, then V1a/V1b = 45, similarly to the fourth embodiment.

[0094] In the present embodiment, an installation operation for an air conditioner was carried out and by performing 40 strokes of reciprocal movement of the handle of the vacuum pump P, a pressure of 28 torr was reached. Fig. 26 illustrates the state of progress of the pressure reduction, in the form of a relationship between the number of strokes and the internal pressure. The progress of the pressure reduction was checked until 50 strokes had been performed, although the pressure level attained reached a state of equilibrium after 40 strokes and did not progress further thereafter. Consequently, it can be seen that when a vacuum pump according to the present embodiment is applied to a system having an internal volume of 1.5 litres, then 40 strokes is the general standard for the attained vacuum level. To obtain an accurate figure, the vacuum level was monitored separately using a digital pressure sensor.

[0095] In the present embodiment, an electronic distortion resistance mechanism was used for the acceleration sensor, but it would also be possible use a piezoelectric mechanism or electrostatic capacitance mechanism.

(Sixth embodiment)

[0096] Fig. 27 is a schematic diagram wherein a counter containing an acceleration sensor is provided in the handle of a vacuum pump according to the present invention, and Fig. 28 is a schematic diagram for further illustrating the mechanism of the acceleration sensor. The present embodiment also uses a mechanical system for the acceleration sensor, and the remaining construction of the vacuum pump is similar to that in the fourth embodiment and detailed description thereof is omitted, only the different parts being described here.

[0097] Here, a construction is adopted wherein a counter 210 containing an acceleration sensor is detachably attached to a portion of the handle 18 of a vacuum pump, by means of a hook and loop fastener 220. The internal mechanism of the counter 210 is designed in such a manner that a pendulum 212 can move in an upward and downward direction about a fulcrum 211, as illustrated in Fig. 28. A magnet 213 is attached to the front end portion of the pendulum 212. Moreover, the upward and downward motion of the pendulum 212 can be controlled by the spring force of a wire spring 214.

[0098] One end of the wire spring 214 is fixed to the main body of the counter 210 by means of a fixing section 215, and the other end thereof is fixed to the pendulum 212 by means of a fixing section 216. Moreover, a reed switch 217 is provided in a position corresponding to that of the magnet 213 when the pendulum 212 has reached its lowermost position. In addition, a display and a primary electric cell forming a power source are provided in the counter 210. A reed switch 217 comprises a pair of reeds made from magnetic material, which are sealed inside a glass tube with an inert gas. The switch performs a repeating on and off operation under the action of an external magnetic field.

[0099] In the aforementioned embodiment, each time the piston of the vacuum pump is caused to perform a downward stroke and reaches the bottom dead center, impacting with the inner wall of the cylinder, the pendulum 212 also reaches its lowermost position, once, the reed switch 217 is switched on by the magnet 213, and thus the stroke is counted. Moreover, each time that the piston is caused to perform an upward stroke and reaches the top dead center, impacting with the inner wall of the cylinder, the pendulum 212 also reaches its lowermost position, once, and the reed switch 217 is switched on by the magnet 213, and hence the stroke is counted. By optimising the diameter and length of the wire spring 214 in accordance with the impact acceleration G accompanying the stroke movement of the piston, it was possible to prevent a state where double counting occurs or where a count is skipped.

(Seventh embodiment)

[0100] Fig. 29 is a schematic diagram showing the mechanism of the acceleration sensor of a vacuum pump according to a seventh embodiment of the present invention, and Fig. 30 is a schematic diagram for further describing the mechanism of the acceleration sensor. This embodiment also uses a mechanical system for the method of the acceleration sensor, and the remaining construction of the vacuum pump is the same as that in the fourth embodiment, and hence detailed description thereof is omitted and only the different parts are described here.

[0101] In the present embodiment, similarly to the fifth embodiment, a counter 230 having a built-in acceleration sensor is detachably attached to a portion of the handle 18 of a vacuum pump, by means of a velcro fastener 240. As shown in Fig. 30, in the internal mechanism of the counter 230, a rotatable arm 232 is installed in such a manner that it can move upwards and downwards about a rotating axle 231. One end of a wire spring 233 is fixed by means a fixing section 234 to the main body of the counter 230 and the other end of the spring is fixed by a fixing section 2321 to the arm 232, in such a manner that the arm 232 is caused to rock in an upward direction.

[0102] An upper contact switch 235 and a lower contact switch 236 of a contact pressing type are provided in order to generate an ON state of an electrical circuit when the arm 232 reaches a lower position. The upper contact switch 235 is connected to a lead wire via a terminal section 2351, and the end portion thereof is bent into an approximate right-angled shape. Furthermore, a lead wire is attached to a terminal section 2361 of the lower contact switch 236. An upper stopper 237 is provided in order to restrict the position of the arm 232 in the upwards direction, and a lower stopper 238 is provided in order to restrict the position thereof in the downward direction. Besides this, a display and a primary cell forming an electrical power source are provided in the counter 230.

[0103] In the embodiment described above, when the piston of the vacuum pump performs a downward stroke movement and reaches the bottom dead center, impacting with .the internal wall of the cylinder, the arm 232 also reaches the lower position, once, thereby causing the upper contact switch 235 to contact with the lower contact switch 236, switching the circuit on and counting the stroke movement. Furthermore, when the piston performs an upward stroke movement and reaches the top dead center, impacting with the internal wall of the cylinder, the arm 232 also reaches the lower position, once, thereby causing the upper contact switch 235 to contact with the lower contact switch 236, switching the circuit on and counting the stroke movement. By optimising the diameter and length of the wire spring 233 in accordance with the impact acceleration G accompanying the stroke movement of the piston, it was possible to prevent a state where double counting occurs or where a count is skipped.

(Eighth embodiment)

[0104] Fig. 31 is a schematic diagram showing the mechanism of the acceleration sensor of a vacuum pump according to an eighth embodiment of the present invention, and Fig. 32 is a schematic diagram for further describing the mechanism of the acceleration sensor. This embodiment also uses a mechanical system for the method of the acceleration sensor, and the remaining construction of the vacuum pump is the same as that in the fourth embodiment, and hence detailed description thereof is omitted and only the different parts are described here.

[0105] In the present embodiment, similarly to the fifth embodiment, a counter 250 containing a built-in acceleration sensor is detachably attached to a portion of the handle 18 of a vacuum pump, by means of a velcro fastener 250. As shown in Fig. 32, in the internal mechanism of the counter 250, a rotatable arm 252 is installed in such a manner that it can move upwards and downwards.about a rotating axle 251, and a circular metal component 2521 is provided on the front end portion of the arm.

[0106] One end of a wire spring 253 is fixed by means a fixing section 254 to the main body of the counter 250 and the other end of the spring is fixed by a fixing section 2522 to the arm 252, in such a manner that the arm 252 is caused to rock in an upward direction. A right-hand contact switch 255 and a left-hand contact switch 256 forming a contact conducting type are provided in order to generate an ON state of an electrical circuit by means of the circular metal component 2521 at the front end of the arm, when the arm 252 reaches a lower position. An upper stopper 257 is provided in order to restrict the position of the arm 252 in the upwards direction, and a lower stopper 258 is provided in order to restrict the position thereof in the downward direction. Besides this, a display and a primary cell forming an electrical power source are provided in the counter 250.

[0107] In the embodiment described above, when the piston of the vacuum pump performs a downward stroke movement and reaches the bottom dead center, impacting with the internal wall of the cylinder, the arm 252 also reaches the lower position, once, whereby the right-hand contact switch 255 and the left-hand contact switch 256 are caused to assume a state of electrical connection by means of the circular metal component 2521, thus switching the circuit on and counting the stroke movement. Furthermore, when the piston performs an upward stroke movement and reaches the top dead center, impacting with the internal wall of the cylinder, the arm 252 also reaches the lower position, once, whereby the right-hand contact switch 255 and the left-hand contact switch 256 are caused to assume a state of electrical connection by means of the circular metal component 2521, thus switching the circuit on and counting the stroke movement. By optimising the diameter and length of the wire spring 253 in accordance with the impact acceleration G accompanying the stroke movement of the piston, it was possible to prevent a state where double counting occurs or where a count is skipped.

[0108] Installation was completed according to the procedures of the aforementioned embodiments, for an air conditioner using R410A as the refrigerant and an ester oil as the cooling unit oil, and reliability testing was carried out for 5000 hours, by setting the output temperature of the compressor to an overload condition of 115°C, and setting both the indoor unit and the outdoor unit to high-temperature cooling conditions of 40°C. No particular irregularities were observed as a result of this testing.

[0109] In the pressure reducing mechanism of a vacuum pump P according to the present invention, the interior of the cylinder 15 can be maintained constantly at a reduced pressure state by operating the piston 27, but the cylinder internal dead space formed when the piston is at the bottom dead center and the spatial volume from the cylinder outlet to the two non-return valves on the intake port side and the exhaust port side create a dead space. The cylinder internal dead space comprises the small gap formed when the piston meets the plane of the bottom dead center of the cylinder, and the intake port and exhaust port flow paths formed inside the cylinder wall.

[0110] Therefore, with regard to the attained vacuum level, the relationship between V1a, which is the total volume of the internal volume of the cylinder space, the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, and V1b which is the total of the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, is very important.

[0111] Moreover, if the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, is clearly greater than the aforementioned dead space, then at the top dead center of the piston, rather than functioning as a vacuum pump, the system conversely reduces the negative pressure level, and therefore, desirably, the dead space formed at the top dead center and the bottom dead centers should be approximately equal. In other words, the reason why the dead space formed at the bottom dead center of the piston is a more crucial element in the level of vacuum attained than that formed at the top dead center, is because the spatial volume of the cylinder 15 is reduced by the volume occupied by the supporting shaft 17.

[0112] It was observed that, if a design is adopted whereby the relationship between V1a, which is the total volume of the internal volume of the cylinder space formed when the piston is at the top dead center, the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, and V1b which is the total of the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to the two non-return valves of the intake ports and exhaust ports, is $V1a/V1b \geq 40$, and if the leakage at the non-return valves is controlled to some extent, then it is possible to achieve a pressure of 30 torr or less, satisfactorily, by performing reciprocal movement of the handle of the vacuum pump P.

[0113] In view of the long-term reliability of the refrigeration cycle, even if there is no leaking of the airtightness in the design, a relationship of $V1a/V1b \geq 40$ is required. If the relationship V1a/V1b is too large, then although there will be no impediment to the level of vacuum attained, the vacuum pump will be become bulky and heavy and portability of the device will be impaired. Moreover, the operation for performing reciprocal movement of the handle 18 will be impaired.

[0114] It can be seen that the number of strokes of the vacuum pump P required in the installation of an air conditioner according to the present invention is determined by the relationship between the internal volume of the piping of the indoor unit and the connection pipes 9, 10, and the internal volume of the cylinder 15 space. If the internal volume of the indoor unit piping and the connection pipes 9, 10 is 1.5 litres, and the internal volume of the cylinder 15 space is 200 ml, then a state of equilibrium is reached after performing approximately 40 strokes of reciprocal movement, and if the internal volume of the indoor unit and the connection pipes 9, 10 is 2.5 litres, and the internal volume of the cylinder 15 space is 250 ml, then a state of equilibrium is reached after performing approximately 70 strokes of reciprocal movement. Therefore, by establishing these relationships in a database, it is possible for an operator to estimate and deduce the general state of the vacuum level attained, by controlling the number of strokes of the vacuum pump by means of the sensor according to the present invention.

[0115] The shaft seal used in the present invention is an elastomer with a hardness of approximately 60 - 90 in a spring-type hardness test (type A). More specifically, it is also suitable to use CR, EPDM, NBR, or the like, in addition to HNBR. Moreover, in the present embodiment, the shaft seals 21a and 21b had a dual O-ring structure and formed a contact with the supporting shaft 17 at two points, and in this case, the contact point on the outer side has the action of removing dust adhering to the supporting shaft when the supporting shaft is outside the cylinder. Moreover, even in the case of sudden movements of the supporting shaft, since there are two or more contact points with the seals, then even if an air leakage occurs on one side, this can be sealed off by the contact point on the other side.

[0116] As a non-return valve structure for the exhaust ports 30 used in the present invention, in addition to the construction described in the embodiments, it is also possible to use an opening and closing valve structure by moving a movable member consisting of a small and lightweight metal ball inside a pipe. For the resin, in addition to nylon, it is also possible to fluorine based resins, such as PFA, PVDF, or the like, or PPS. In the non-return valves used in the present invention, the minimum operating pressure differential is more important on the intake port 31 side than on the exhaust port 30 side. In other words, the exhaust port 30 side gradually moves towards a greater pressure differential as the vacuum pump P is operated, but on the intake port 31 side, conversely, the pressure differential between the indoor unit and connection pipes 9, 10 and the interior of the cylinder 15 becomes smaller.

[0117] Therefore, it is desirable that the non-return valves on the intake port side should close and seal even at a small pressure differential, and more specifically, that the minimum operating pressure differential should be 10 torr or less. More desirably, the fluid leakage volume at a pressure differential of 1 kgf/cm^2 should be 1 ml/min or less. This is because operability is impaired, in such a manner that as soon as the operator stops operating the handle of the vacuum pump, the vacuum level attained thus far drops suddenly. More specifically, it is desirable that the non-return valve shuts off the flow path by pressing a resin film against a valve seating member, by means of a compression coil spring such as that used in the present embodiment. In this case, the spring constant of the compression coil spring was 0.01 - 0.04 N/mm. If the spring constant is 0.01 N/mm or less, then depending on the direction of the vacuum pump during operation, the compression coil spring may be affected by gravity and may fail to function satisfactorily.

[0118] In the present embodiment, the vacuum pump was operated using a manual handle, but it is also possible to adopt a mechanical construction, wherein a pedal is provided and the operation of the piston 27 is synchronized to the pedal. Taking the global environment into consideration, the fact that a satisfactory level of vacuum can be obtained by using a handle or a pedal, as opposed to an electric pump as in the prior art, brings significant benefits in terms of reducing the environment load when installing an air conditioner.

(Ninth embodiment)

[0119] Fig. 33 is a diagram of the construction of a refrigerating cycle of an air conditioner in a ninth embodiment which is installed using a vacuum pump according to the present invention and it is virtually the same as the construction of the first embodiment illustrated in Fig. 1.

[0120] Fig. 34 is a schematic diagram for giving a detailed description of the construction of the vacuum pump P and the connection path of the pressure-resistant hose 13 according to the present invention. The structure of the vacuum pump P is such that an aluminium piston 28 is disposed inside the main body of an aluminium cylinder 15 in such a manner that it divides the interior of the cylinder 15 into an upper chamber 15a and a lower chamber 15b, the piston 28 being coupled via a stainless steel supporting shaft 17 to an aluminium handle 18.

[0121] An acceleration sensor 181 and a primary electric cell 182 as illustrated in Fig. 3 and Fig. 4 are built into the handle 18, and a display 183 is provided on the surface of the upper portion of the handle 18, in such a manner that a signal from the acceleration sensor 181, which detects acceleration G caused by the impact of the piston 16 against the cylinder 15 due to upward and downward movement thereof, is displayed on the display 183, thereby allowing the vacuum level of the vacuum pump P to be estimated. Furthermore, an exhaust port 30 having a non-return valve 30a and an intake port 31 having a non-return valve 31a are provided in the main wall of the cylinder 15, at positions corresponding to the top dead center of the piston 28. The total weight of the main body of the vacuum pump is approximately 1 kg.

[0122] Fig. 3 is a schematic view showing the principal part of the construction of the handle 18, and Fig. 4 is a schematic constitutional view of the acceleration sensor

181. The acceleration sensor 181 is composed of a thinly formed sensor section 41 made from a silicon semiconductor 40, and a weight section 42 having a large surface area. In the operation of the acceleration sensor 181, when the piston 28 arrives at the top dead center or the bottom dead center of the cylinder 15 due to the manual operation thereof, it impacts with the wall of the cylinder 15 and the stroke movement of the handle 18 halts, at which time an acceleration G is generated by this impact and the weight section 42 receives this acceleration and the sensor section 41 is caused to distort.

[0123] This distortion in turn causes a change in the electrical resistance of a diffused layer 43 formed on the top of the sensor section 41. In other words, a construction is adopted wherein the acceleration sensor 181 detects the stress caused by distortion of the sensor section 41 due to the acceleration G, by means of a piezo effect of the sensor section 41, converting this into a voltage output by means of a bridge circuit, and if this output exceeds a certain prescribed value, then one stroke can be counted. In the diagram, 44 is an electrode, and 45 is a case comprising a base plate onto which the electrode 44 is fixed.

[0124] The flowchart of the procedure until the acceleration sensor of the vacuum pump displays a count display is similar to that shown in Fig. 22 corresponding to the fourth embodiment.

[0125] Fig. 5 is a schematic diagram of a non-return valve 30a provided at the exhaust port 30 and Fig. 6 is a sectional view along line A - A' in Fig. 5. The vacuum pump P is composed in such a manner that when the piston 28 moves inside the cylinder 15, the non-return valves 30a, 31a are directly coupled to the main wall of the cylinder 15 at the top dead center of the piston 28, and an open port 37 is provided in the main wall of the cylinder 15 at the bottom dead center of the piston 28. An air filter 38 is provided at the front end of the open port 37. The non-return valve 30 at the exhaust port has the structure shown in Fig. 5 and Fig. 6, whilst the non-return valve 31a at the intake port has the structure shown in Fig. 7.

[0126] The copper tube 191 of the non-return valve 30a is processed with roll grooves at two points, and a brass valve seating member 192 is fixed in groove section 191a. A nylon valve member 193 impacts with the valve seating member 192, and the movement thereof is halted by a contact face with the valve seating member 192 in a section having an oblique face. Moreover, in the opposite direction, the movement of the valve member 193 is halted by the groove section 191b. Therefore, a non-return valve structure is obtained wherein air only flows in the direction of the arrow.

[0127] The copper tube 201 of the non-return valve 31a is processed with roll grooves at two points, and a brass valve seating member 202 is fixed to the groove section 201a. A compression coil spring member 203 is joined to a film plate 204 and under the force of the compression coil spring, the nylon film plate 204 is caused to impact with a brass valve seating member 205, the fluid path being sealed by the contact between the respective faces of the seating member 205 and the film plate 202, thereby achieving a non-return valve structure wherein air is only able to flow in the direction of the arrow.

[0128] Fig. 35 shows the detailed construction in a case where the piston 28 is situated at the top dead center of the cylinder 15. Shaft seals 21a, 21b are disposed in the region where the supporting shaft 17 comes into contact with the outer wall of the cylinder 15, the seals being constituted by a dual O-rings made from HNBR. Shaft seal 22s, 22b consisting of dual O-rings made from HNBR are also provided in the portion of the piston 28 where it contacts the inner wall of the cylinder 15.

[0129] A filter 14 having a similar construction to that of the fourth embodiment illustrated in Fig. 9 is used.

[0130] Next, the operation of the vacuum pump P will be described. An indoor unit is previously connected to a liquid-side two-way valve 7 and gas-side three-way valve 8 of an outdoor unit. A pressure-resistant hose 13 of a gauge manifold 12 is connected to the intake port 31 of the vacuum pump P and a pressure-resistant hose 11 thereof is connected to the gas-side three-way valve 8.

[0131] Firstly, when the handle 18 is pulled in direction a (towards the top dead center), the air in the upper chamber 15a in the cylinder 15 is exhausted from the exhaust port 30into the atmosphere via the non-return valve 30a, whilst air is drawn into the lower chamber 15b through the air filter 38 via the open port 37. Next, when the handle 18 is pushed in the direction of arrow b (towards the bottom dead center), the air inside the indoor unit and the connection pipes 9, 10 is drawn in from the service port section 8b, via the pressure-resistant hose 11, gauge manifold 12, and pressure-resistant hose 13, and into the upper chamber 15a of the cylinder 15 by means of the intake port 31 and the non-return valve 31a, whilst, conversely, the air in the lower chamber 15b is exhausted into the atmosphere from the open port 37, via the air filter 38.

[0132] Thereupon, the handle 18 is caused to perform reciprocal movement in such a manner that the handle is pulled up in the direction a (towards the top dead-center), and the movement of the piston 28 is synchronized to this. A pressure reducing mechanism is achieved constantly when the piston 28 is moved in the direction of arrow b, whilst switching between the intake non-return valve 31a and the exhaust non-return valve 30a provided in the walls of the cylinder 15, and ultimately, a satisfactory negative pressure state is achieved. In this case, since the lower chamber 15b is in a state which allow it to take in air via the open port 37, then if the force on the handle 18 is relaxed when the handle 18 reaches the bottom dead center of the cylinder 15, the piston 28 will return of its own accord with the application of little force, so as to rise upwards in the direction of arrow a, in order to correct the pressure differential existing between the upper chamber 15a and the lower chamber 15b.

[0133] In the vacuum pump P of the present embodiment, it is possible to continue the pressure reducing mechanism, as long as it is possible to generate a pressure differential between the interior of the pressure-resistant hose 13 and the upper chamber 15b of the cylinder 15 when performing reciprocal movement of the handle 18. Therefore, the non-return valve 31a provided at the intake port 31 is required to have a low minimum operating pressure differential. In the case of a non-return valve as in the present embodiment, the factor determining this minimum operating pressure differential is the spring constant of the compression coil spring member 203.

[0134] Moreover, when the vacuum pump P performs a series of reciprocal movements, the operator causes the piston 16 to impact respectively with the inner wall of the cylinder 15 at the top dead center and the bottom dead center, respectively, and in these impacts, the operator is able to cause an acceleration of 1 to 5 G. This acceleration G is transmitted to the handle 18 via the supporting shaft 17, and the acceleration sensor 181 detects this acceleration G and is able to display the number of strokes of reciprocal movement on the display 183, thereby making it possible to estimate the level of vacuum.

[0135] In the vacuum pump P, the shaft seals 21a, 21b are formed by a double O-ring structure, in order to prevent air leakage, as far as possible, and hence it is possible satisfactorily to guarantee the pressure differential state between the negative pressure (30 torr or less) inside the upper chamber 15a of the cylinder 15 and the external atmosphere (760 torr). Moreover, by adopting a dual structure in this way, it is possible to prevent foreign material which is liable to adhere to and infiltrate inside the seal section when the supporting shaft 17 is operated. Furthermore, the shaft seals 22a, 22b are formed by a double O-ring structure in order to prevent air leakage as far as possible, and hence they provide a sufficient guarantee of a differential pressure state between the negative pressure (30 torr or less) of the upper chamber 15a of the cylinder 15 and the pressure of the lower chamber 15b (760 torr), generated when the piston 28 performs reciprocal movement.

[0136] Now, a concrete installation procedure for an air conditioner is described. The indoor unit-is connected via connection pipes 9 and 10 to the liquid-side two-way valve 7 and gas-side three-way valve 8 of the outdoor unit. The vacuum pump P is connected to the low pressure port 12b of the gauge manifold 12 and the pressure-resistant hose 11 leading from the central port 12 a is attached to the service port section 8b of the gas-side three-way valve 8, thereby achieving a state in which the pressure-resistant hose 11 is communicated with the indoor unit and the interior of the connection pipes 9, 10. Moreover, the interior of the pressure-resistant hose 13 is in the communication state by opening the low pressure side handle 12c of the gauge manifold 12.

[0137] Next, the operator causes the handle 18 of the vacuum pump to perform reciprocal movement, as described previously, and by reading the number of strokes of reciprocal movement from the display 183, he or she is able to estimate when the interior of the indoor unit and the connection pipes 9, 10 has reaches a sufficient negative pressure state. Moreover, the sufficient negative pressure state is finally confirmed by the operator from the reading on the vacuum gauge 12d on the gauge manifold 12. Immediately after that, the low pressure side handle 12c of the gauge manifold 12 is closed off, and the after waiting for a short while, it is checked that there is not change in the reading on the vacuum gauge 12d. Here, if there is a change in the reading, then this means that there is an air leak occurring at some point of the coupling of the connection pipes 9, 10.

[0138] Next, the screw section 7a of the liquid-side two-way valve 7 is slightly loosened, and refrigerant gas from the outdoor unit is introduced, thereby setting the interior of the connection pipes 9, 10 and the indoor unit to a slightly positive pressure state (approximately 0.2 kgf/cm^2). Thereupon, the pressure-resistant hose 11 is detached from the service port section 8b, and the screw section 7a of the liquid-side two-way valve 7 is rotated by a further quarter turn to apply a more pressurized state (approximately 3 - 6 kgf/cm^3) in order to recheck for leaking in the connection pipe sections. Finally, the screw section 7a of the liquid-side two-way valve 7 is opened fully, and the screw, section 8a of the gas-side three-way valve 8 is also opened fully, thereby completing the tasks for installation of an air conditioner.

[0139] In the present embodiment, the internal volume of the piping of the indoor unit including the indoor heat exchanger 6, and the connection pipes 9, 10, was 1.5 litres. In the vacuum pump P, the internal volume of the upper chamber when the piston is at the bottom dead center was 150 ml, and the total volume from the cylinder outlet formed when the piston is at the top dead center, to the two non-return valves on the intake port side and the exhaust port side, was 1.5 ml. These figures are taken to include the port flow path space arising in the cylinder wall. The cylinder internal dead space formed when the piston is at the top dead center was 2 ml. Taking via to be the total volume of the internal volume of the upper chamber formed when the piston is at the bottom dead center, and the internal space from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve, and taking V1b to be the total volume of the cylinder internal dead space formed when the piston is at the top dead center, and the internal space from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve, then the relationship between Via and V1b is V1a/ V1b = 44. Fig. 35 is a concrete illustration of the V1b region comprising the cylinder internal dead space and the total spatial volume from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve when the piston is at the top dead center.

[0140] Using this construction and following the work procedure described above, it was possible to achieve a pressure of 30 torr with this vacuum pump, by performing 40 strokes of reciprocal movement of the handle. Fig. 11 illustrates the progress of the negative pressure state in this case, in the form of a relationship between the number of strokes and the internal pressure. The progress of the negative pressure was checked up to 50 strokes, but the attained pressure level reached a state of equilibrium at 40 strokes and does not progress any further thereafter.

[0141] Consequently, it can be seen that when a vacuum pump according to the present embodiment is applied to a system having an internal volume of 1.5 litres, then 40 strokes is the general standard for the attained vacuum level. To obtain an accurate figure, the vacuum level was monitored separately using a digital pressure sensor. Reliability testing was carried out for 5000 hours in an air conditioner using R410A as the refrigerant and an ester oil as the cooling unit oil, by setting the output temperature of the compressor to an overload condition of 115°C, and setting both the indoor unit and the outdoor unit to high-temperature cooling conditions of 40°C. No particular irregularities were observed as a result of this testing.

(Tenth embodiment)

[0142] Fig. 36 is a schematic diagram giving a detailed illustration of the construction of the vacuum pump and the connection path of the pressure-resistant hoses in the present embodiment. Since the present embodiment uses a vacuum pump that is virtually the same as that in the ninth embodiment, detailed description thereof is omitted here and the description will focus on the different parts. In the vacuum pump P, a one-touch pipe joint 26 was detachably attached to a connecting section to the non-return valve 31a of the intake port 31 provided on the cylinder 15, via the pressure-resistant hose 25. Furthermore, a screw-fitting sealing cap 39 was provided for the open port 37 as a member for sealing of the air intake or exhaust actions.

[0143] Fig. 19 is a sectional view of the construction of the aforementioned one-touch pipe joint 26. The more specific aspects of the construction are described below. A release bush 341 is provided around the pressure-resistant hose, and the release bush 341 is fixed by providing a guide 343 and collet 344 on the main body 342 of the tubular pipe joint. A tubular chuck 345 is disposed between the release bush 341 and collet 344, and the chuck 345 is caused to bite on the outer circumference of the pressure-resistant hose, thereby preventing the pressure-resistant hose from detaching, by pressing the front end of the chuck 345 in the direction of the pressure-resistant hose by means of a CR rubber lip seal 346.

[0144] Furthermore, since the biting pressure of the front end of the chuck 345 can be released by pushing the release 341 towards the inner side along the pressure-resistant hose 13, the pressure-resistant hose 13 can be detached readily. Provided that the lip seal 346 is functioning sufficiently, then it is possible to prevent air leakage.

[0145] Next, a concrete installation procedure for an air conditioner according to the present invention is described. Firstly, a pressure-resistant hose 13 is connected to the one-touch pipe joint 26 arranged on the intake port 31 of the vacuum pump P. The sealing cap 39 screwed onto the open port 37 is removed, the handle 18 is pulled upwards to reposition the piston 28 in an approximately central position in the cylinder 15, and the sealing cap 39 is then screwed into the open port 37, thereby sealing the intake and exhaust flow path. The pressure-resistant hose 13 is also coupled to the low pressure port 12b of a gauge manifold 12, and a pressure-resistant hose 11 is attached to the service port section 8b. Therefore, the pressure-resistant hose 11 is in a state of connection with the interior of the indoor unit and the connection, pipes 9, 10. Moreover, the pressure-resistant hose 13 is also connected thereto by opening the low pressure side handle 12c of the gauge manifold 12.

[0146] Next, the operating mechanism of the vacuum pump is described. Firstly, when the handle 18 is pushed in the direction of arrow b (towards the bottom dead center), the air inside the indoor unit and the connection pipes 9, 10 is drawn in from the service port section 8b, via the pressure-resistant hose 11, the gauge manifold 12 and the pressure-resistant hose 13, and into the upper chamber 15a inside the cylinder 15, by means of the non-return valve 31a of the intake port 31. Conversely, the air in the lower chamber 15b is in a sealed space, and is therefore compressed, which means that when the bottom dead center is reached and the force on the handle 18 is relaxed, the piston 28 returns of its own accord, without applying virtually any external force, and moves upwards in the direction of arrow b, due to the joint effect of the reactive action of the compressed air and the pressure differential between the upper chamber 15a and the lower chamber 15b. The air in the upper chamber 15a is exhausted into the atmosphere via the non-return valve 30a of the exhaust port 30. When the handle 18 is pressed down again, it is possible to advance the interior of the indoor unit and the connection pipes 9, 10 in the negative pressure direction.

[0147] In this way, a vacuum pump can be achieved having a pressure reducing mechanism in the b direction when reciprocal movement of the handle 18 of the vacuum pump is performed. By reading the number of stroke movements of the piston 28 from the display 183, the operator is able to estimate and determine when the interior of the indoor unit and the connection pipes 9, 10 has reached a sufficient negative pressure state. Moreover, the operator can also confirm the sufficient negative pressure state from the reading of the vacuum gauge 12d on the gauge manifold 12. Immediately thereupon, the low pressure side handle 12c of the gauge manifold 12 is closed, and after waiting for a short while, it is checked that there has been no change in the reading of the vacuum gauge 12d. Here, if there has been change in the reading, then this means that an air leak is occurring at some point in the connection pipe sections.

[0148] Next, the screw section 7a of the liquid-side two-way valve 7 is slightly loosened, and refrigerant gas from the outdoor unit is introduced, thereby setting the interior of the connection pipes 9, 10 and the indoor unit to a slightly positive pressurestate (approximately 0.2 kgf/cm^2). Thereupon, the pressure-resistant hose 11 is detached from the service port section 8b, and the screw section 7a of the liquid-side two-way valve 7 is rotated by a further quarter turn to apply a more pressurized state (approximately 3 - 6 kgf/cm^2) in order to recheck for leaking in the connection pipe sections. Finally, the screw section 7a of the liquid-side two-way valve 7 is opened fully, and the screw section 8a of the gas-side three-way valve 8 is also opened fully, thereby completing the installation tasks for installation of an air conditioner.

[0149] Finally, when storing away the vacuum pump P, the sealing cap 39 screwed onto the open port 37 is again removed, the handle 18 is pressed downwards to drive out the air in the lower chamber 15b, and the sealing cap 39 is then screwed on and the pressure-resistant hose 13 is removed from the one-touch pipe joint 26. Thereby, it is possible to compactify the vacuum pump to achieve good portability.

[0150] In the present embodiment, the sealing cap 39 was provided for the open port 37 when the piston 28 had been repositioned in an approximately central position in the cylinder 15, but the position to which the piston 28 should be moved in the cylinder 15 should be determined in the following manner. Since the level to which air can be compressed by manual force is approximately 10 kg/cm^2 at maximum, then the total internal volume of the cylinder internal dead space formed when the piston is at the bottom dead center, and the volume from the cylinder outlet to the open port sealed by the sealing cap, should be approximately 10 - 20 ml.

[0151] In the present embodiment, a one-touch pipe joint 26 as illustrated in Fig. 19 was used as a connecting section whereby the pressure-resistant hose can be readily attached to and detached from the vacuum pump, but the attachable and detachable connecting section which can be used in the present invention is not limited to this. In addition to this, it is also possible to use a tube coupler, or the like, which does not comprise a self-sealing mechanism.

(Eleventh embodiment)

[0152] The present embodiment is an installation method, in which the air inside the indoor unit piping and the connection pipes 9, 10 of an air conditioner as illustrated in Fig. 33 is substituted with carbon dioxide gas, using a carbon dioxide gas pump, whereupon the work procedure according to the ninth embodiment is followed. Compared to the installation method implemented in the ninth embodiment, the oxygen inside the indoor unit piping and the connection pipes 9, 10 can be further reduced, thus increasing accuracy, and a vacuum pump P having the same construction as that in the ninth embodiment was used. The internal volume of the piping of the indoor unit, including the indoor heat exchanger 6, and the connection pipes 9, 10, was 1.5 litres.

[0153] In the vacuum pump, the internal volume of the upper chamber formed when the piston is at the bottom dead center was 80 ml, and the total internal space from the cylinder outlet formed when the piston is at the top dead center to the two non-return valves on the intake port side and the exhaust port side was 1.5 ml. These figures are taken to include the port flow path space arising in the main wall of the cylinder. The cylinder internal dead space from when the piston is at the top dead center was 2 ml. Taking V1a to be the total volume of the internal volume of the upper chamber formed when the piston is at the bottom dead center, and the internal space from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve, and taking V1b to be the total volume of the cylinder internal dead space formed when the piston is at the top dead center, and the internal space from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve, then the relationship between V1a and V1b is V1a/V1b = 23.

[0154] Firstly, the air inside the piping of the indoor unit and the connection pipes 9, 10 was substituted with carbon dioxide gas, using a carbon dioxide pump. More specifically, the outlet of a carbon dioxide gas pump is connected to the service port 8b of a liquid side gas three-way valve 8, a flare nut of the liquid-side two-way valve 7 (not illustrated) is loosened to connect the connection pipe 9 to the atmosphere, and when the air inside the connection pipe 10, the internal pipes of the indoor unit and the connection pipe 9 has been exhausted into the atmosphere and substituted by carbon dioxide gas, the flare nut of the liquid-side two-way valve 7 is closed, and the carbon dioxide gas pump is detached from the service port 8b. Thereupon, by using the vacuum pump in accordance with the work procedure according to the ninth embodiment, it was possible to achieve 60 torr. Reliability testing was carried out for 5000 hours in an air conditioner using R410A as the refrigerant and an ester oil as the cooling unit oil, by setting the output temperature of the compressor to an overload condition of 115°C, and setting both the indoor unit and the outdoor unit to high-temperature cooling conditions of 40°C. No particular irregularities were observed as a result of this testing.

[0155] In the present embodiment, the interior of the indoor unit piping and the connection pipes was substituted with carbon dioxide gas, but the specific gas which can be used in the present invention is not limited to this. In addition, it is possible to use any gas which is not liable to affect the reliability of the refrigerating cycle. More specifically, besides carbon dioxide gas, it would be possible to-use gases such as nitrogen, methane, ethane, propane, isopropane, argon, or the like.

[0156] In the pressure reducing mechanism in a vacuum pump according to the present invention as described above, it is possible to generate pressure reduction by a pressure reducing mechanism inside the cylinder, only when the piston is moved in the downward direction, and the cylinder internal dead space formed when the piston is at the top dead center, and the spatial volume from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve, form a dead space. The cylinder internal dead space comprises the small gap formed when the piston meets the plane of the bottom dead center of the cylinder, and the intake port and exhaust port flow paths formed inside the cylinder wall. Therefore, with regard to the attained vacuum level, the relationship between V1a, which is the total volume of the internal volume of the upper chamber formed when the piston is at the bottom dead center, and the volume of the internal space from the cylinder outlet to-the intake port non-return valve and the exhaust port non-return valve, and V1b which is the total of the cylinder internal dead space formed when the piston is at the top dead center, and the volume of the internal space from the cylinder outlet to the intake port non-return valve and the exhaust port non-return valve, is very important. If a design is adopted whereby the relationship between V1a and V1b is $V1a/V1b \geq 40$, and if the leakage at the non-return valves is controlled to some extent, then it was found that it is possible to achieve a pressure of 30 torr or less, satisfactorily, by performing reciprocal movement of the handle of the vacuum pump. If the relationship V1a/V1b is top large, then although there will be no impediment to the level of vacuum attained, the vacuum pump will be become bulky and heavy and portability of the device will be impaired. Moreover, the operation for performing reciprocal movement of the handle will be impaired.

[0157] It can be seen that the number of strokes of the vacuum pump required in the installation of an air conditioner according to the present invention is determined by the relationship between the internal volume of the piping of the indoor unit and the connection pipes, and the internal volume of the cylinder space. If the internal volume of the indoor unit piping and the connection pipes is 1.5 litres, and the internal volume of the cylinder space is 150 ml, then a state of equilibrium is reached after performing approximately 40 strokes of reciprocal movement, and if the internal volume of the indoor unit and the connection pipes is 2.5 litres, and the internal volume of the cylinder space is 250 ml, then a state of equilibrium is reached after performing approximately 70 strokes of reciprocal movement. Therefore, by establishing these relationships in a database, it is possible for an operator to estimate and deduce the general state of the vacuum level attained, by controlling the number of strokes of the vacuum pump by means of the sensor according to the present invention.

[0158] The piston shaft seal which can be used in the present invention was taken to be a seal having a dual O-ring structure, similarly to the seals used for the supporting shaft, and since the open port of the lower chamber is sealed off to form a sealed space, and the air is compressed when the piston is moved downwards, then a large pressure differential is generated between the lower chamber and the upper chamber. In this case, a dual O-ring structure is superior in order to sufficiently control air leakage from the lower chamber to the upper chamber.

[0159] In the respective embodiments described above, a drier was provided inside the main body of the outdoor unit. In the vacuum pump according to the present invention, it is difficult to exhaust moisture present inside the indoor unit and the connection pipes, in comparison to an electric vacuum pump. Therefore, long term reliability can be guaranteed more readily in the case of air conditioners which are equipped with a drier in the refrigerating cycle.

Claims

1. A vacuum pump, comprising a cylinder (15) an interior of which is divided into two chambers by a piston (16), and intake ports (20) and exhaust ports (19) being provided with non-return valves (19a, 19b, 20a, 20b) respectively at a top dead center and a bottom dead center of the two chambers obtained by dividing the cylinder, wherein

when the piston (16) is caused to move in either direction,

if the exhaust ports (19) are coupled together, gas inside the cylinder (15) is exhausted, thereby to cause the exhaust port-side interior of the cylinder (15) to assume a pressurized state, and

if the intake ports (20) are coupled together, the intake port-side interior of the cylinder is caused to assume a negative pressure state.

2. The vacuum pump according to claim 1, wherein a compression coil spring (203) is provided inside the non-return valves (20a, 20b) disposed in the intake ports (20), the compression coil spring (203) having a spring constant of 0.01 to 0.04 N/mm.

3. An installation method for an air conditioner using a vacuum pump to install an air conditioner comprising an indoor unit (B) and an outdoor unit (A) connected by connection pipes (9, 10), wherein

the vacuum pump comprises a cylinder (15) an interior of which is divided into two chambers by a piston (16), and intake ports (20) and exhaust ports (19) each being provided with non-return valves (19a, 19b, 20a, 20b) respectively at a top dead center and a bottom dead center of the two chambers obtained by dividing the cylinder, and

the installation method comprising:

at least a first step in which the exhaust ports (19) are coupled together and if the piston (16) is caused to move in either direction, gas inside the cylinder (15) is exhausted to cause interiors of the indoor unit (B) and the connection pipes (9, 10) to assume a pressurized state; and

a second step in which the intake ports (20) are coupled together, thereby causing the interiors of the indoor unit (B) and the connection pipes (9, 10) to assume a negative pressure state.

4. The installation method for an air conditioner according to claim 3, wherein the air conditioner comprises a first coupling section for coupling together the exhaust ports (19, 30), a second coupling section for coupling together the intake ports (20, 31), a connecting section (33a) for connecting the first coupling section with the exhaust ports (19, 30), and a connecting section (35a) for connecting the second coupling section with the intake ports (20, 31).

5. The installation method for an air conditioner according to claim 3 or claim 4, wherein the connecting sections (33a, 35a) are detachable.

6. A vacuum pump, comprising a cylinder an interior of which is divided into two chambers by a piston (16, 27), and intake ports (20, 31) and exhaust ports (19, 30) each being provided with non-return valves respectively at a top dead center and a bottom dead center of the two chambers obtained by dividing the cylinder, wherein

the respective intake ports (20, 31) are coupled together by means of a coupling port section,

when the piston (16, 27) is caused to move in either direction, pressure differential between the two chambers is gradually reduced from an initial differential, thereby to cause the intake port-side interior to assume a negative pressure state, and

a sensor (181) is provided which is capable of counting the number of reciprocal movements of the piston (16, 27).

7. The vacuum pump according to claim 6, wherein the sensor (181) to an acceleration sensor, of which response sensitivity is 1 to 5 G.

8. The vacuum pump according to claim 6, wherein the sensor (181) comprises a wire spring or an arm (134) held in a cantilever fashion.

9. The vacuum pump according to claim 6, wherein the acceleration sensor is a mechanical sensor, which is of a contact pressing type, a reed switch type or a contact conduction type.

10. A vacuum pump, comprising:

a cylinder (15) an interior of which is divided into an upper chamber (15a) and a lower chamber (15b) by a piston (28), the piston (28) being coupled to a handle (18) for causing the piston to move via a supporting shaft (17) located in the upper chamber-side cylinder,

an intake port (31) provided with a non-return valve (31a) and an exhaust port (30) provided with a non-return valve (30a), respectively at top dead center of the upper chamber, and

an open port (37) located in the lower chamber (15b) of the cylinder (15) in order for taking in or exhausting air,

wherein the upper chamber (15a) assumes a negative pressure state when the piston (28) is moved in a downward direction, and the piston (28) is moved in an upward direction by an air-intake action via the open port (37).

11. An installation method for an air conditioner using a vacuum pump to install an air conditioner comprising an indoor unit and an outdoor unit connected by connection pipes, wherein

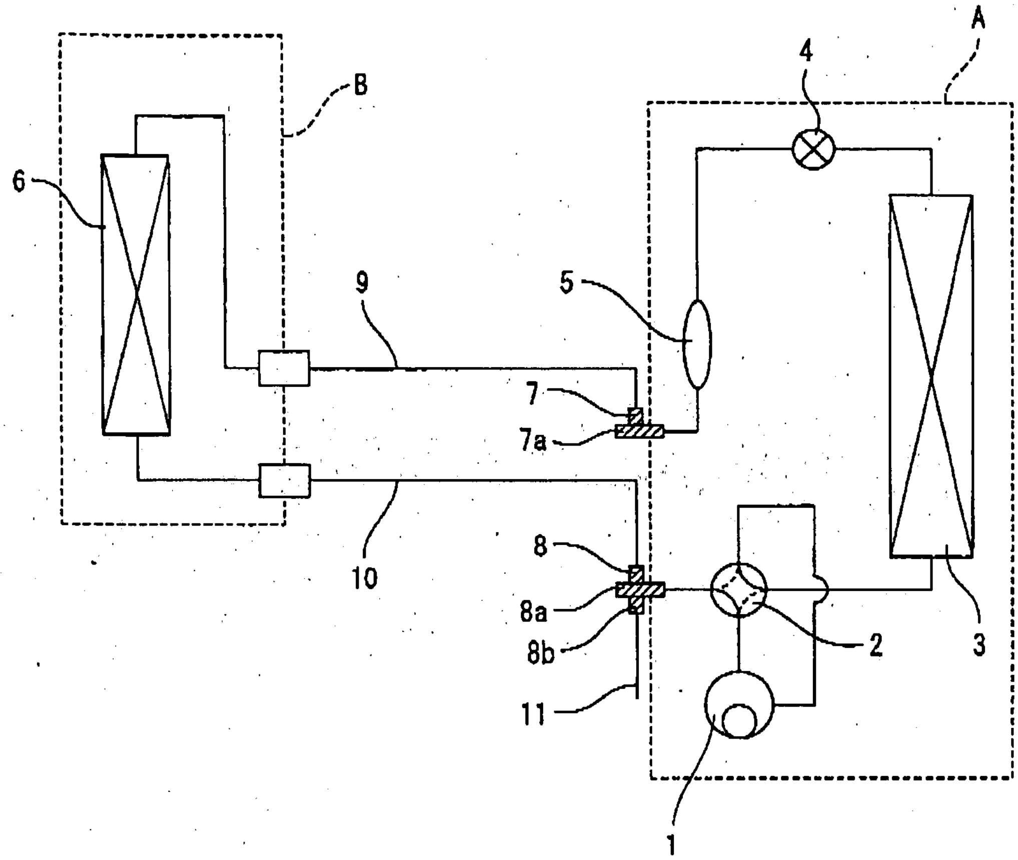
the vacuum pump comprises a cylinder (15) an interior of which is divided into an upper chamber (15a) and a lower chamber (15b) by a piston (28), the piston (28) being coupled to a handle (18) for causing the piston to move via a supporting shaft (17) located in the upper chamber-side cylinder, an intake port (31) provided with a non-return valve (31a) and an exhaust port (30) provided with a non-return valve (30a) respectively at a top dead center of the upper chamber, and an open port (37) located in the lower chamber (15b) of the cylinder (15) in order for taking in or exhausting air,

a relationship between V1a, that is a total volume of an internal spatial volume of the upper chamber formed when the piston (28) is at the bottom dead center and an internal volume of a space from the cylinder outlet to the intake port non-return valve (31a) and the exhaust port non-return valve (30a), and V1b, that is a total volume of a cylinder internal dead space formed when the piston (28) is at the top dead center and an internal volume of a space from the cylinder outlet to the intake port non-return valve (31a) and the exhaust port non-return valve (30a), is $V1a/V1b \geq 20$, and after the upper chamber has been caused to assume a negative pressure state by moving the piston in a downward direction, the piston (28) is induced to move in an upward direction by an air intake action via the open port (37), whilst interiors of the indoor unit (B) and the connection pipes (9, 10) are caused to assume a negative pressure state.

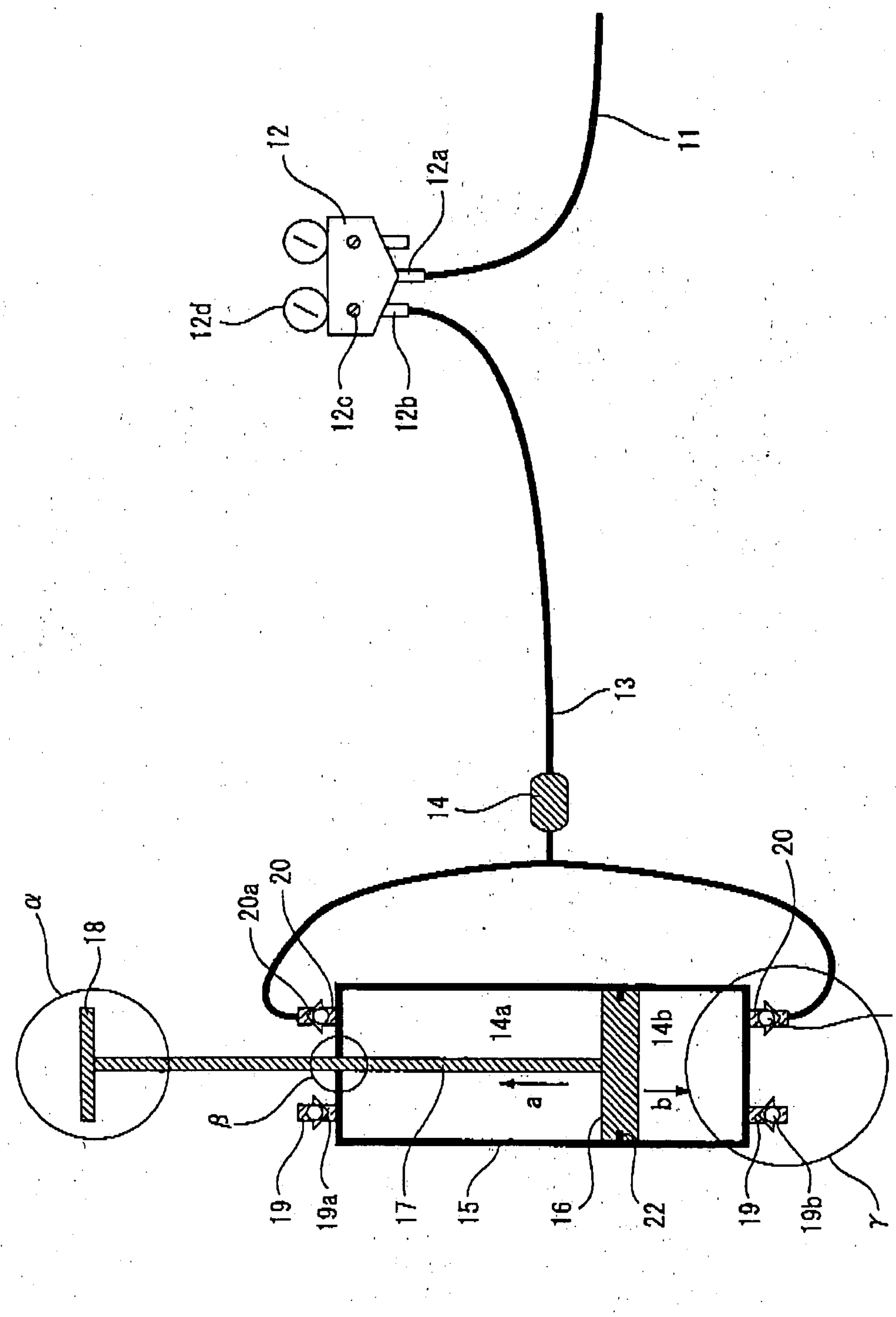
12. The installation method for an air conditioner according to claim 11, wherein, in the installation process, the interiors of the indoor unit (B) and the connection pipes (9, 10) are caused to assume a negative pressure state, after a specific gas has been introduced into the indoor unit (B) and the connection pipes (9, 10) and the air inside the indoor unit (B) and the connection pipes (9, 10) has been replaced by the specific gas.

13. The installation method for an air conditioner according to claim 11 or 12, wherein $V1a/V1b \geq 40$.

FIG. 1



F I G. 2


12
12a
12b
12c
12d
11
13
14
14a
14b
15
16
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18
19
19a
19b
20
20a
20b
22
a
b
α
β
γ

FIG. 3

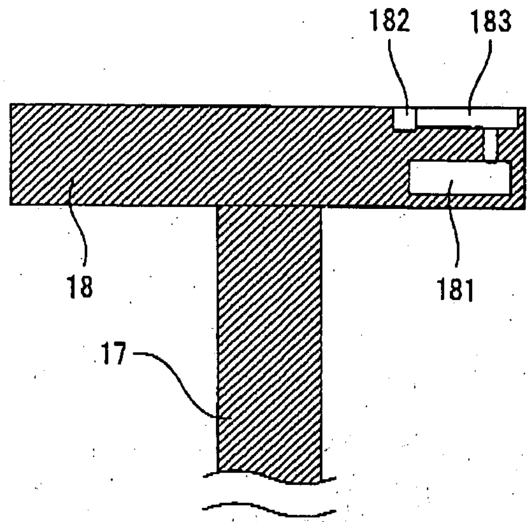
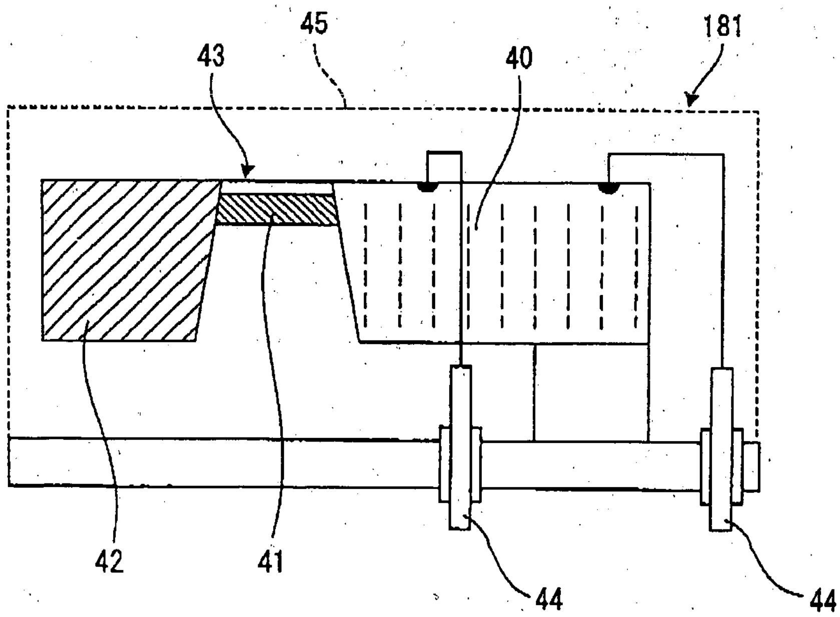
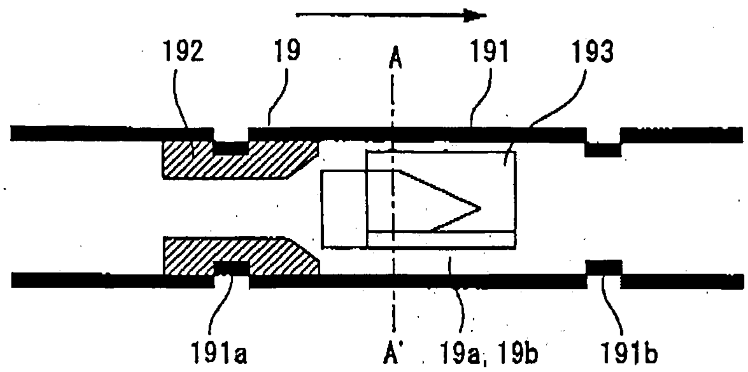


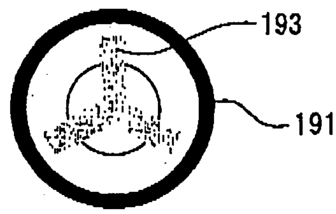
FIG. 4



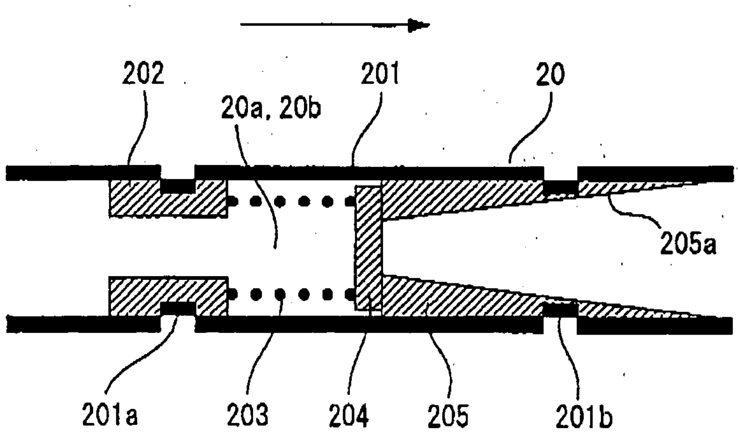
F I G. 5



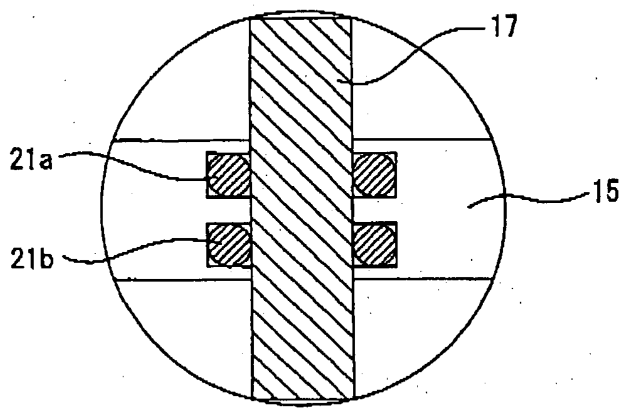
F I G. 6



F I G. 7



F I G. 8



F I G. 9

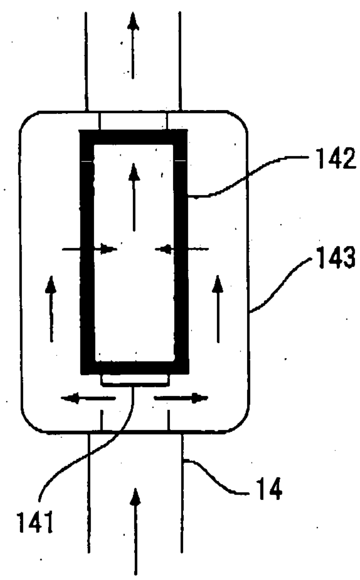


FIG. 10

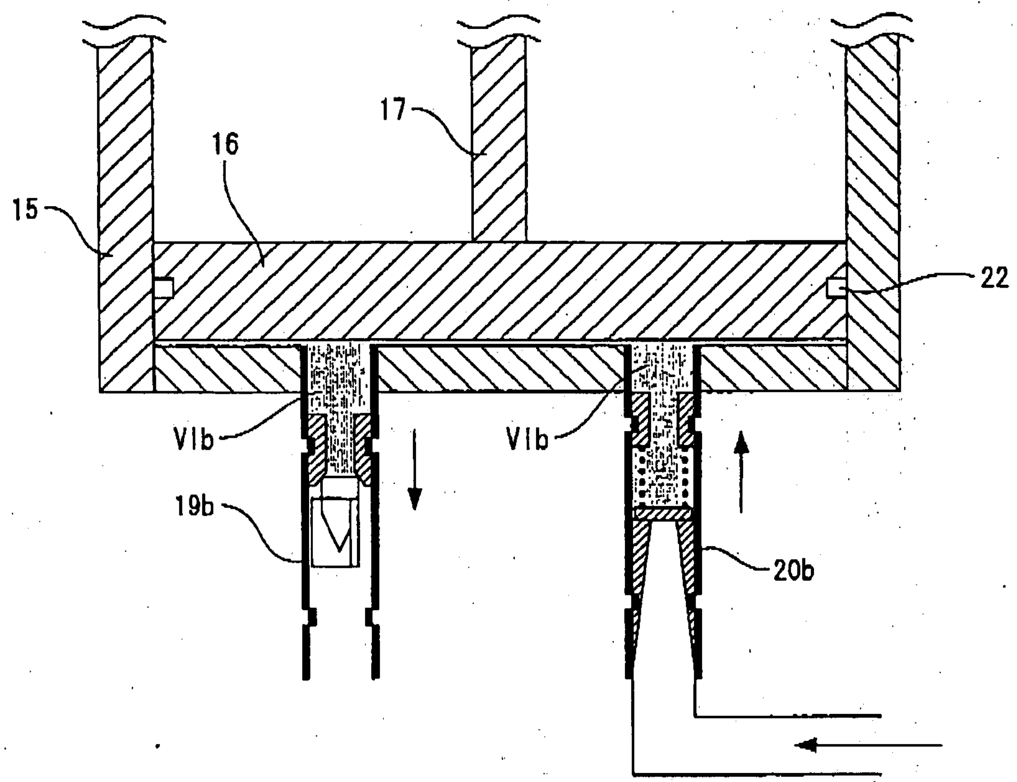

17
16
15
22
VIb
VIb
19b
20b

FIG. 11

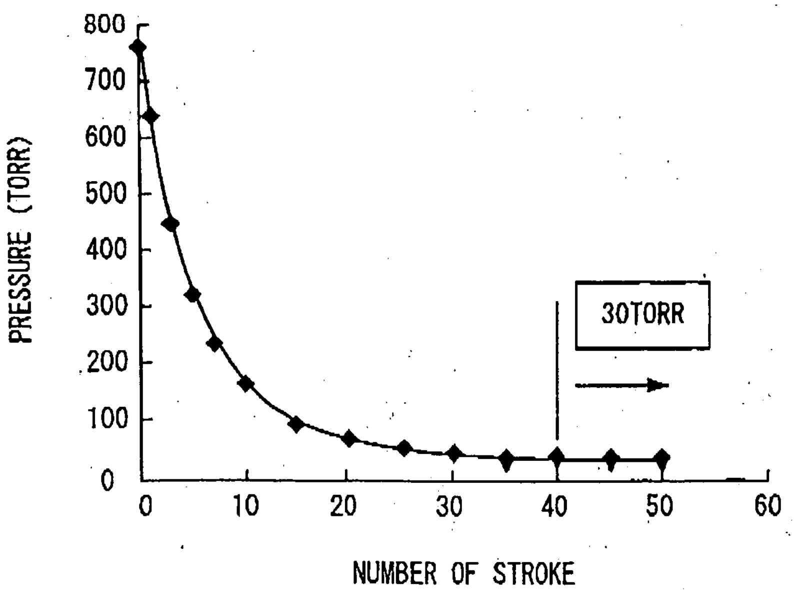
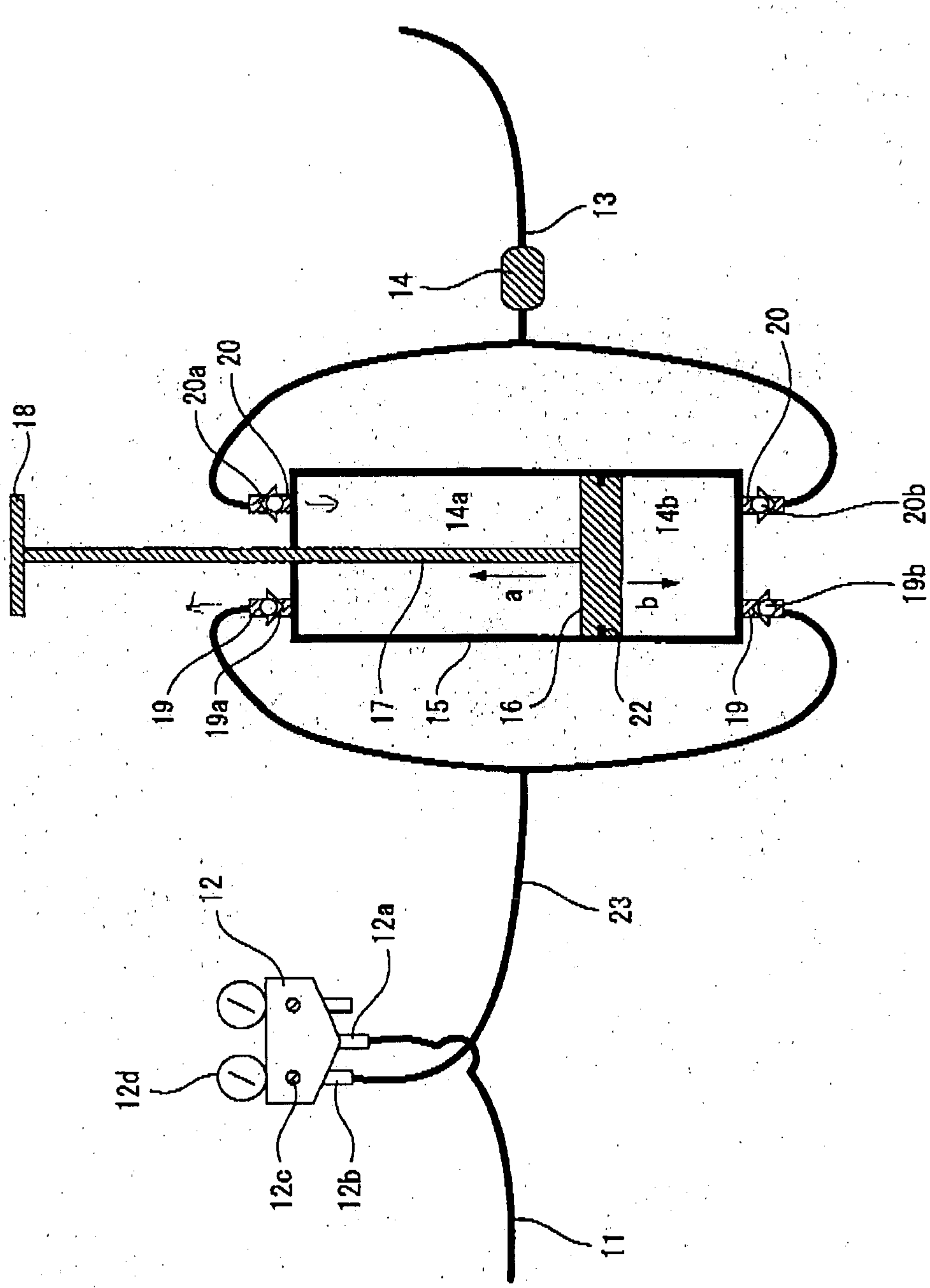

800
700
600
500
400
300
200
100
0
PRESSURE (TORR)
30TORR
0
10
20
30
40
50
60
NUMBER OF STROKE

FIG. 12



11
12
12a
12b
12c
12d
13
14
14a
14b
15
16
17
18
19
19a
19b
20
20a
20b
22
23
a
b

FIG. 13

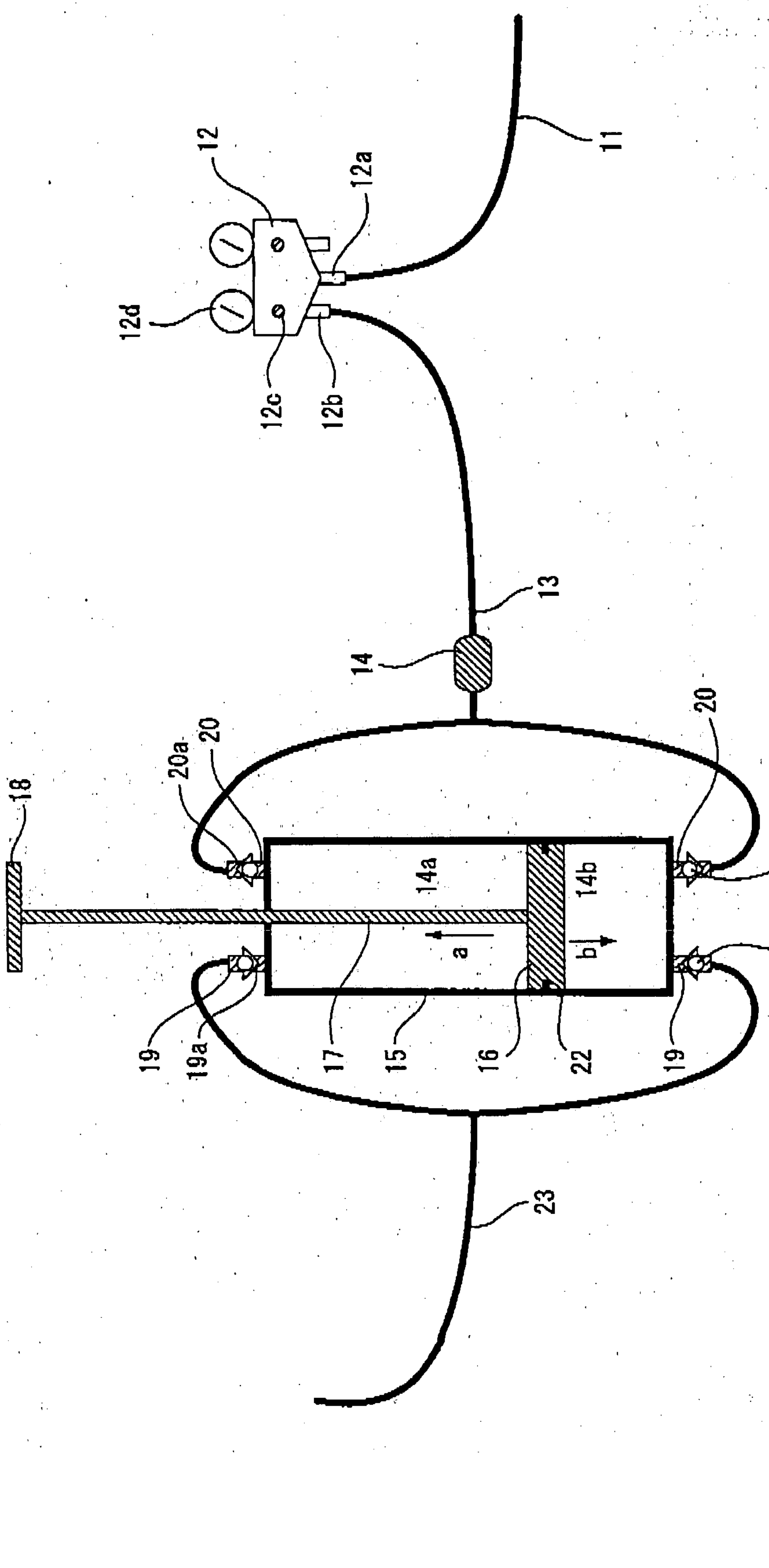
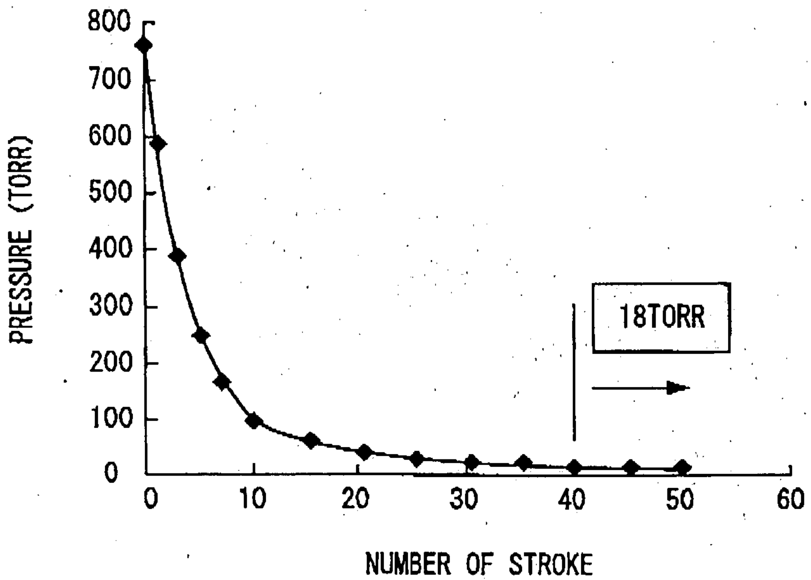

11
12
12a
12b
12c
12d
13
14
14a
14b
15
16
17
18
19
19a
19b
20
20a
20b
22
23
a
b

FIG. 14


800
700
600
500
400
300
200
100
0
PRESSURE (TORR)
0
10
20
30
40
50
60
NUMBER OF STROKE
18TORR

F I G. 1 5

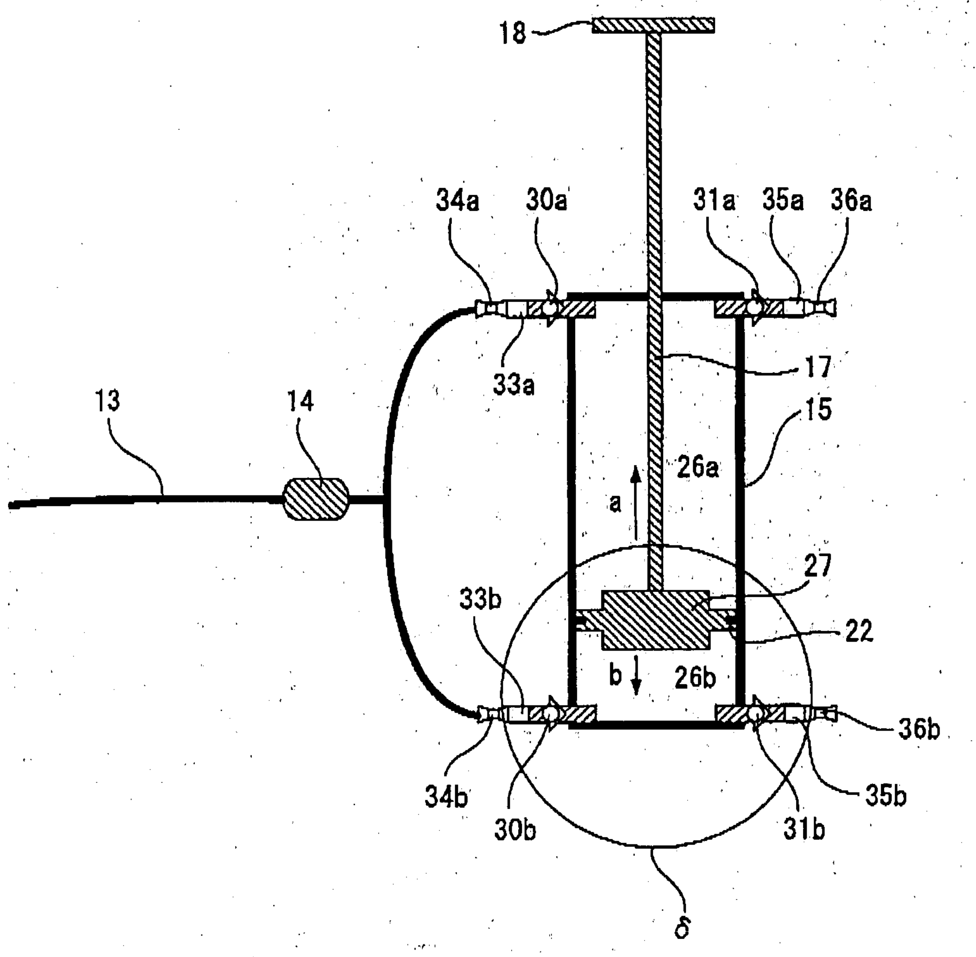

18
34a
30a
31a
35a
36a
33a
17
13
14
15
26a
a
27
33b
22
b
26b
36b
34b
35b
30b
31b
δ

FIG. 16

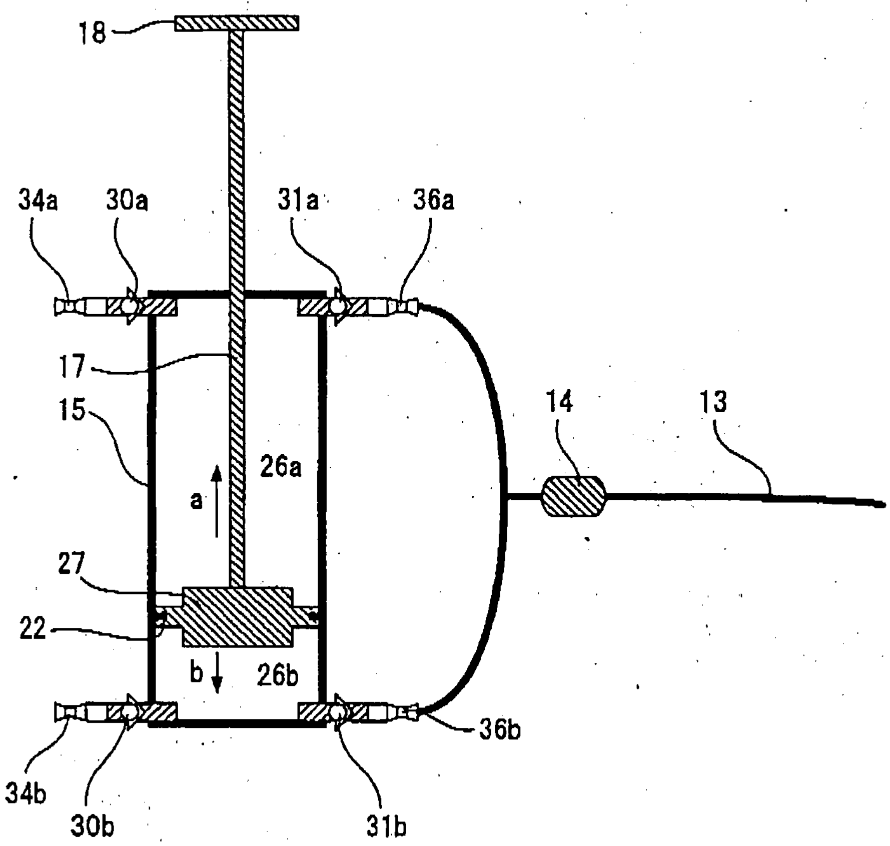


FIG. 17

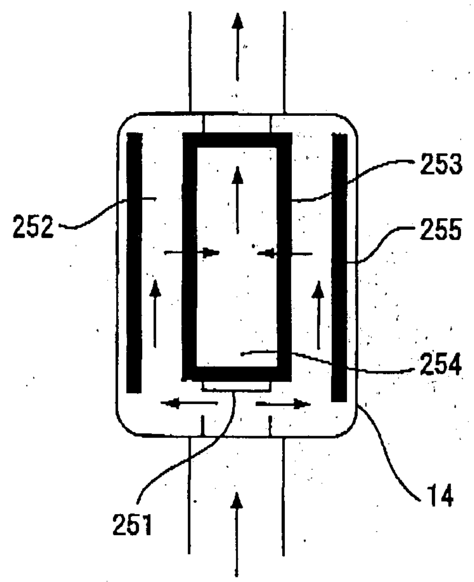


FIG. 18

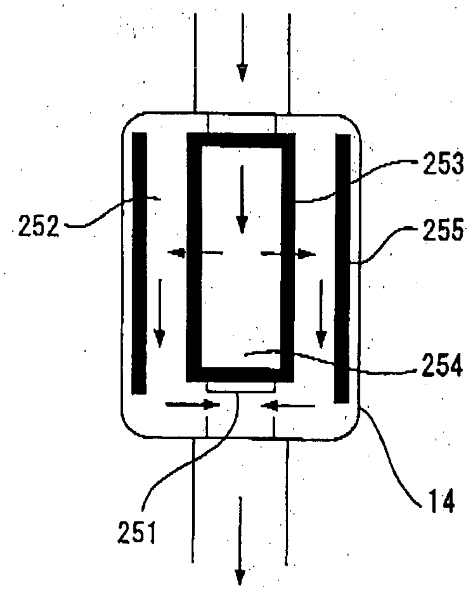


FIG. 19

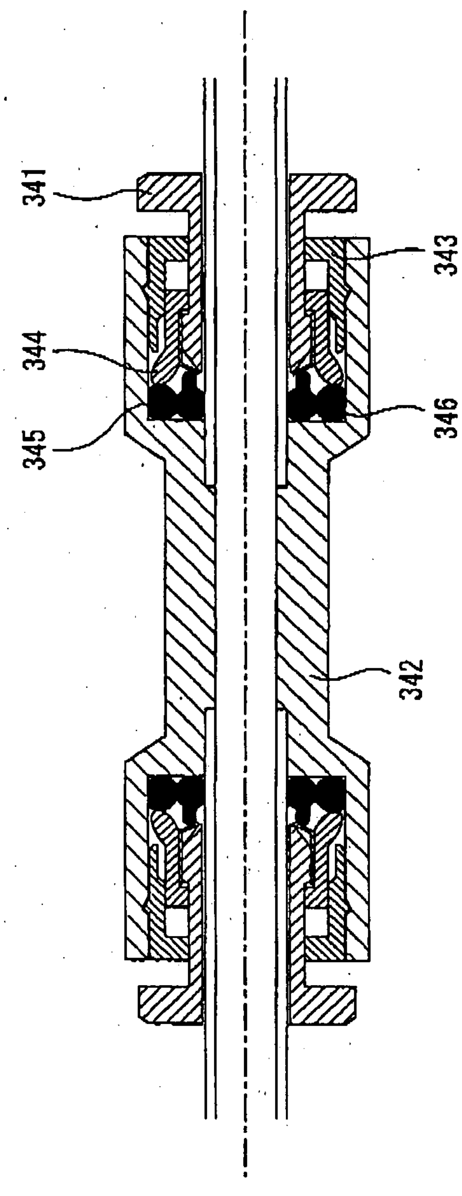


FIG. 20

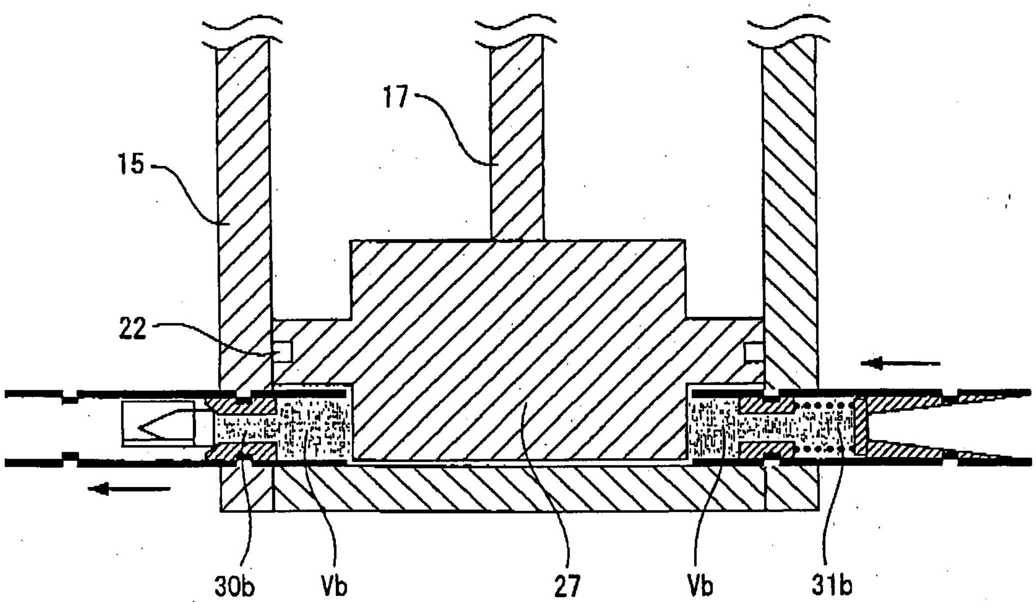

17
15
22
30b
Vb
27
Vb
31b

FIG. 21

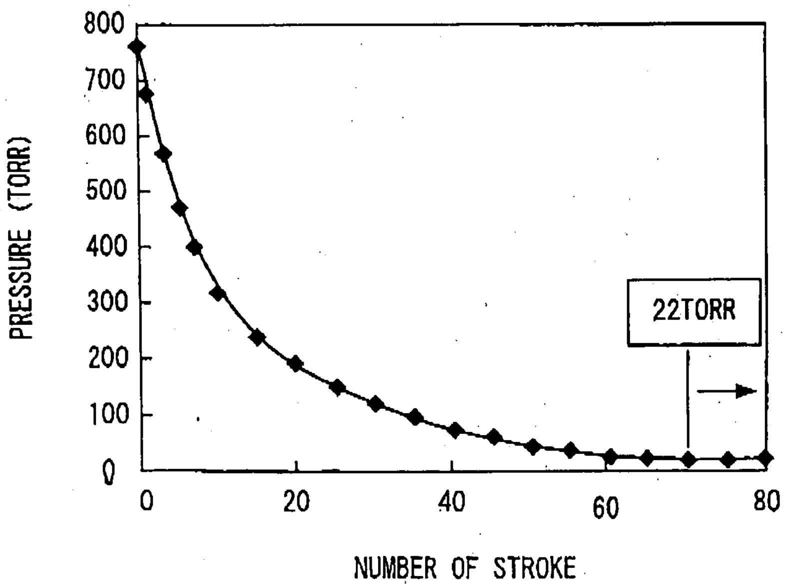

800
700
600
500
400
300
200
100
0
PRESSURE (TORR)
22TORR
0
20
40
60
80
NUMBER OF STROKE

FIG. 22

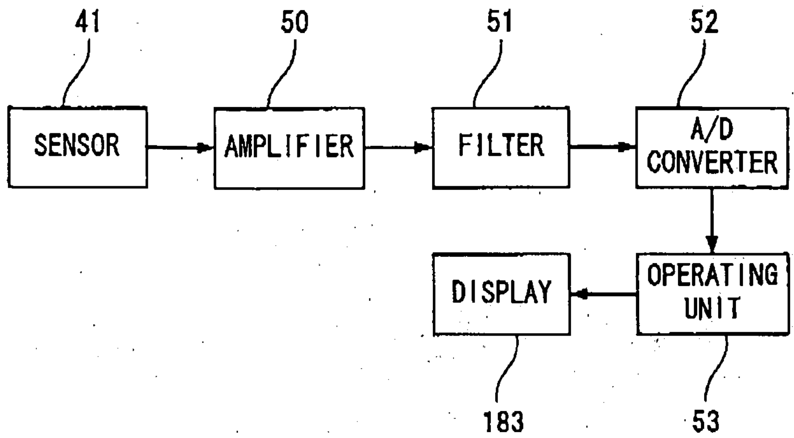
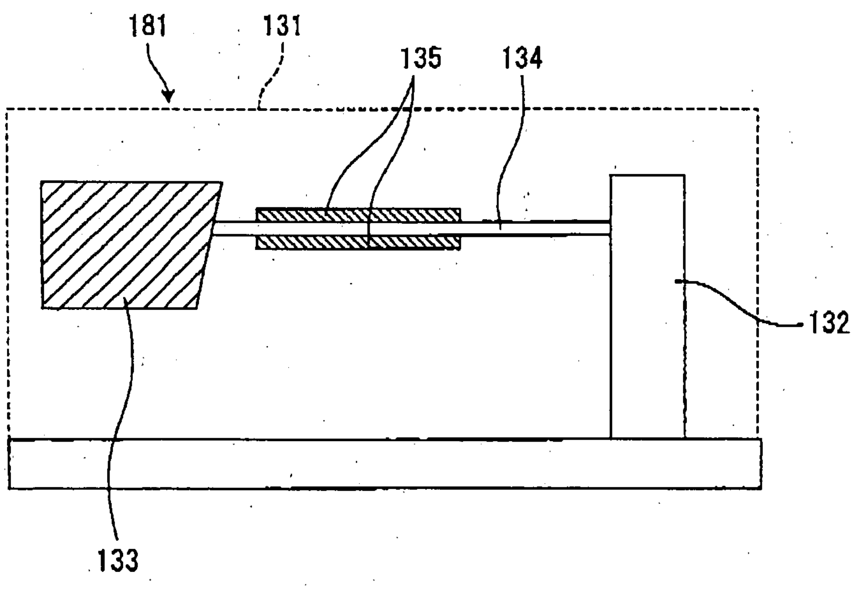
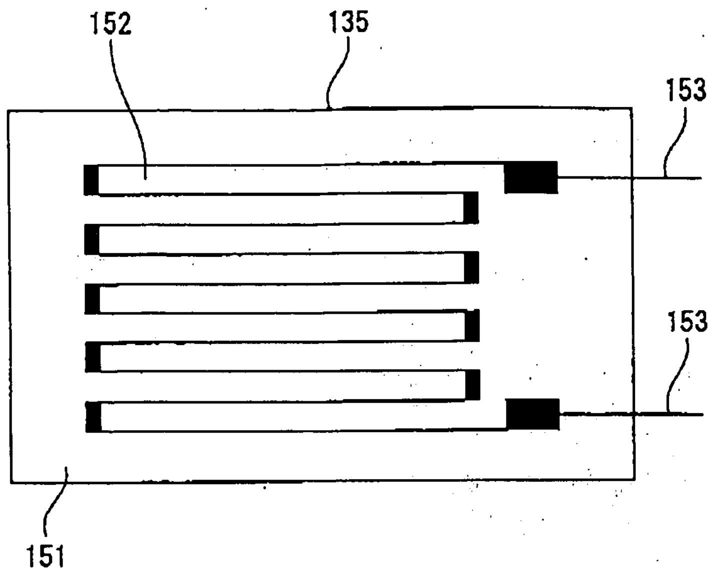

41
50
51
52
SENSOR
AMPLIFIER
FILTER
A/D CONVERTER
DISPLAY
OPERATING UNIT
183
53

FIG. 23


181
131
135
134
132
133

F I G. 2 4



F I G. 2 5

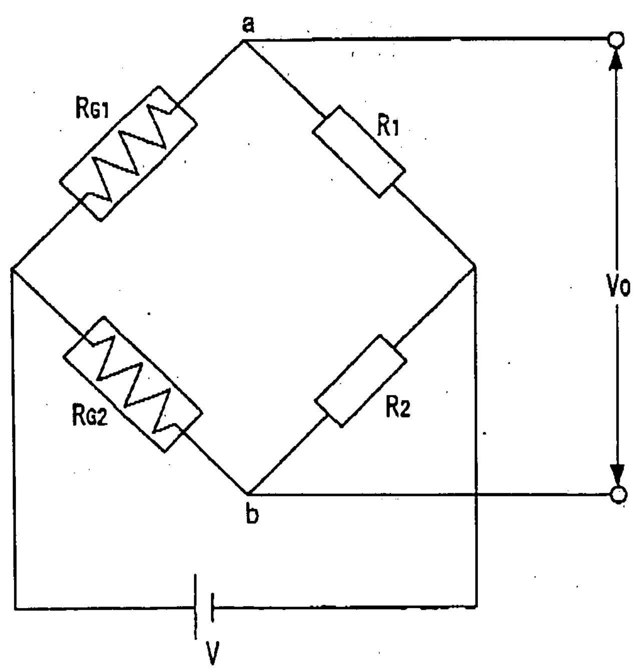


FIG. 26

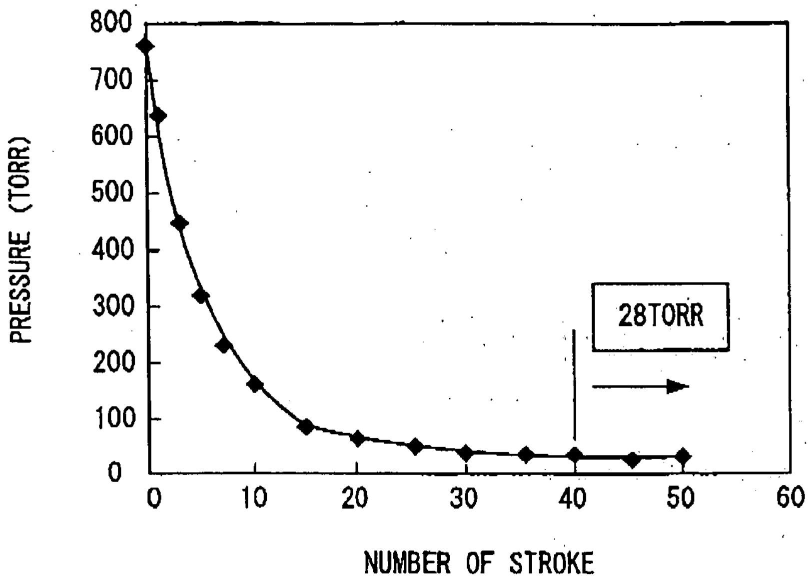

800
700
600
500
400
300
200
100
0
PRESSURE (TORR)
28TORR
0
10
20
30
40
50
60
NUMBER OF STROKE

FIG. 27

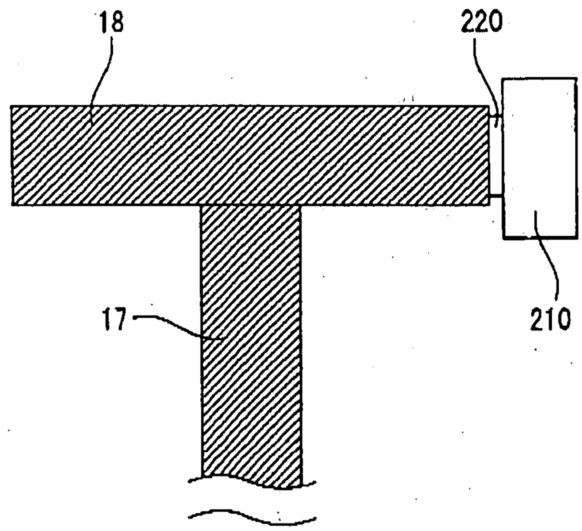

18
220
17
210

FIG. 28

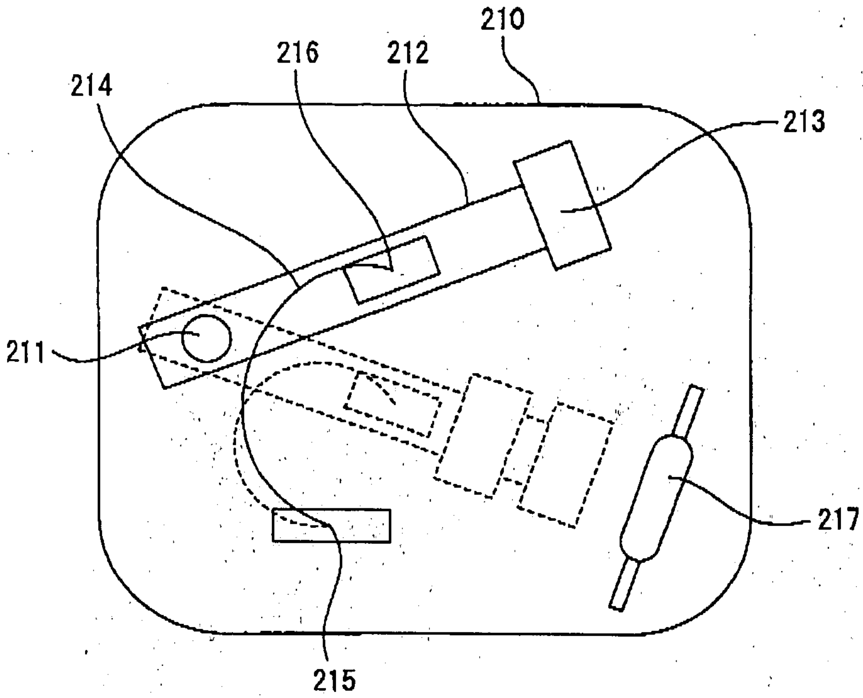


FIG. 29

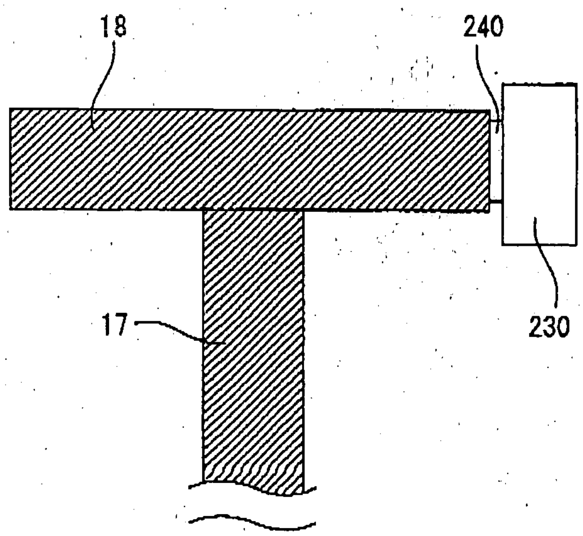


FIG. 30

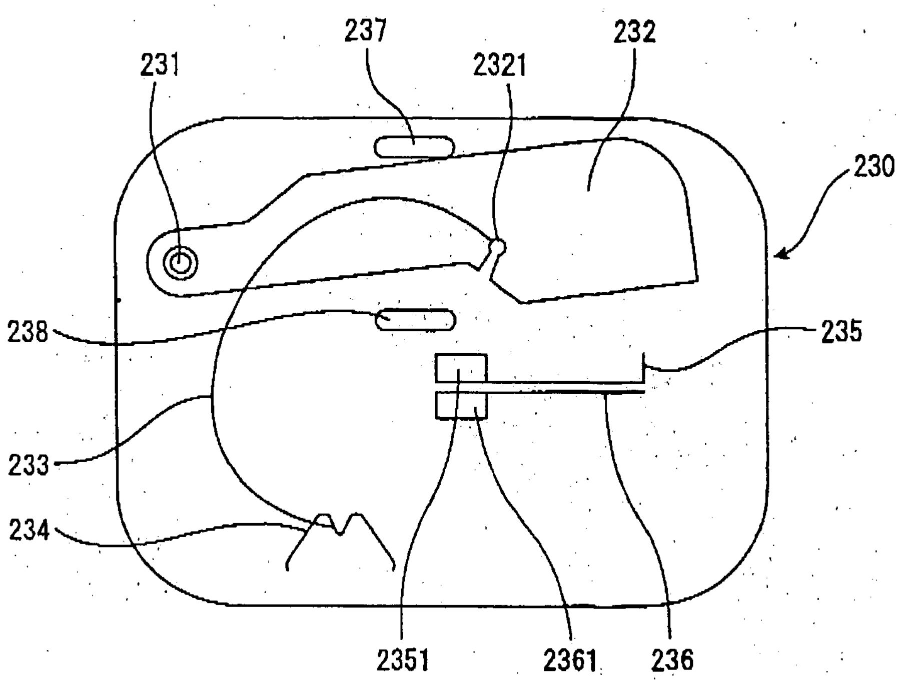


FIG. 31

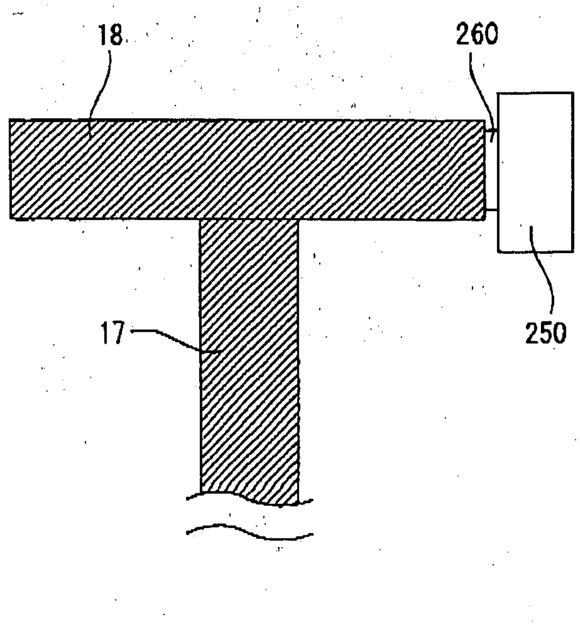


FIG. 32

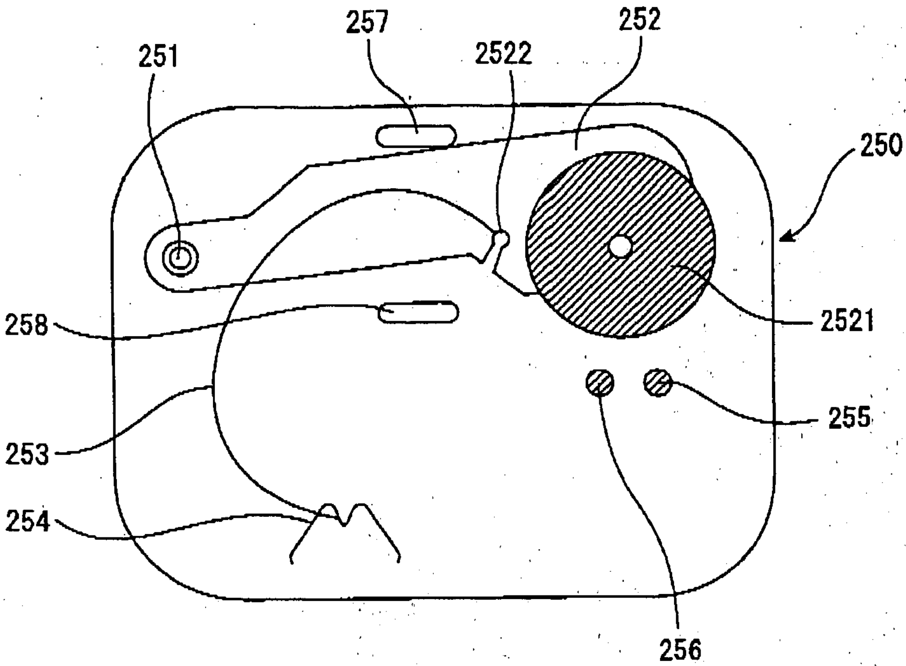
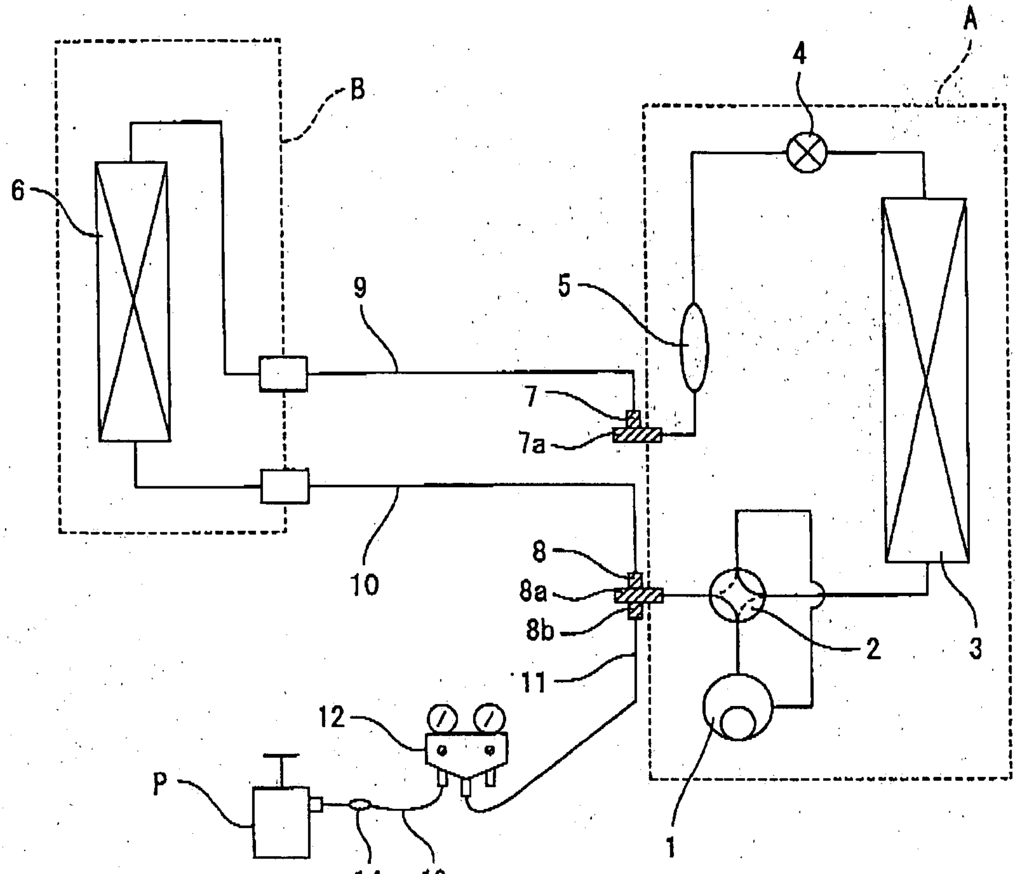


FIG. 33



F I G. 3 4

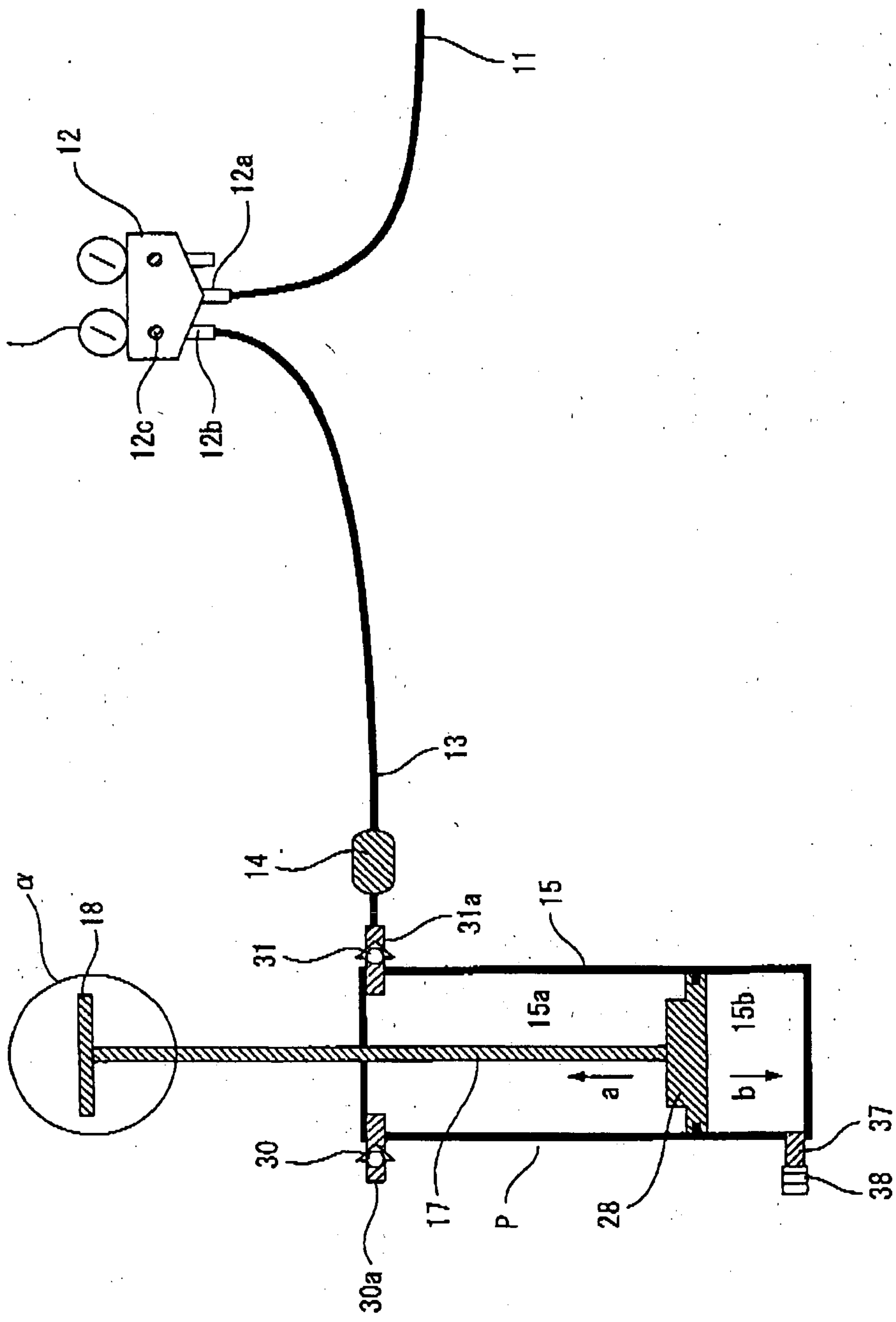

11
12
12a
12b
12c
12d
13
14
15
15a
15b
17
18
28
30
30a
31
31a
37
38
P
a
b
α

FIG. 35

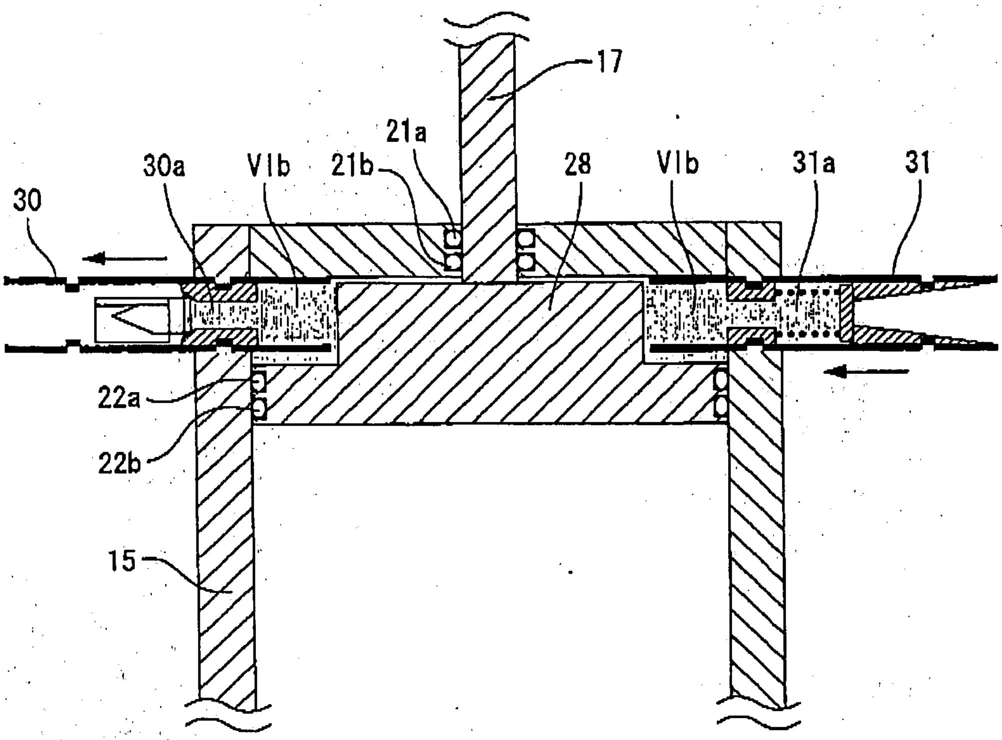
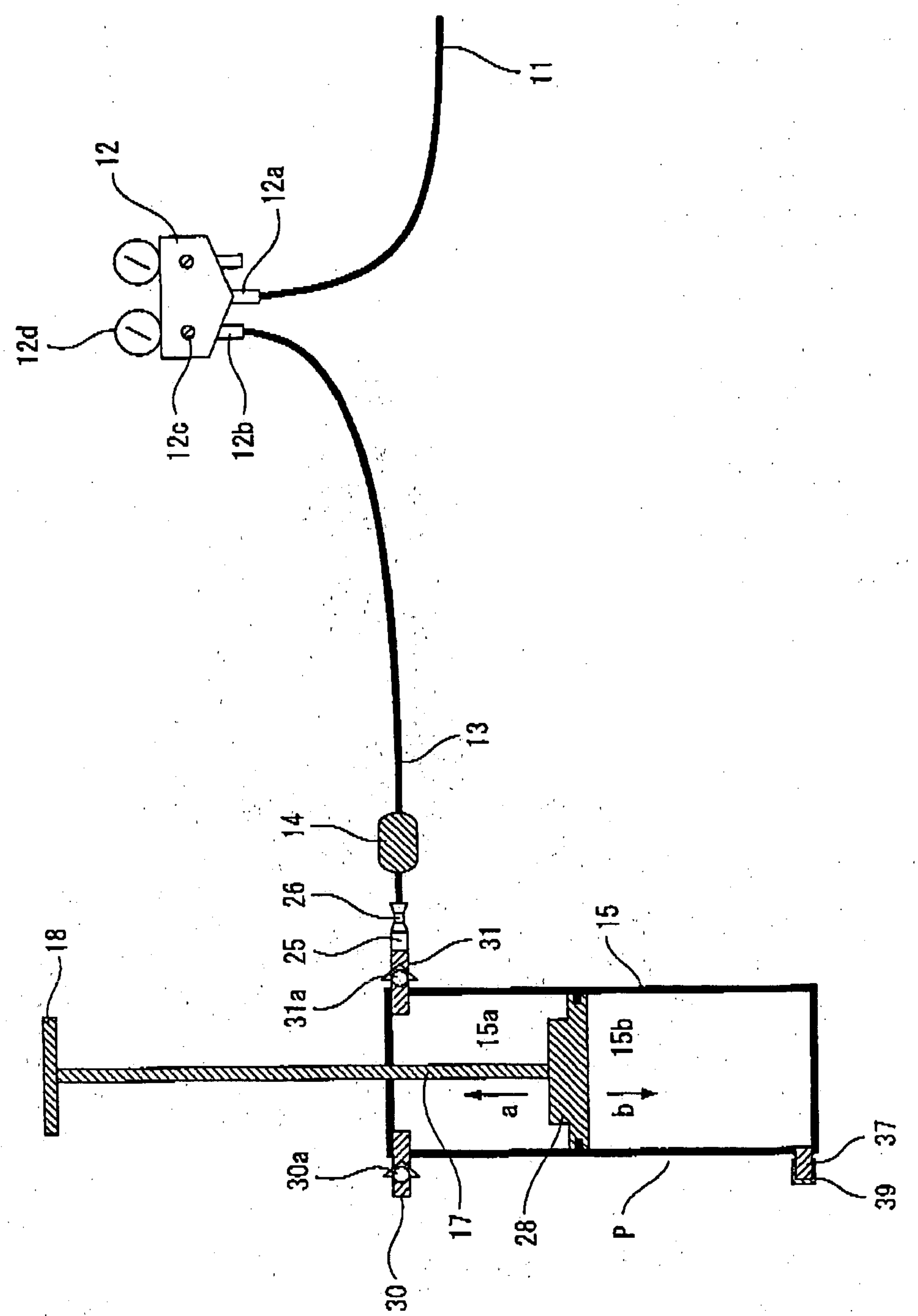


FIG. 36


11
12
12a
12b
12c
12d
13
14
15
15a
15b
17
18
25
26
28
30
30a
31
31a
37
39
a
b
P