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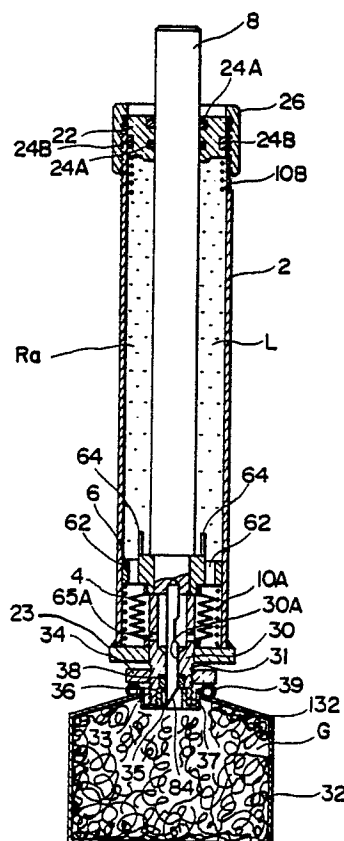
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⑤4 A thermally responsive actuator.

57) A thermally responsive actuator comprises a barrel (2) which is disposed in an atmosphere in which temperature changes take place. There is a slidable piston (6) within the barrel (2), and a thermally expansive material (6) sealed in the barrel (2), which causes the piston (6) to slide by thermal expansion and thermal contraction due to temperature changes. An extension rod (8) is secured to the piston (6) which slides together with the piston (6). Spring means (10) between relative slide members within the barrel (2) act to cancel the starting frictional force created on the sliding faces.

FIG. 1



A THERMALLY RESPONSIVE ACTUATOR

The present invention relates to an actuator having a fast thermal response which is used for opening a roof window for room ventilation, for closing a shut-down door on fire, for opening and closing a dumper used in a duct of refrigeration facilities and relates to a thermally responsive actuator which automatically operates in quick response to changes in ambient temperature and relates to an apparatus for automatically opening and closing a roof window, using the thermally responsive actuator.

The temperature may become unexpectedly high in a vinyl house or greenhouse which is not provided with an air vent for enhancing a heating effect in winter or a factory which is not provided with a window in order to prevent noise leakage. Accordingly, these buildings are provided with a window and a door so that ventilation is carried out by frequently opening and closing the window or door to prevent high temperature problems.

On the other hand, in large buildings such as hotel having passages, the passages are provided with shut-down doors for fireproofing so that the passages can be shut-down by the shut-down doors on fire.

The adjustment of the cooling temperature at the refrigeration facilities is generally carried out by opening and closing, in a suitable manner, a dumper disposed in a duct along which coolant is fed into a refrigeration chamber.

However opening and closing of the roof window is generally carried out at any time by an operator who operates a mechanism such as electric apparatus or hydraulic actuator. In order to accomplish the automation of these operations both a thermal sensor and an opening and closing control mechanism should be provided in addition to aforementioned apparatus for opening and closing the roof window, resulting in complication of apparatus and increase in cost of facilities.

The structure of the shut-down door opening and closing apparatus should be able to be automatically operated in view of the fact that it is used in an emergency such as fire. But it is a matter of course that problems similar to those mentioned above will occur.

Most of temperature controls of refrigeration facilities have been already automated. These involve same problems similar to the case of automation of the opening and closing of the roof window or shut-down door.

In order to solve the problems, the present inventor noticed materials having a high thermal expansion coefficient such as fron and made this invention after researching whether an automatic

operation of the closing and opening apparatus would be possible without using a thermal sensor and an opening and closing control mechanism if such materials may be used as a moving source for the opening and closing apparatus.

The present invention was made in view of the aforementioned problems. It is the first object of the present invention to provide a thermally responsive actuator having an excellent response which quickly responds to ambient temperature. It is the second object of the present invention to provide an apparatus for automatically opening and closing a door, shut-down door or dumper by simple facilities and at a low cost and in a high accuracy.

In an aspect of the present invention there is provided a thermally responsive actuator comprising; a barrel which is disposed within an atmosphere in which temperature changes take place; a piston which is slidably disposed in the barrel; a thermally expansive material sealed in the barrel, which causes the piston to slide by thermal expansion and thermal contraction due to temperature changes; an extension rod secured to the piston which slides together with the piston; and spring means interposed between relative slide members in the barrel, which acts to cancel the starting frictional force created on the sliding faces.

In another aspect of the present invention, there is provided an apparatus for automatically opening and closing a roof window in response to an ambient temperature of a barrel comprising; a barrel which is disposed in an atmosphere in which temperature changes take place; a piston slidably disposed in the barrel; a thermally expansive material sealed in the barrel which causes the piston to slide by thermal expansion and contraction due to temperature changes; an extension rod secured to the piston which slides together with the piston; a roof window which is closed or opened in response to the sliding operation of the extension rod; and spring means interposed between relative sliding members in the barrel, which acts to cancel the starting frictional force created on the sliding faces.

The thermally expansive material which is used as drive source of the actuator includes liquid or gas having a high thermal expansion coefficient. Various material may be used depending upon the usage of the present actuator. If freon having a boiling point near the room temperature such as R11 (boiling point 23.77°C), R21 (boiling point 8.92°C), R113 (boiling point 47.57 °C), R114 (boiling point 3.55°C) is used, and these freons are sealed in a barrel, they thermally expand and contract

(liquid to gas, gas to liquid) at a room temperature by sliding the piston to extend the extension rod so that automatic opening and closing of the roof window and shut-down door can be accomplished.

Since 18cc (18g) of water boils at 100 °C and becomes 22.41 (22400cc) of steam, water may be sealed and used for an apparatus for opening and closing the shut-down door.

Since butane (C_4H_{10}) has a boiling point of $-0.5^\circ C$ and 58g of liquid butane expands into 22.41 by vaporization, it can be used for an apparatus for opening and closing a dumper for circulating the coolant in refrigeration facilities if it is charged into a barrel. Since ammonia similarly expands and contracts at a vaporization temperature of $-33^\circ C$, similar use is possible.

Of course, liquid of gas which exhibits remarkable expansion and contraction without involving transformation from liquid to gas and vice versa may be used. Hydrogen which is sealed as gas may be used. In this case, a hydrogen absorption alloy of Ti-Fe system is put into the barrel so that the hydrogen which is absorbed by or emitted from the alloy may be used.

In a first type of actuator in which a piston is slid by the thermal expansion and contraction, an extension member such as bellows is disposed within a barrel. A thermally expansive material is sealed in the extension member so that a piston is caused to slide by the extension of the extension member. In a second type of actuator, the pressure receiving areas of the front and rear sides of a piston which is disposed in the barrel are made different so that the piston is caused to slide by using the pressure difference created by the thermal expansion and contraction of the thermally expansive material. In a third type of actuator, the piston is disposed in a barrel so that it may slide in an air-tight manner and one of two chambers defined in the barrel by the piston is filled with a thermally expansive material and the other chamber is opened to atmosphere so that the piston is caused to slide by the thermal expansion and contraction of the thermally expansive material.

In accordance with the present invention, a thermally expansive material such as iron sealed in the barrel thermally expands and contracts depending upon the ambient temperature of the barrel so that it causes a relative slide of the barrel and the piston to lift and lower the extension rod. Although a starting frictional force is created at the relative sliding interfaces between the piston and the barrel and between the extension rod and the barrel simultaneously with the elevation of the ambient temperature of the barrel prior to starting of the piston, the piston can be started without being influenced by the starting frictional force since a spring in the barrel acts to cancel the starting

frictional force. Accordingly the piston slides quickly and positively in response to the ambient temperature of the barrel.

In the drawings:

Fig. 1 is a longitudinal sectional view showing a thermally responsive actuator of a first embodiment of the present invention;

Fig. 2 is an enlarged sectional view showing a part of the actuator shown in Fig. 1;

Fig. 3 is a longitudinal sectional view showing the operation of the actuator;

Fig. 4 is a sectional view showing the connection of a barrel with a liquid iron containing tank;

Fig. 5 is a perspective view showing an example in which the thermally responsive actuator of the first embodiment is applied to a roof window opening and closing mechanism;

Fig. 6 is a longitudinal sectional view showing a thermally responsive actuator of a second embodiment of the present invention;

Fig. 7 is a longitudinal sectional view showing a thermally responsive actuator of a third embodiment of the present invention;

Fig. 8 is a longitudinal sectional view showing a thermally responsive actuator of a fourth embodiment of the present invention;

Fig. 9 is a longitudinal sectional view showing a thermally responsive actuator of a fifth embodiment of the present invention;

Fig. 9(a) is a longitudinal sectional view showing the essential parts of the thermally responsive actuator in which a part of the fifth embodiment is improved;

Fig. 10 is a longitudinal sectional view showing a thermally responsive actuator of a sixth embodiment of the present invention;

Fig. 11 is a longitudinal sectional view showing the operation of the actuator shown in Fig. 10;

Fig. 12 is a longitudinal sectional view showing a thermally responsive actuator of a seventh embodiment of the present invention;

Fig. 13 is a longitudinal sectional view showing the situation of the operation of the actuator shown in Fig. 12;

Fig. 14 is a longitudinal sectional view showing a thermally responsive actuator of an eighth embodiment of the present invention;

Fig. 15 is a longitudinal sectional view showing a thermally responsive actuator of a ninth embodiment of the present invention;

Fig. 16 is a longitudinal sectional view showing a thermally responsive actuator of a tenth embodiment of the present invention.

In Figs. 1 to 4, a thermally responsive actuator of a first embodiment of the present invention comprises a barrel 2 disposed in an atmosphere, of which the temperature changes without artificial

heating or cooling means, an extension bellows 4 disposed in the barrel 2, from gas G sealed in the bellows 4, piston 6 inserted in the barrel 2, which slides in upward and downward directions in response to the extension of the bellows 4, an extension rod 8 secured to the piston 6, which extends through an upper lid 22 of the barrel 2 and protrudes upward, and compression coil springs 10 (10A, 10B) provided at the upper and lower ends of the barrel respectively.

A term "an atomosphere, of which the temperature changes without artificial heating or cooling means" means vinyl house or greenhouse in which the temperature difference takes place due to temperature changes between day and night and passages in buildings and the like in which temperature changes are expected due to fire and includes liquid and gas.

The barrel 2 is made of a metal having an excellent thermal conductivity such as iron, copper, aluminium and filled with a lubricating oil L. A reference numeral 24A represents a sealing member which prevents the lubricating oil in the barrel 2 from leaking, 24B a sealing member which seals the lubricating oil within the barrel 2, 26 a stopper member of the upper lid 22 screwed on the outer periphery of the upper end of the barrel 2.

The piston 6 which is disposed within the barrel 2 has an appropriate number of communication holes 62 extending vertically. An upper chamber Ra and a lower chamber Rb of the barrel which are divided by the piston 6 are communicated with each other via the communication holes 62 so that the piston 6 is smoothly slidable in a vertical direction along the inner periphery wall of the barrel 2. An abutting member 64 is provided on the upper end face of the piston 6 so that it projects therefrom. The piston 6 is stopped at the uppermost limit position when the abutting member 64 abuts on the lower face of the upper lid 22.

The extension rod 8 which passes through the upper lid 22 and extends in an upward direction is disposed in the barrel 2. the extension rod 8 is secured to the piston 6 at the lower end thereof so that it is integral with the piston 6. The lower end 82 of the extension rod 8 passes through the piston 6 so that it slightly projects beyond the lower face of the piston 6. A barrel bottom plate 23 which is opposed to the lower end 82 of the rod is provided with a cylindrical tank connector 30 which is a from gas supply port.

The lower end 82 of the rod is connected to the tank connector 30 through a cylindrical bellows 4. The from gas G which is a thermally expansive material is supplied into the bellows 4 from the tank connector 30. The bellows 4 is air-tight so that the inner from G will not be leaked. The bellows 4 has such a structure that it may be extended from

a contracted position as shown in Fig. 1 to an extended position in which the abutting member 66 abuts on the upper lid 22. The bellows 4 is made of a material such as fluorine rubber, which is not corroded by the from gas G contained therein.

The bellows 4 is dipped in the lubricating oil L sealed in the barrel 2. When the pressure of the from gas in the bellows 4 increases due to its thermal expansion, the force lifting up the piston 6 acts upon the lower face of the piston 6. The increased pressure due to thermal expansion of the from will efficiently act on the lower face of the piston while the bellows 4 does not expand in a lateral direction since the lubricating oil L surrounding the outer periphery of the bellows 4 is non-compressive and the barrel is hermetically sealed.

The extension rod 8 is provided with a needle 84 at the lower end 82 thereof. The needle 84 is in the form of hollow pipe and is formed with an obliquely cut tip end and a notch 84B extending along a hollow portion without being influenced by the starting friction when the piston 6 begins to move. The compression coil springs 10(10A, 10B) also function as absorbing members which absorb impacts created when the piston 6 stops at the uppermost (or lowermost) position and function to prevent in cooperation with the abutting member 65 an unwanted strong force from acting on the contracting bellows 4.

The lower end of the tank connector 30 projects downward beyond the barrel bottom plate 23. A liquid from containing tank 32 which is shown in Figs. 1, 3 and 4 is connected to the downward projecting portion 31 which is formed with an externally threaded portion 33 at the outer periphery thereof. A connector fastening nut 34 is screwed on the externally threaded portion 33. An internally threaded portion 33 is formed at the inner periphery of the lower end of the communication hole 30A formed in the tank connector 30. A connector receptacle projection 36 which is formed at the upper end of the tank 32 is adapted to be threaded with the internally threaded portion 35. That is, the externally threaded portion 37 is formed at the outer periphery of the connector receptacle projection 36. When the connector receptacle projection 36 is brought into engagement with the projecting portion 31 and the barrel 2 is rotated with relation to the tank 32, the internally and externally threaded portions 35 and 37 are brought into thread engagement with each other so that the connector receptacle projection 36 is threadably connected with the projection 31.

The upper end face 36A of the connector receptacle projection 36 is made thinner relative to the outer peripheral wall of the tank 32. When the projection 31 is brought into thread engagement with the connector receptacle projection 36 or after

they have been threadedly engaged, the needle 84 will break the upper end face 36A of the connector receptacle projection 36 by pressing the extension rod 8 downward. The inside of the tank 32 is then brought into communication with the inside of the bellows 4 via the hollow portion 84A of the needle 84 and the notch 84B. A packing 38 of flurine rubber is disposed within the innermost end of the externally threaded portion 35 of the cylindrical downward projection 31. When the barrel 2 is threadedly engaged with the tank 32, the outer peripheral edge of the upper end of the connector receptacle projection 36 will tightly adhere to the packing 38 so that a gas communication passage between the tank 32 and the connector receptacle projection 36 is brought into hermetical sealed relation for preventing the gas from leaking.

Reference numeral 39 represents a ring-shaped reinforcing frame member which is provided at the upper end of the tank 32 to surround the connector receptacle projection 36. An appropriate threading position of the connector receptacle projection 36 into the projection 31 may be confirmed by the fact that the reinforcing frame member 39 abuts on the lower side of the fastening nut 34 when the tank 32 is to be connected to the barrel 2. The threading connecting portion between the connector receptacle projection 36 and the projection 31 may be more firmly fastened by rotating the fastening nut 34.

Metal fiber integrated material 132 such as iron, copper having an excellent thermal conductivity is disposed in such a manner that it is in contact with the inner periphery of the tank 32 at the outer periphery thereof. The contact surface area between the inner wall of the tank 32 and the iron in the tank 32 is assured to be larger. This promotes the heat transfer between the iron in the tank 32 and the atmosphere around the tank 32 to provide a fast response of the actuator.

The operation of the thus formed actuator of the first embodiment will be described as follows:

Representing the load acting on the extension rod 8 as W , the biasing force of the compression coil spring 10 as F , the pressure in the tank 32 as P , the efficient receiving area of the piston 6 as A , and the total starting frictional force acting on the piston 6 and the extension rod 8 as f the sum of the upward forces acting upon the piston 6 may be represented as $PA + F$, and the sum of the downward forces acting on the piston 6 may be represented as $w + f$. The piston 6 begins to slide upward from the lowermost position when the temperature of the outer periphery of the tank 32 is elevated and the iron in the tank 32 and bellows 4 expands to increase its pressure so that $PA + F > w + f$. The piston 6 begins to slide at a predetermined pressure P without being subject to

resistance of the starting frictional force f when $PA > W$ since the biasing force F of the compression coil spring 10A is preset to be equal to the starting frictional force f . That is, when the ambient temperature of the tank 32 slightly exceeds the temperature T which is preset as a temperature at which the actuator begins to actuate, the piston 6 will slide to lift for pressing the compression coil spring 10B to reach at the uppermost position.

When the ambient temperature of the tank 32 is slightly lower than the preset temperature T , the pressure in the tank 32 becomes not higher than p , and the piston 6 is lowered. The piston 6 will be smoothly lowered at a given preset temperature T since the starting frictional force f is cancelled by the biasing force F of the compression spring 10B also when the piston 6 is lowered. The lower side of the piston 6 will press the spring 10A and abuts on the abut member 65 and then piston 6 stops.

In the afore-mentioned first embodiment there are following advantages.

(1) Accurate operation can be assured approximately at the preset temperature since the piston 6 is not influenced by the starting frictional force f .

(2) Pressure changes due to iron's thermal expansion or contraction acts on the piston 6 without loss so that temperature changes are efficiently converted into the sliding force of the piston 6 since the lubricating oil L is sealed in the barrel 2 and the bellows 4 is disposed in the lubricating oil.

(3) Since the barrel 2 is filled with the lubricating oil L in lieu of iron gas G , the adhesion properties of the sealing member 24A may be loosened so far as liquidtight is assured. This enhances slidability of the sealing member 24A to decrease starting frictional force and sliding frictional force for assuring accurate operation at a preset temperature.

(4) The bellows 4 is supplied with iron by connecting the tank connector 30 with the tank 32. The iron may be readily charged into the bellows without making thermally expansive material thinner such a iron since bellows 4 is brought into communication with the tank 32 under the condition in which the bellows 4 is contracted.

(5) Since charging of the iron gas into bellows 4 may be easily carried out in site, safe transportation of actuator components to the site would become possible without any fear of gas leakage due to vibration on transportation in comparison to the type in which iron gas is preliminarily sealed in the barrel if a iron gas containing tank is connected with a barrel in site.

A lubricating oil L is sealed in the barrel 2 in this embodiment. Water, air and other liquid or gas may be sealed.

Compression coil springs 10 (10A, 10B) are

provided at the barrel's bottom plate 23 and barrel's upper lid 22 respectively. However the springs 10A and 10B may be provided at the lower and upper sides of the piston 6 respectively.

The thermally expansive material which is sealed in the tank 32 is not limited to iron gas, but may be water, butane, ammonium, hydrogen absorption alloy and other liquid or gas having a high thermal expansion coefficient.

Fig. 5 shows an embodiment of an apparatus for automatically opening and closing a roof window in which a thermally responsive actuator is used as a drive source for opening and closing a roof window, provided at the top of the roof of a vinyl house.

At the top of a vinyl house, frame pipes (lateral pipes 202, 204 and longitudinal pipe 206) which form a framework intersect with each other. A roof window supporting frame 208 is secured to the intersections by suitable means such as welding.

Two lateral supporting levers 212 and four longitudinal supporting levers 214 are secured to the supporting frame 208. The thermally responsive actuator in the first embodiment is secured to the supporting frame 208 by means of these supporting levers 212 and 214. That is, the actuator is supported in such a manner that it is suspended on the ceiling of the vinyl house via the supporting levers 212 and 214. A roof window 210 which just fits to the supporting frame 208 is bolted to the tip end of the extension rod 8 so that the window 210 may be vertically slid together with the rod 8. The supporting frame 208 and the roof window 210 which is engaged therewith are both in a true-circular shape so that they are normally enable to be fitted with each other even when the extension rod 8 is rotated on a horizontal face to rotate the roof window 210 with respect to the supporting frame 208.

Reference numeral 216 represents a fixing which fixes the upper end of the barrel 2 of the actuator on the lateral supporting lever 212 and reference numeral 218 represents a fixing for fixing the lower end of the barrel 2 on the longitudinal supporting lever 214. In order to secure the actuator to the supporting frame 208, the barrel is first fixed through the supporting levers 212 and 214. Then the tank 32 is screwed into the barrel 2 for making the barrel 2 and the tank 32 integral with each other.

In thus formed roof window opening and closing mechanism, the total weight of the roof window 210, the extension rod 8, an adjustment weight and the like act on the piston 6, and the biasing force of the compression coil springs 10 (10A, 10B) and the sort of the iron gas in the tank 32 are predetermined so that the roof window 210 is opened or closed below and above approximately

35°C.

Such a roof window opening and closing mechanism will causes the roof window 210 to start to open when the temperature in the vinyl house reaches at 36 to 37 °C and then to fully open soon. When the temperature in the vinyl house is 33 to 34 °C the roof window 210 begins to lower from the uppermost position and then is brought into a full closed position soon. That is, opening and closing of the roof window 210 can be carried out in a range of a slight error (2°C) at 37 °C (33°C on return) in the vicinity of 35°C.

The different plants have different temperatures as an optimum for breeding the plants in the vinyl house, for example 18 to 26°C for strawberry, 20 to 26°C for tomato and 26 to 30°C for melon in day time. Accordingly it is preferable to adjust the stroke of the piston 6 and reciprocation starting temperature by changing the sort of thermally expansive material such as iron in the tank 32, the weight of a weight member incorporated in the extension rod 8 and the biasing force of the compression spring 10A and 10B in such a manner that the actuator will operate in an optimum condition for each of plants.

Fig. 6 is a partially cutaway and longitudinal sectional view showing a thermally responsive actuator of a second embodiment of the present invention.

In the drawing, reference numeral 4A represents a bellows disposed between the upper lid 22 of the barrel 2 and the piston 6. The bellows 4A is airtight and is of the type in which a relative sliding portion between the upper lid 22 communicated with the inside of the bellows 4A and the extension rod 8 isolated from the lubricating oil L in the barrel 2.

Therefore, there is no fear of oil leakage from the relative sliding portion between the upper lid 22 and the extension rod 8. At the bearing of the extension rod 8, a highly slidable sealing member 24C is used in place of the sealing member 24A which is used in the first embodiment. The starting friction and sliding friction at the relative sliding portion between the upper lid 22 and the extension rod 8 is suppressed very low. Since the other structure is identical with those in the first embodiment and like components are represented by like numerals, the explanation of them is omitted herein.

Use of rolling bearing at the sliding portion between the extension rod 8 and upper lid 22 furthermore reduce the starting friction and sliding friction. This can assure the low error operation of the actuator at the preset temperature.

Fig. 7 shows a third embodiment of present invention.

In both first and second embodiments, the

lubricating oil L is sealed in the barrel 2. In the third embodiment, the barrel 2 is formed with an air bleeding hole 28. The inside of the barrel 2 is opened to the atmosphere via the air bleeding hole 28. The piston 6a is slid along the inner periphery of the barrel 2. The air in the barrel 2 may be transferred each other via the slide face. Since the other structure is identical with that of the second embodiment and the like components are represented by like numerals, its explanation will be omitted herein.

In such a manner the third embodiment has a feature that the structure of the actuator is very simplified in comparison with those in the aforementioned two embodiments. As is similar with the second embodiment, a sealing member 24C having an excellent slidability is interposed in a sliding portion between the extension rod 8 and the upper lid 22 so that the friction at the sliding face is low. As is similar with the explanation of the second embodiment, use of a rolling bearing at the sliding portion between the extension rod 8 and the upper lid 22 reduces frictional resistance.

Fig. 8 shows the details of the fourth embodiment of the present invention. The bellows 4 is cylindrical in any of first to third embodiments, while the bellows 4B is blind at the upper end thereof. The bellows 4B is secured to the lower side of the piston 6 at the upper end thereof. The bellows 4B is normally in contact with the piston 6. The bellows 4B is formed at the lower end thereof with a diameter reduced projection 42 which is a fron charging inlet. The hole 23A is bored at the center of the bottom plate 23 of the barrel 2. The diameter reduced projection of the bellows 4 is secured to the inner periphery of the hole 23A. The diameter reduced projection 42 is internally threaded at the inner periphery thereof. After the fron is charged into the bellows 4B from the diameter reduced projection 42, the bellows 4B can be sealed by a plug 44.

Although a member which corresponds to the abutting member 65 in the afore-mentioned embodiments is provided due to lacking in space, there is no problem since the piston 6 is supported from lower side by the compression coil spring 10A. Alternatively a member which corresponds to the abutting member 65 may be provided in such a manner that it projects from the underside of the piston 6 or the inner periphery of the barrel 2. Since the other structure is identical with that in the first embodiment and like components are represented by like numerals, the explanation will be omitted herein.

Since in this embodiment there is no components which correspond to the tank 32 shown in the first and the second embodiments, the actuator may be made compact.

Fig. 9 shows a fifth embodiment of the present invention.

In the drawing, the barrel 2 is airtight. A liquid fron containing tank 32 is connected to a lower projection 31. Fron is directly charged into the barrel 2. Accordingly the sealing members 24A₁, 24B₁ have an enough sealability to keep airtight. The piston 6 is formed with communication holes 62. The upper and lower chambers Ra and Rb which are divided by the piston 6 are communicated with each other via the communication hole 62 so that the piston 6 may smoothly slide upward and downward. The pressure receiving area of the lower side of the piston 6 is larger than that of the upper side thereof by the cross sectional area of the extension rod 8. Accordingly, when the pressure of the fron gas in the barrel 2 changes, the balance of the upward and downward forces is lost so that the piston 6 and barrel 2 will relatively slide in an upward and downward directions.

A compression coil springs 10A and 10B are secured to the lower and upper sides of the piston 6 respectively. The springs 10A and 10B are adapted to cancel the starting frictional force when the piston 6 begins to move at the lowermost and uppermost positions respectively.

Since the other structure is identical with that in the first embodiment and like components are represented by like numerals, the explanation of them will be omitted herein.

The operation of the actuator of the fifth embodiment will be explained briefly.

Representing a load acting upon the extension rod 8 by W, a biasing force of the compression coil spring 10A₁(10B₁) by F, a pressure in barrel 2 by P, a cross sectional area of the extension rod 8 by a, pressure receiving area of the lower side of the piston 6 by A, the pressure receiving area of the upper side of the piston 6 by A-a, a total starting frictional force acting upon the piston 6 and the extension rod 8 by f, the sum of the upward forces acting on the piston 6 is $PA + F$ when the piston 6 begins to move from the lowermost position and the sum of the downward force acting upon the piston 6 is $P(A-a) + w + f$. The piston 6 begins to move upward when $PA + F > P(A-a) + w + f$. Since the biasing force F of the compression spring 10A₁ cancels the starting frictional force f, the piston 6 begins to move at a given pressure $P(>W/a)$ without being subject to resistance of the starting frictional force f.

Accordingly, it is possible to operate the actuator approximately at the preset temperature also in this embodiment.

Since in the fifth embodiment the piston 6 is adapted to directly slide by means of thermal expansion and contraction without using any extension member such as bellows 4, 4B in the barrel 2,

which are used in the first to fourth embodiments, the structure of the actuator is simplified.

While the compression springs $10A_1$ and $10B_1$ are secured to the upper and lower end faces respectively, they may be secured to the lower side of the upper lid 22 and the upper side of the bottom plate 23 as is done in the first embodiment of the present invention (refer to Fig. 1).

Fig. 9(a) shows a partially improved thermally responsive actuator of the fifth embodiment shown in Fig. 9. The barrel 2 is formed with a lubricating oil chamber 27 at the upper end thereof (upper portion of the upper lid 22). The relative slide portion between the upper lid 22 and the extension rod 8 is supplied with the lubricating oil in the lubricating oil chamber 27. Reference numeral 27A represents a lubricating oil supply inlet.

Airtight condition of the barrel which is filled with fron gas G should be assured for effectively operating the cylinder. In order to do so, an sealing member $24A_1$ having an excellent sealability which is inserted into the relative sliding portion between the upper lid 22 and the extension rod 8 is used. Accordingly the frictional force of the relative sliding portion becomes larger. Hence provision of a structure shown in Fig. 9(a) causes the relative sliding portion between the upper lid 22 and the extension rod 8 to be normally filled with the lubricating oil to enable the extension rod 8 smoothly to slide without involving shortage of oil irrespective of a long period of use over several years. As a result, it makes it possible to continue to use the actuator at a given preset temperature for a long period of time while preventing the sealing member $24A_1$ and the extension rod 8 from wearing.

Figs. 10 and 11 show a sixth embodiment of the present invention.

In the drawings, the first difference between the sixth embodiment and the fifth embodiment shown in Fig. 9 resides in that a tank 32A is formed at the lower end of the barrel 2A so that tank and barrel are integral with each other. Fron liquid is charged from the fron liquid charging inlet 42 which projects from the tank 32A. Fron is then sealed in the barrel 2A by sealing a plug 43. the second difference resides in that a compression coil spring $10B_2$ is secured to the upper lid 22 so that the piston 6 is supported by a compression coil spring $10A_2$ having a very longer free length than that of the compression coil spring $10B_2$.

A spring seat 44 is provided in such a manner that it projects from a branch between a piston sliding face of the barrel 2A and tank 32A. The compression coil spring $10A_2$ is interposed between the spring seat 44 and the lower side of the piston 6. The compression coil spring $10A_2$ has a free length when the piston 6 is in the uppermost stop position as shown in Fig. 11 and it is pressed

to provide an upward biasing force to the piston 6 when the piston 6 is the lowermost stop position as shown in Fig. 10. The compression coil spring $10B_2$ which is secured to the lower side of the upper lid 22 of the barrel has a length longer than that of the abutting member 64. The spring $10B_2$ is adapted to bias the piston 6 downward when the piston 6 is in the uppermost stop position as shown in the Fig. 11. The upward and downward biasing forces of the compression coil springs $10A_2$ and $10B_2$ act to cancel the starting frictional force when the piston 6 begins to move. Since the upward biasing force upon the piston exerted by the compression coil spring $10A_2$ acts until the piston 6 reaches at the uppermost stop position as well as when the piston begins to move, the upward sliding of the piston 6 is rapidly carried out.

Since the other structure is identical with that in the fifth embodiment and like numerals represent like components, the explanation of them will be omitted herein.

Figs. 12 and 13 show a seventh embodiment of the present invention. Although an upward biasing force is provided to the piston 6 by the compression coil spring $10A_2$ in the sixth embodiment, a tension coil spring 10C is interposed between the upper side of the piston 6 and the lower side of the upper lid 22 of the barrel 2 and the tension coil spring 10C provides the upward biasing force to the piston 6. The tension coil spring 10C is in a pulled position to act to cancel the starting frictional force when the abutting member 66 which projects from the lower side of the piston 6 abuts on the barrel bottom plate 23 and the piston 6 is in a lowermost stop position as shown in Fig. 12. The spring 10C is preset to have a free length when the piston 6 is in the uppermost position as shown in Fig. 13.

Since the other structure is identical with the sixth embodiment as shown in Figs. 10 and 11, and like numerals represent like components, the explanation of them will be omitted herein.

Since the piston 6 is usually subject to an upward biasing force by the tension coil spring 10C in the seventh embodiment, the piston may thus rapidly slide upward.

Fig. 14 shows an eighth embodiment of the present invention. The compression coil spring $10B_2$ which is secured to the upper lid 22 of the barrel and the abutting member 64 in the actuator structure (the sixth embodiment of the present invention) shown in Figs. 10 and 11 are omitted in this embodiment. The other structure is identical with that of the sixth embodiment shown in Figs. 10 and 11.

The compression coil spring $10A_2$ has a free length between upper lid 22 and the piston 6 is L_1 as shown in Fig. 14. When the piston 6 further as

cends so that it abuts on the upper lid 22, the compression coil spring 10A₂ is pulled to function as a tension coil spring to bias the piston 6 downward. Therefore the downward biasing force functions to cancel the starting friction when the piston 6 begins to descend. In other words the compression coil spring 10A₂ also functions as the compression coil spring 10B₂ shown in Figs. 10 and 11. Reference numeral 66 represents an abutting member which projects from lower side of the piston 6.

Fig. 15 shows a ninth embodiment of the present invention. This embodiment differs from the seventh embodiment shown in Figs. 12 and 13 in that the compression coil spring 10B₂ is omitted and a tension coil spring 10C is inserted between the upper side of the piston 6 and the lower side of the upper lid 22 of the barrel. The other structure is identical with the seventh embodiment shown in Figs. 12 and 13.

The tension coil spring 10C₁ has a free length when the piston 6 ascends so that the length between the piston 6 and the upper lid 22 is l_2 as shown in Fig. 15. When the piston 6 furthermore ascends so that the abutting member 64 abuts on the upper lid 22 of the barrel, the tension coil spring 10C₁ is compressed to function as a compression spring to bias the piston 6 downward. The downward biasing force exerted by the spring 10C₁ functions to cancel the starting friction when the piston 6 descends. In other words, the tension coil spring 10C₁ also functions as the compression coil spring 10B₂ shown in Figs. 12 and 13.

Fig. 16 shows a tenth embodiment of the present invention.

In the drawing, the piston 6A is adapted to slide along the inner periphery of the barrel 2 while it is in a close contact therewith. It is sealed in a barrel chamber Rb formed below the piston 6A. An air bleeding hole 28 is bored at the upper level of the side wall of the barrel 2 and the barrel chamber Ra which is above the piston 6A is open to the atmosphere so that the piston 6 can smoothly slide within the barrel 2 in an airtight manner by the thermal expansion and contraction of from gas in the barrel 2. Compression coil springs 10A₃ and 10B₃ are secured to the upper side of the barrel bottom plate 23 and the lower side of the upper lid 22 of the barrel respectively so that the actuator can operate without being subject to the starting friction by the action of the springs 10A₃ and 10B₃. A sealing member 24C having a same excellent slidability as that used in the aforementioned second and third embodiments (refer to Figs. 6 and 7) is interposed in a sliding face between the extension rod 8 and barrel upper lid 22.

Since the other structure is identical with that in the aforementioned embodiment and like numerals represent like component, the explanation of them

will be omitted herein.

In the fifth to tenth embodiment (Figs. 9 to 16), the pressure changes directly act upon the piston 6 (6A) to slide the piston 6 (6A). However starting and sliding friction resistance at the relative sliding faces between the piston 6 (6A) and the barrel 2 and between the extension rod 8 and the upper lid 22 can be reduced by adding a lubricating agent in front of gas and the response of the actuator can be thus made higher. Although the apparatus for automatically opening and closing roof window has been explained only with reference to the case in which the thermally responsive actuator of the first embodiment is applied to the opening and closing apparatus, an apparatus for automatically opening and closing a roof window having an excellent response may be provided even when any of the thermally responsive actuators of the second to tenth embodiments is applied thereto.

Claims

1. A thermally responsive actuator comprising;
a barrel which is disposed in an atmosphere in which temperature changes take place;
a piston which is slidably disposed within the barrel;

a thermally expansive material sealed in the barrel, which causes the piston to slide by thermal expansion and thermal contraction due to temperature changes;

an extension rod secured to the piston which slides together with the piston; and

spring means between relative slide members within the barrel, which acts to cancel the starting frictional force created on the sliding faces.

2. The thermally responsive actuator defined in claim 1 in which an extensive member such as bellows which expands and contracts in a sliding direction of the piston is disposed in the barrel, said thermally expansive material being sealed within the extensive member.

3. The thermally responsive actuator defined in claim 2 in which a noncompressive fluid is sealed around the outer periphery of the extensive member in the barrel.

4. the thermally responsive actuator defined in claim 3 in which the relatively sliding faces between the extension rod and the barrel is covered with a second extensive member such as bellows which interposed between the barrel and the piston in such a manner that it is isolated from the non-compressive fluid in the barrel.

5. The thermally responsive actuator defined in claim 2 in which the ambient around the extensive member in the barrel is communicated with the atmosphere.

6. The thermally responsive actuator defined in claim 1 in which the piston has two different pressure receiving areas at front and rear sides in a sliding direction in such a manner that it slides in the barrel due to pressure difference created by thermal expansion and contraction of the thermally expansive material.

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7. The thermally responsive actuator defined in claim 1 in which two barrel chambers are defined by the piston, one of the chambers being filled with the thermally expansive material, the other chamber being communicated with the atmosphere so that the piston slides in the barrel within an airtight manner.

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8. An apparatus for automatically opening and closing a roof window in response to an ambient temperature of the barrel comprising;
a barrel disposed in an atmosphere in which temperature changes take place;
a piston slidably disposed in the barrel;
a thermally expansive material sealed in the barrel for sliding the piston by thermal expansion and contraction due to temperature changes;
an extension rod secured to the piston which slides together with the piston;
a roof window which is closed or opened in response to the sliding operation of the extension rod; and

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spring means interposed between relative sliding members in the barrel to act to cancel the starting frictional force created at the sliding members.

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9. The apparatus defined in claim 8 in which the roof window is adapted to engage with a roof window supporting frame on a building such as vinyl house, the roof window and the roof window supporting frame being in the form of true circle.

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FIG.1 FIG.2 FIG.3

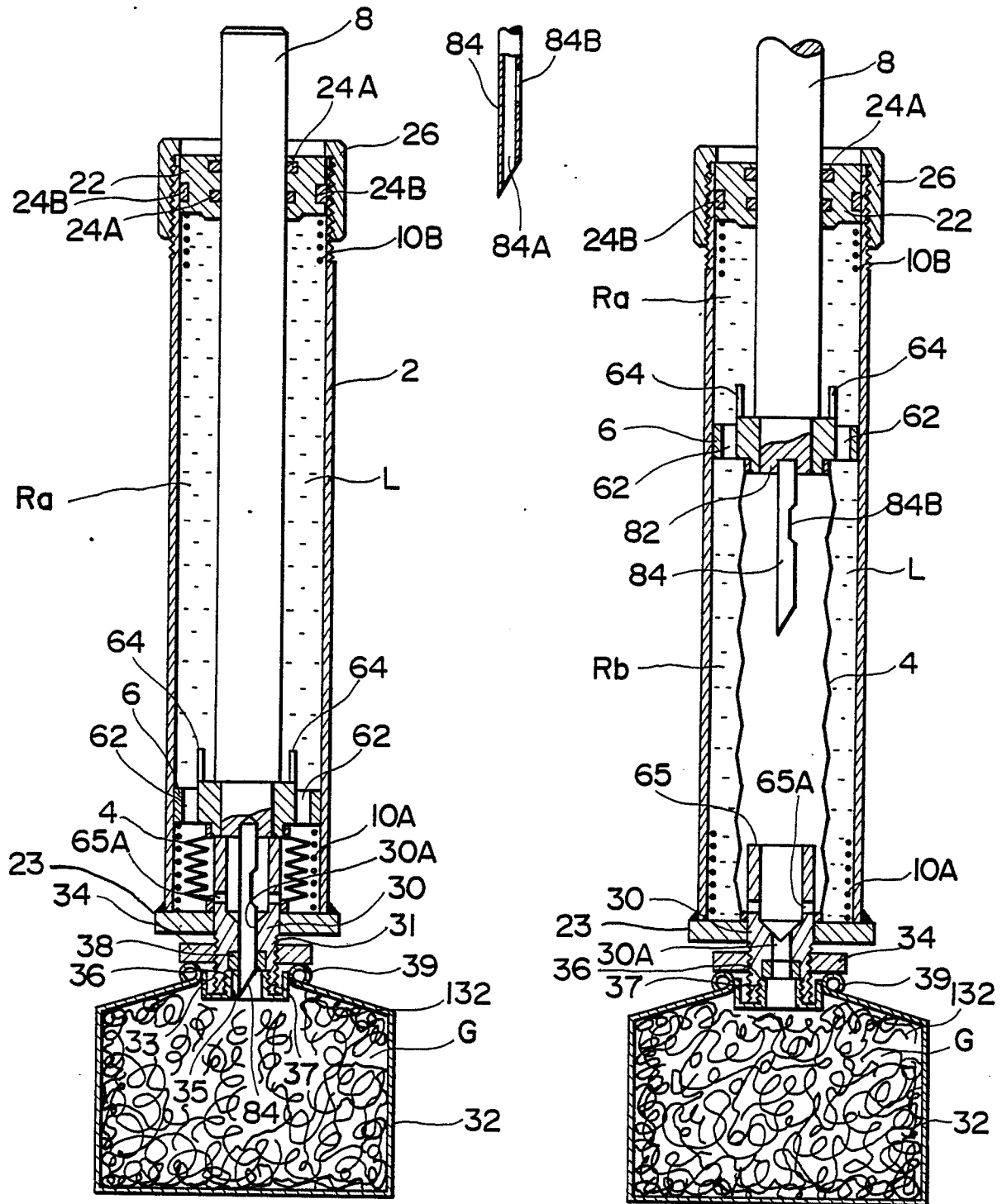


FIG.4

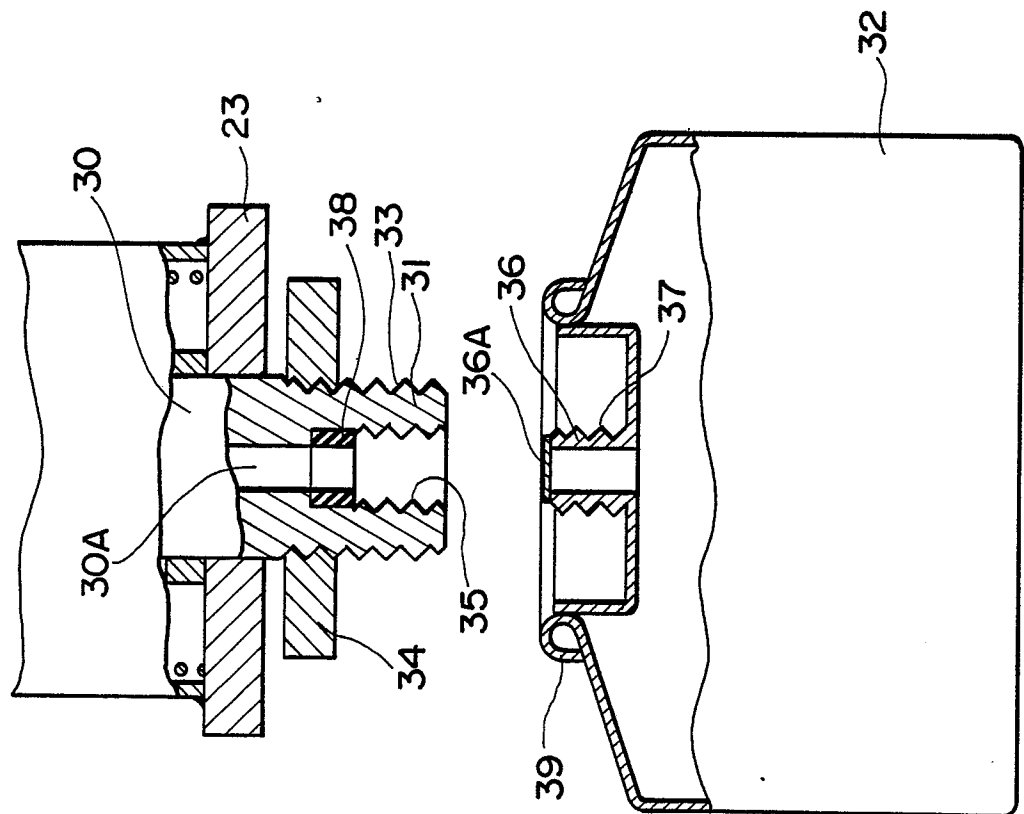
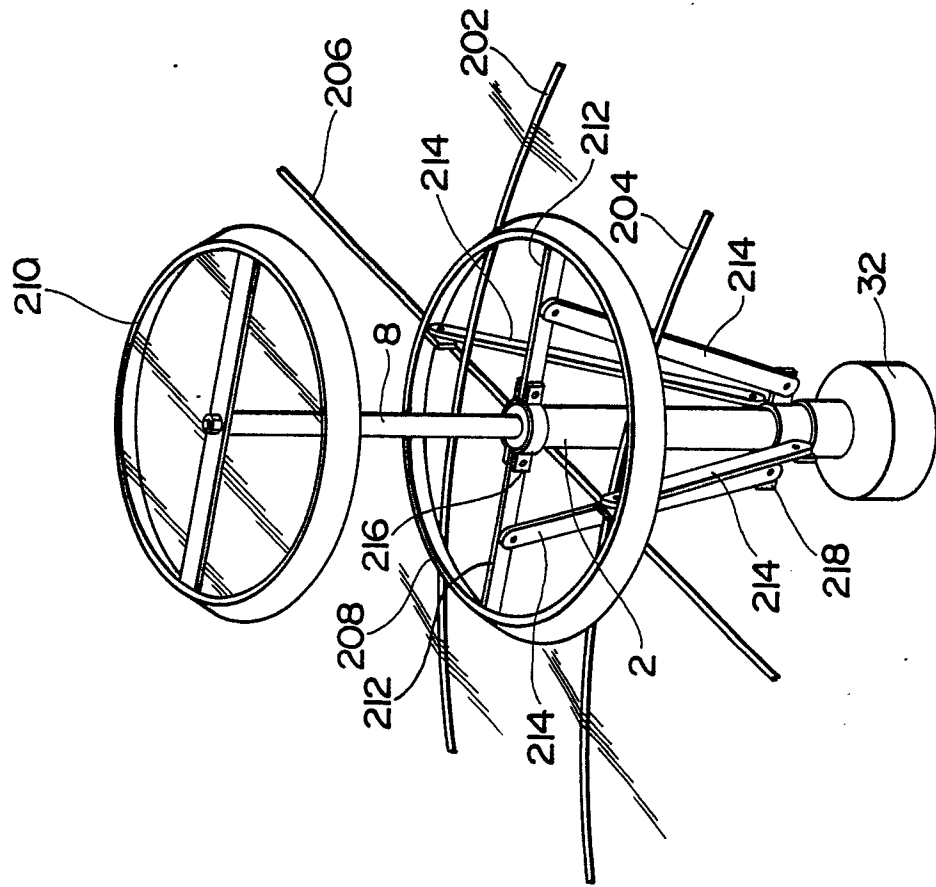


FIG.5



F I G. 6

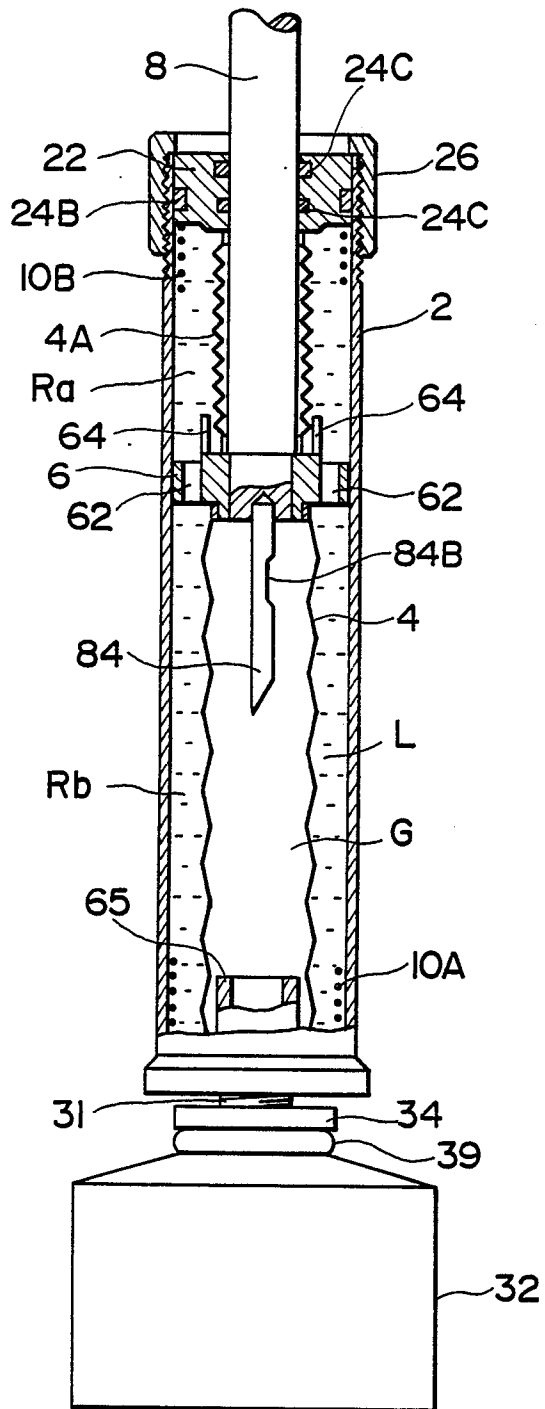


FIG. 7

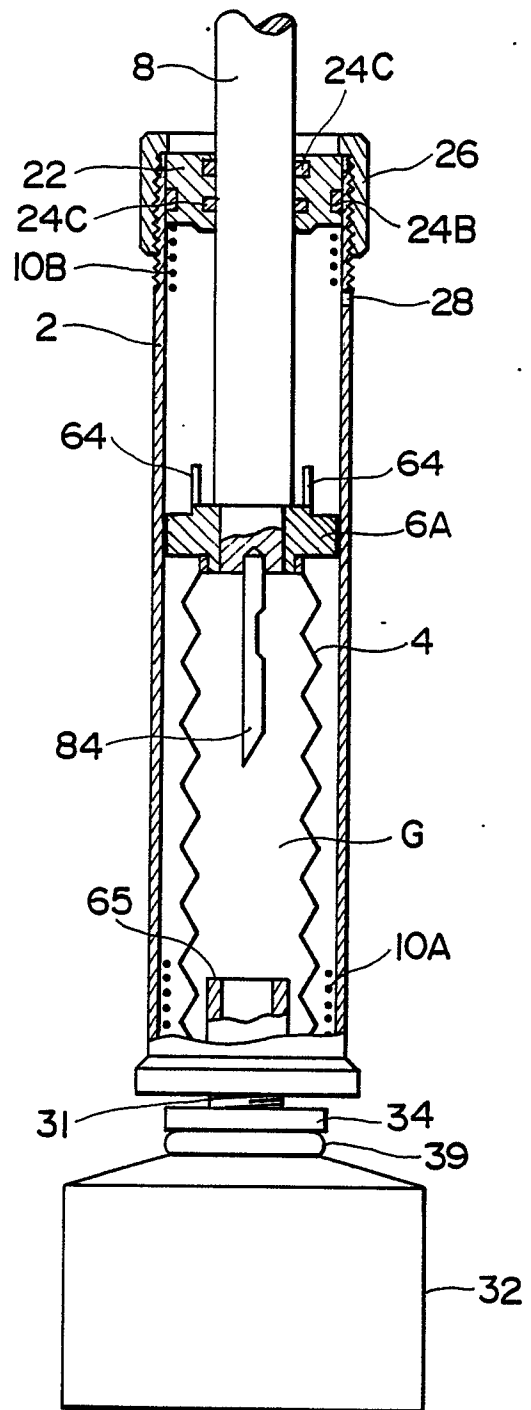


FIG. 8

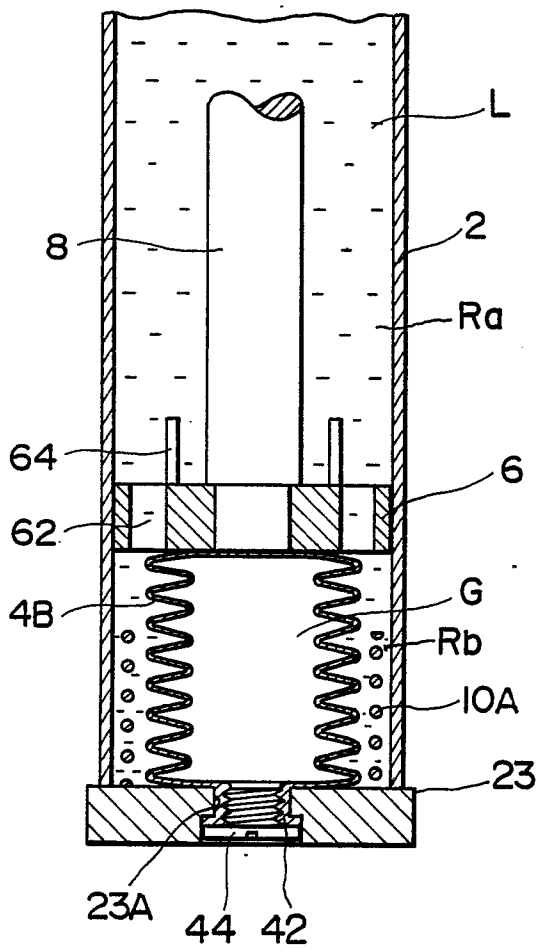


FIG. 9

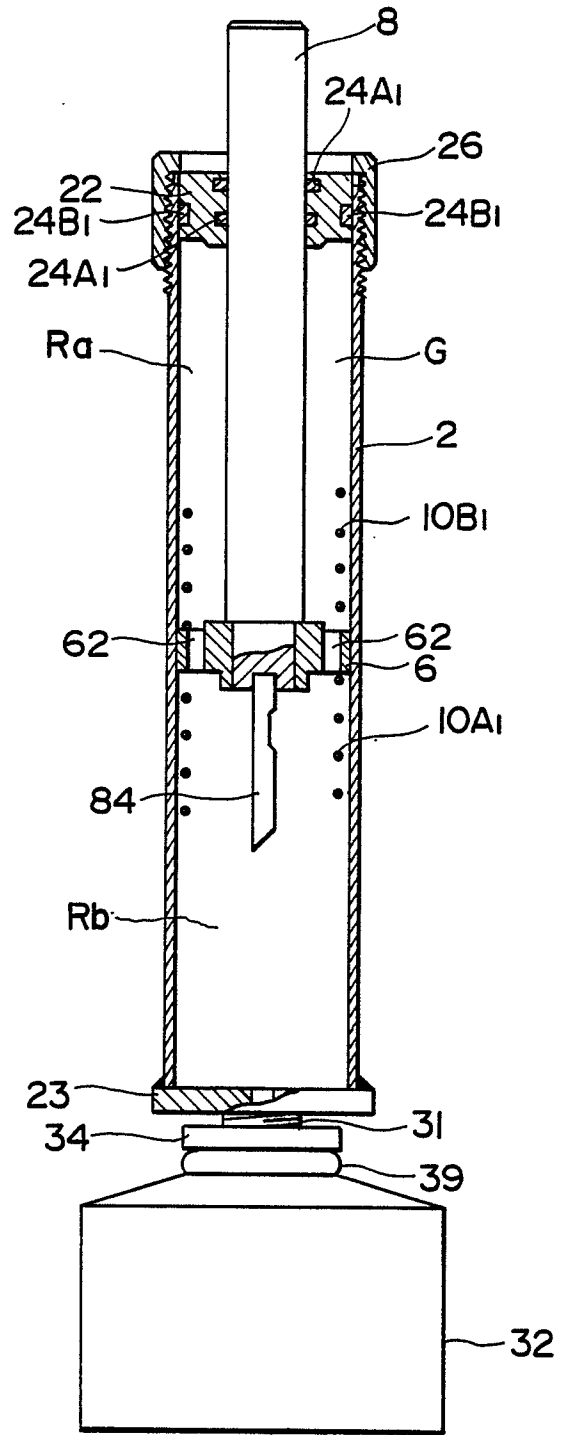


FIG. 9(a)

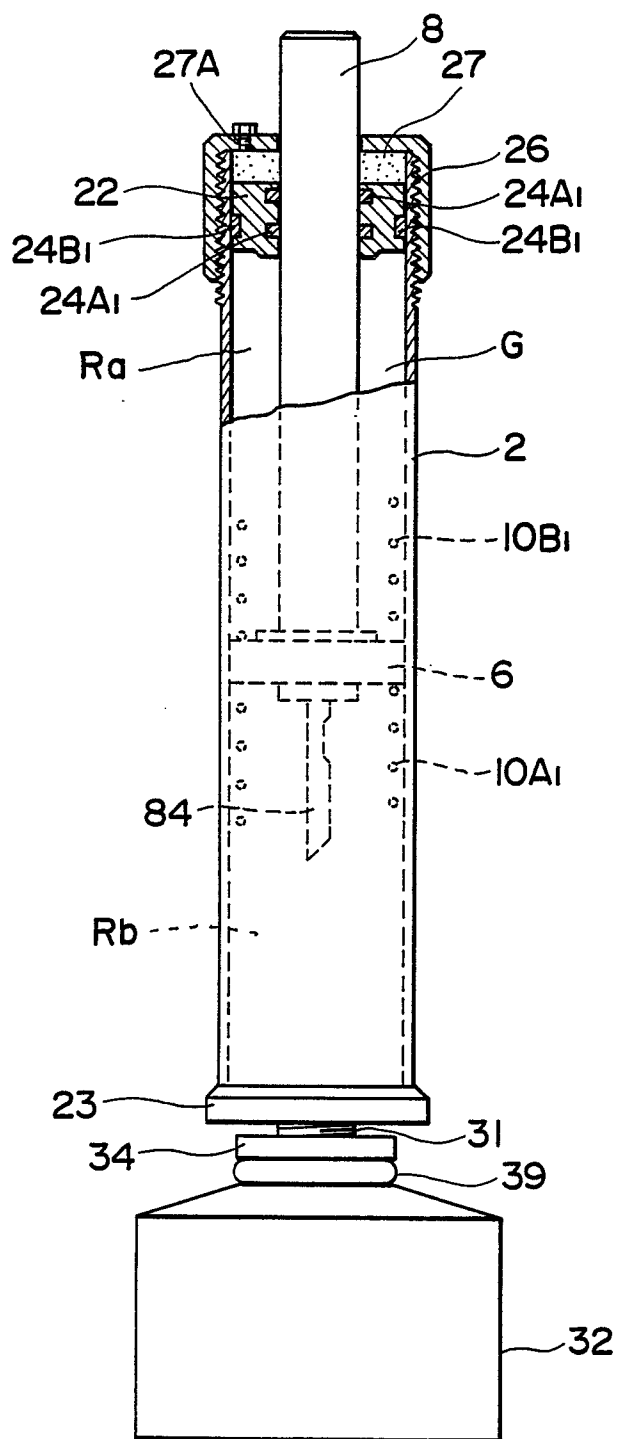


FIG. 10

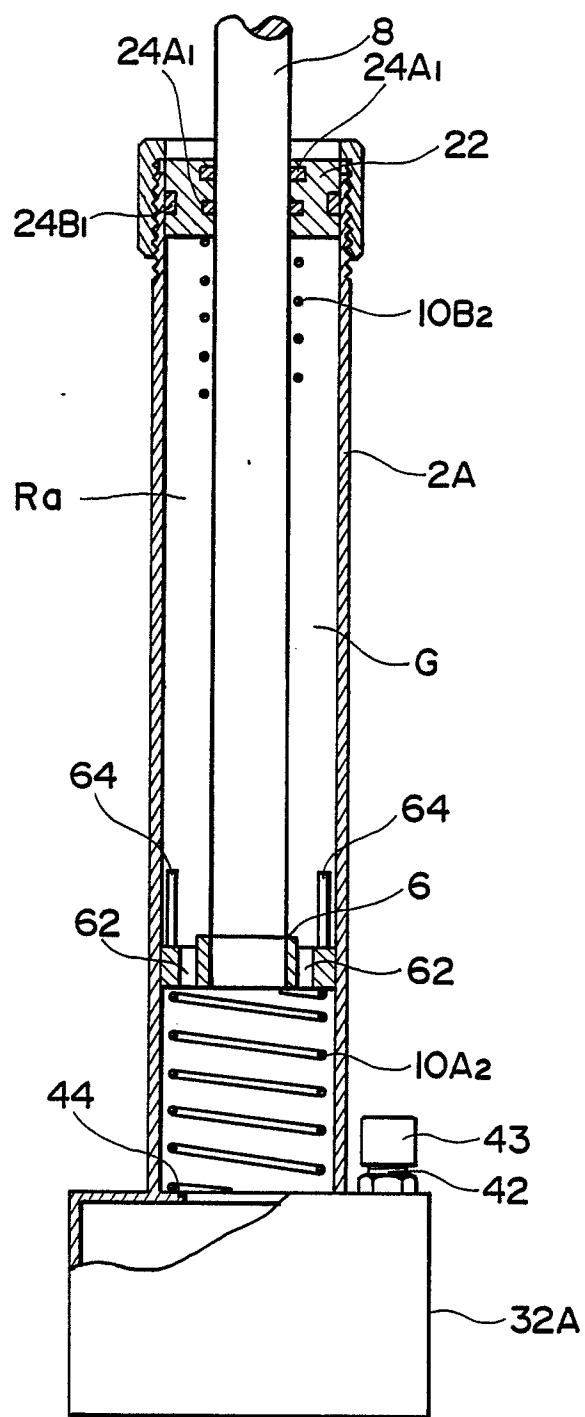


FIG. 11

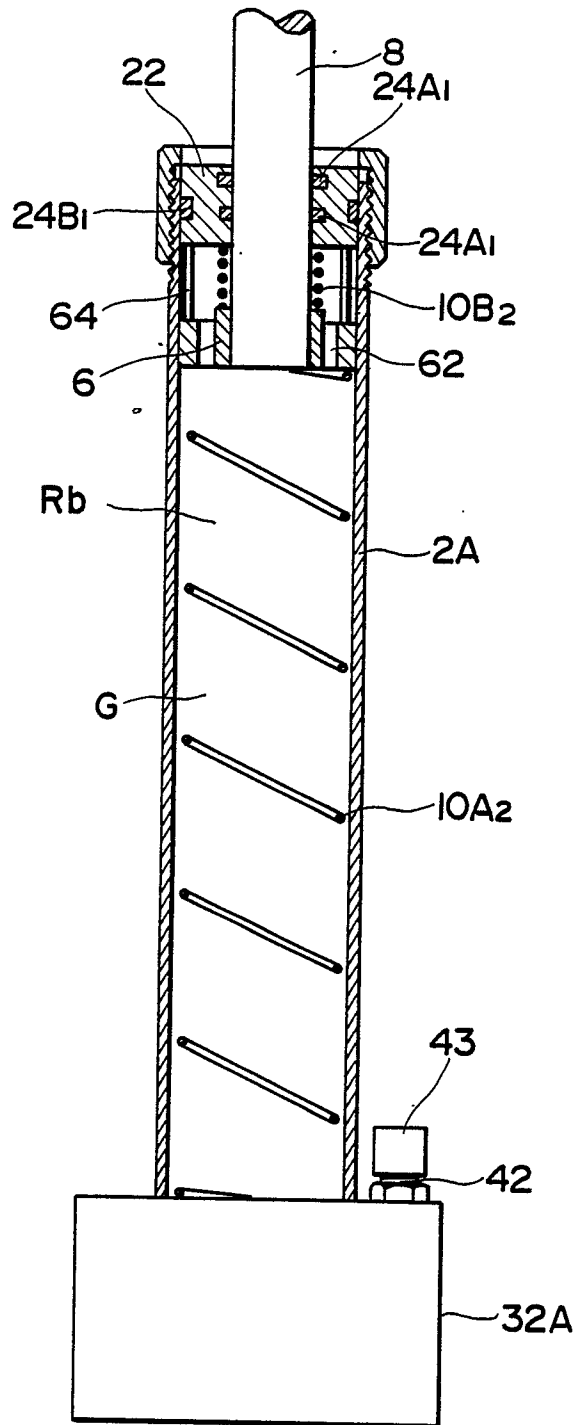


FIG. 12

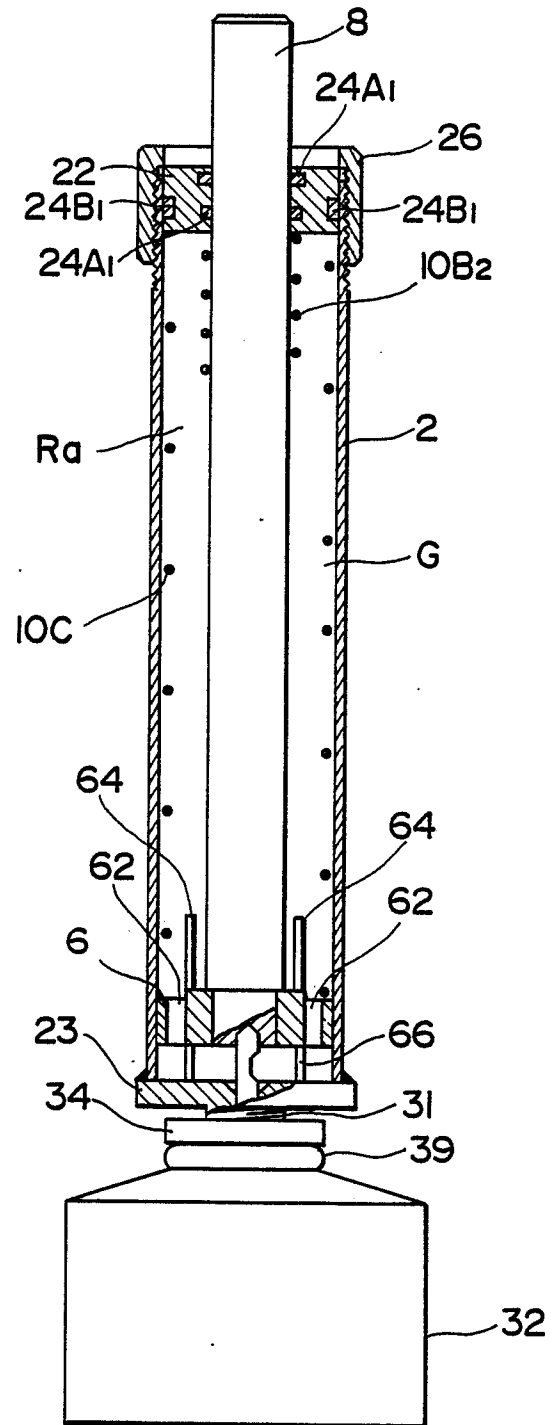


FIG. 13

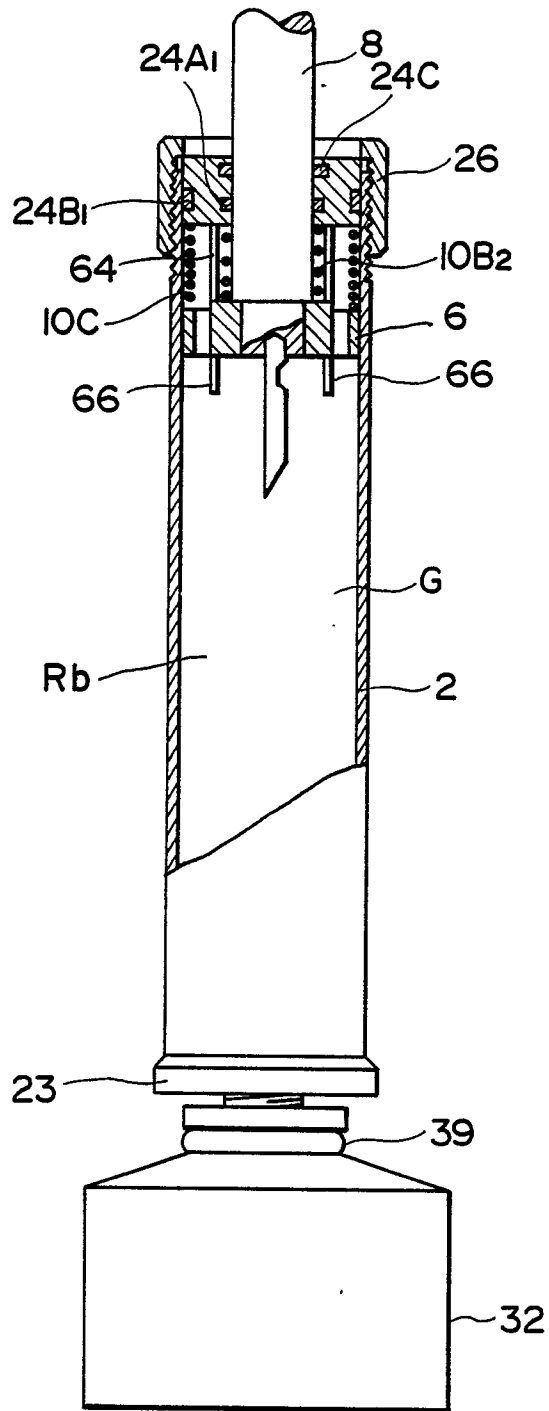


FIG. 14

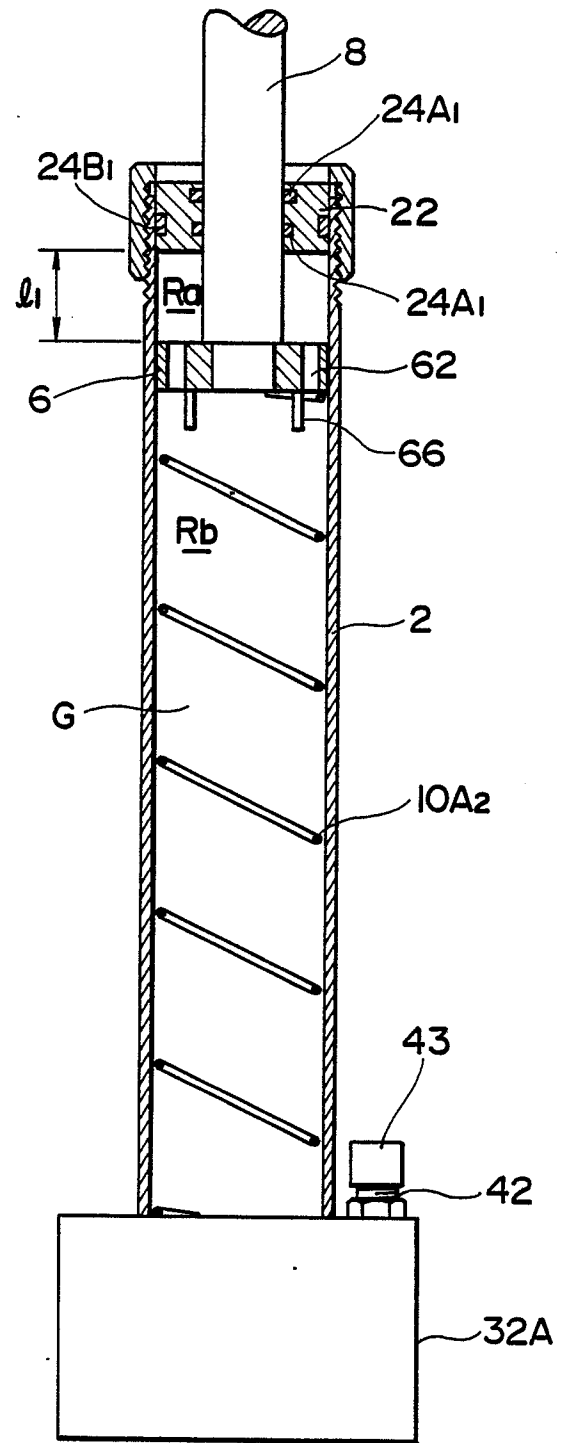


FIG. 15

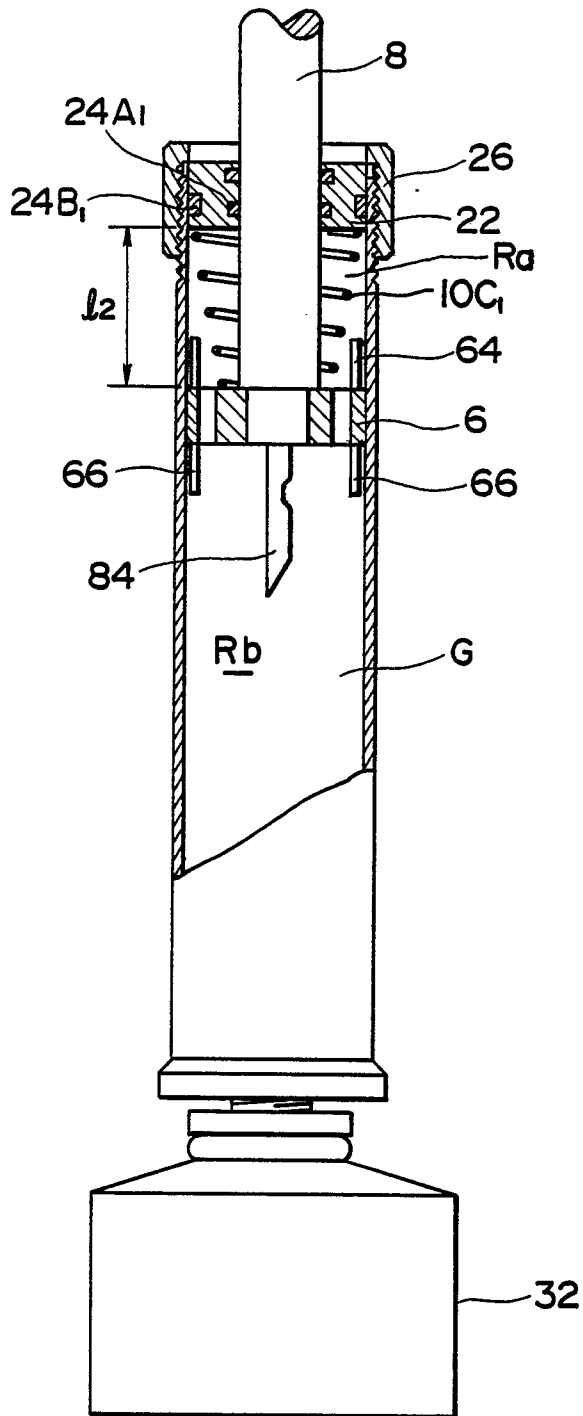


FIG. 16

