



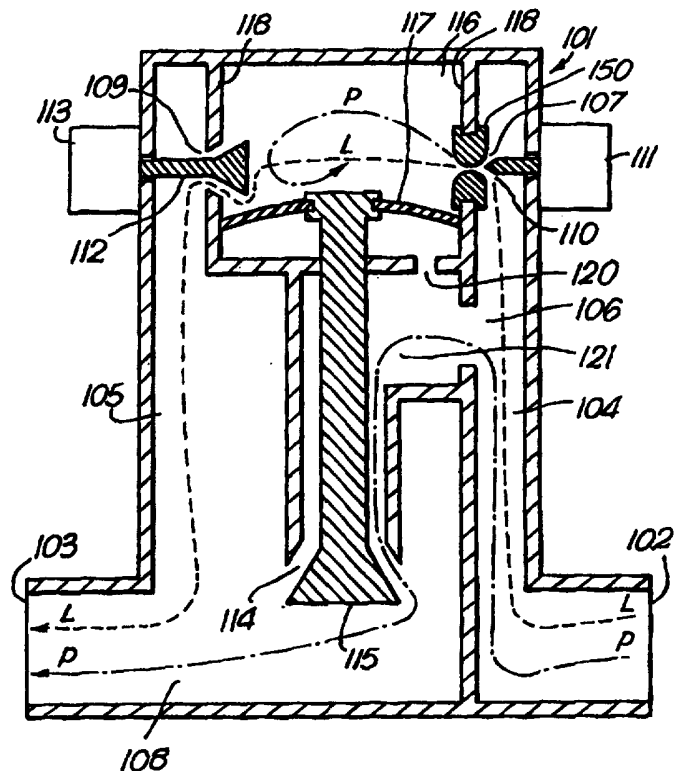
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(54) Title: PROPORTIONAL CONTROL VALVE

(57) Abstract

A gated proportional control valve (101) is disclosed which allows both high-flow proportional dispensing and precision low flow. The design includes one or more controlled-diameter and controlled-shape orifices (150) in the control path, which, when both of gate valves (110, 112) are opened, allow for consistent low flow dispensing. The gate valves (110, 112) can alternatively be opened or closed to allow proportional dispensing or valve closure. The invention is particularly useful in a fuel dispensing apparatus.



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## PROPORTIONAL CONTROL VALVE

The present invention relates to valve apparatus and more particularly a proportional gated diaphragm flow control valve used in dispensing fuel in a proportional blending device.

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Gated diaphragm proportional flow control valves are known in the art of fuel dispensing, automotive and industrial control. Figure 1 shows a schematic representation of a prior art gated diaphragm flow control valve 1, which has been used in the above applications and particularly in a fuel dispenser with proportional blending. Valve 1 includes an inlet 2 and an outlet 3 for, respectively, receiving and discharging a flow of fluid such as fuel. Inlet 2 leads to an inlet path 4, and outlet path 5 leads to outlet 3. Inlet path 4 includes two fluid flow openings, valve inlet opening 6 and gate chamber inlet opening 7. Gate inlet opening 7 is opened and closed by a gate chamber inlet valve 10, which is reciprocated from opened to closed positions by a gate inlet solenoid 11. Outlet path 5 includes two fluid flow openings, valve outlet opening 8 and gate chamber outlet opening 9. Gate outlet opening 9 is opened and closed by a gate chamber outlet valve 12, which is reciprocated from opened to closed positions by a gate outlet solenoid 13.

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The body of valve 1 contains a valve opening 14 which is opened and closed by a valve member 15. The valve stem projects into a gate chamber 16, and includes a valve stem diaphragm 17, which seals against walls 18 of gate chamber 16. A relief port 20 connects the portion of gate chamber 16 below valve stem diaphragm 17 to a valve flow area 21.

In operation of the device of Fig. 1, pressurized fluid is supplied to inlet 2 from a pressurized fluid source. When it is desired to commence fluid flow through valve 1, signals are sent to solenoids 11 and 13 to close gate outlet valve 12 and open gate inlet valve 10, thereby allowing pressurized fluid from inlet 2 and inlet path 4 to pass into gate chamber 16 through gate inlet opening 7 but not to leave gate chamber 16 through gate outlet opening 9. The operation of solenoids 11 and 13 are coupled, so that when one is in an open position, the other is in a closed position. If there is a sufficient pressure difference between the fluid pressure at inlet 2 and outlet 3, pressure on valve stem diaphragm 17 will move valve stem 15 downwardly, opening valve opening 14 and allowing fluid to flow from inlet 2 to outlet 3. The degree to which valve opening 14 is opened depends upon the proportional value of the inlet pressure to the outlet pressure, such that the valve opening 14 is opened more with a higher pressure difference, and opened less with a lower pressure difference. As a result, the fluid flow through valve opening 14 is proportional to the relative difference between the inlet 2 and outlet 3 pressures.

When it is desired to stop flow through valve 1, signals are sent to solenoids 11 and 13 to simultaneously open gate outlet valve 12 and close gate inlet valve 10, thereby allowing pressurized fluid from gate chamber 16 to exhaust through outlet path 5 and outlet 3, while simultaneously preventing fluid from inlet 2 and inlet path 4 from entering gate chamber 16. As a result, the pressure on diaphragm 17 is relieved, thereby causing valve stem 15 to move upwardly to close valve opening 14, under the action of pressure on valve stem 15 and diaphragm 17 -- through relief port 20 -- from outlet 3. This

position of solenoids 11 and 13 prevents fluid from flowing from inlet 2 to outlet 3.

The above-described prior art device operates adequately to provide proportional flow control when there is a sufficiently large difference in the inlet and outlet pressures for the valve 1, hereinafter referred to as a proportional flow mode. However, when it is  
5 desired to operate the valve 1 at low flow rates hereinafter referred to as a low flow mode (for example when a fuel dispenser dispenses a preset volume amount of fuel and must dispense fuel at a low flow rate as it reaches the preset amount, or when the dispensing nozzle is variably closed or only partially open) the above-described valve can have a  
10 tendency to either not open at all or to "flutter" between opened and closed positions in an unstable manner. Accordingly, prior art fuel dispensers which use the valve shown in Fig. 1 generally include an additional valve which controls the flow of fuel at low fuel flow rates. Adding an extra valve to the fuel dispenser, however, can increase costs of the overall system. Adding the extra valve also requires extra controls for controlling the  
15 dispensing apparatus to switch between the two valves, increasing costs and adding complexity to the dispensing apparatus.

Valves of the type described above are commonly used in automotive and industrial applications to control fluid flow. As described above, the normal operation of gated  
20 diaphragm control valves is to use upstream and downstream pressure to act on a diaphragm and/or a diaphragm stem valve in order to control flow. Gated diaphragm valves are low cost because of their simple construction and are often preferred over more expensive valve technologies. Gated diaphragm valves can be used as normal on/off

valves and can perform virtually all of the functions required by a proportional control valve, except reliable low flow operation. Low flow operation of a valve is normally required in precision fluid applications for dispensing exact or very precise volumes. Direct control proportional valves or stepper motor valves perform precision low flow dispensing, but are expensive.

The aim of the present invention is to provide a modified gated diaphragm flow control valve, to overcome the deficiency of such a valve for low flow dispensing, to provide for excellent low flow characteristics, while at the same time maintaining the typical low cost of a traditional gated diaphragm flow control valve.

In accordance with the present invention there is provided valve apparatus comprising a valve and valve control means, the valve comprising:

a valve inlet;

a valve outlet;

a valve opening;

a valve member arranged to control the flow of fluid passing through the opening between the valve inlet and valve outlet;

a gate chamber arranged such that the pressure of fluid therein acts to control the position of the valve member;

a gate chamber inlet in fluid communication with the valve inlet;

a gate chamber outlet in fluid communication with the valve outlet; and

at least one gate chamber valve;

wherein the valve control means is arranged to control the position of the at least one gate chamber valve such that in a proportional flow mode pressure in the chamber acts to control the position of the valve member in dependance on the relative pressure between the valve inlet and outlet, wherein in that in a low flow mode the valve control means controls the gate chamber valve such as to permit fluid to flow from the valve inlet to the valve outlet via the chamber, the flow path defining a by-pass flow path (L).

By employing the present invention to bypass the main valve and create a fixed and repeatable flow rate, the valve is allowed to operate at low flow conditions that are unattainable or uncontrollable by normal flow using the main valve and the diaphragm without any additional valve actuators. Preferably the by-pass flow path (L) comprises an orifice of known dimensions which determines flow rate through the chamber in the low flow mode, the dimensions of the orifice being selected such that in the low flow mode flow is restricted such that the pressure in the chamber causes the valve member to close the valve opening. This allows for precise low flow control in applications that require precision dispensing of fluid, such as in gasoline preset transactions.

In one embodiment the apparatus comprises an inlet gate chamber valve and an outlet gate chamber valve the valve control means being arranged to control the inlet and outlet gate chamber valves such that:

- a) in a proportional flow mode the inlet valve is open and outlet valve is closed whereby at high flow rates fluid pressure in the chamber causes the valve element to restrict the flow through the valve opening in dependance on said pressure in

the chamber;

- b) in a low flow mode both the inlet and outlet gate chamber valves are open such that fluid flows from the valve inlet to the valve outlet via the by-pass flow path (L), and the pressure in the chamber permits the valve member to close the valve opening; and
- c) in a closed mode the inlet gate chamber valve is closed and the outlet gate chamber valve is open such that the pressure in the chamber permits the valve member to close the valve opening.

10 Alternatively a restricted flow can be achieved by rapidly opening and closing the gate chamber valve(s) on a conventional gate proportional flow valve, and according to an alternative embodiment of the invention the valve control means in a low flow mode causes the at least one gate chamber valve to be pulsed between two positions such as to partially restrict fluid flow through the chamber.

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Various embodiments of the present invention will now be described by way of example only with reference to the accompanying figures of which:

Fig. 1 is a schematic, cross-sectional view of a prior art gated proportional valve;

20 Fig. 2 is a schematic, cross-sectional view of a first embodiment of the present invention;

Fig. 3 is a schematic, cross-sectional view of a second embodiment of the present invention;

Fig. 4 is a schematic, cross-sectional view of a third embodiment of the present invention;



Fig. 5 is a schematic, cross-sectional view of a fourth embodiment of the present invention;

Fig. 6 is a schematic, cross-sectional view of a fifth embodiment of the present invention;

Fig. 7 is a schematic, cross-sectional view of a sixth embodiment of the present invention;

5 and

Figs. 8 and 9 are schematic, partial, cross-sectional views of a seventh embodiment of the present invention.

Referring to Fig. 2, this shows a first embodiment of the present invention. Valve 101  
10 includes an inlet 102 and an outlet 103 for, respectively, receiving and discharging a flow of fluid such as fuel. Inlet 102 leads to an inlet path 104, and outlet path 105 leads to outlet 103. Inlet path 104 includes two fluid flow openings, valve inlet opening 106 and gate chamber inlet opening 107. Gate inlet opening 107 is opened and closed by a gate chamber inlet valve 110, which is reciprocated from opened to closed positions by a gate inlet solenoid 111. In the embodiment of Fig. 2, gate inlet opening 107 is configured as  
15 a controlled-diameter and controlled-shape orifice in an orifice element 150. Gate inlet valve 110 is configured so as to seal against the orifice of gate inlet opening 107 in its closed position. Outlet path 105 includes two fluid flow openings, valve outlet opening 108 and gate chamber outlet opening 109. Gate outlet opening 109 is opened and closed  
20 by a gate chamber outlet valve 112, which is reciprocated from opened to closed positions by a gate outlet solenoid 113. Gate outlet opening 109 in the embodiment of Fig. 2 is configured as a conventional valve opening.

Valve 101 body contains a valve opening 114 which is opened and closed by a valve stem 115. Valve stem projects into a gate chamber 116, and includes a valve stem diaphragm 117, which seals against walls 118 of gate chamber 116. A relief port 120 connects the portion of gate chamber 116 below sealing flange 117 to valve inlet opening 106.

5 The device of Fig. 2 has three modes, proportional flow, low flow and closed. A proportional flow path of fluid is shown in dot-dash lines P. When it is desired to commence fluid flow through valve 101, signals are sent to solenoids 111 and 113 to close gate outlet valve 112 and open gate inlet valve 110, thereby allowing pressurized fluid from inlet 102 and inlet path 104 to pass into gate chamber 116 but not to leave gate chamber 116. If there is a sufficient pressure difference between the fluid pressure at inlet 102 and outlet 103, pressure on valve stem diaphragm 117 will overcome any upward force by the pressure at outlet 103 on the valve stem 115 and the pressure at valve opening 106 on valve stem diaphragm 117, through relief port 120, to thereby move valve stem 115 downwardly, opening valve opening 114 and allowing fluid to flow from inlet 102 to outlet 103. The degree to which valve opening 114 is opened depends upon the amount of differential pressure across the control diaphragm 117. The biasing force on the main flow (lower) side of control diaphragm 117 is equal to the area of the control diaphragm 117 exposed to the inlet pressure through relief port 120 times the inlet pressure at 106, plus the area of the valve stem 115 exposed to the outlet pressure times the outlet pressure at 108. This biasing force is the net force acting on the main flow side of diaphragm 117 and is subtracted from the main valve opening force acting on the control (upper) side of the diaphragm 117. The opening force is one of three forces, depending on the state of the gate valves 110, 112. If the inlet gate 110 is opened and the

outlet gate 112 is closed, the opening force is the inlet pressure at 106 times the area of the control side of the diaphragm 117. If the inlet gate 110 is closed and the outlet gate 112 opened, the opening force is the outlet pressure at 105 times the area of the control side of the diaphragm 117. If both the inlet gate 110 and the outlet gate 112 are open, the opening force is the inlet pressure at 106, minus the pressure drop across control orifice 150, times the area of the control side of the diaphragm 117. These three forces are referred to hereinafter as the "net inlet force," "net outlet force," and "net preset force," respectively. Note also that these three forces will be generally termed "opening forces" and the net force on the opposite side of the diaphragm will be termed the "biasing forces."

The net inlet force, net outlet force or net preset force and their relation to the biasing force determine whether the valve stem 115 is open, and the amount which the valve 115 is opened. This is true whether the gates 110 and 112 are pulsed open for discreet time intervals or held completely open. In order to optimize the control characteristics of the valve 115, both the opening and closing characteristics of the valve can be modified by changing the area on the main flow side of the diaphragm 117 exposed to the inlet pressure. The limitation to such modification is the point where the net preset force is equal to the biasing force on diaphragm 117. If the net preset force is greater than the net biasing force, then the diaphragm 117 will deflect and the valve stem 115 will not remain seated during preset flow, when both the inlet gate 110 and the outlet gate 112 are open.

Whenever controlled amounts of fluid flow are allowed to enter or exhaust from the gate

chamber 116, the change in volume of gate chamber 116 is equal to the flow rate entering through orifice 150, or exhausted through outlet 109, times the elapsed time for this flow. In this way, the change of volume in the gate chamber 116 is essentially the integration (or summation) of the flow allowed to enter or leave the chamber. The increase in flow rate through valve opening 114 is proportional to the displacement stroke of valve stem 115 caused by the change in the volume of gate chamber 116, resulting in the effective area of opening 114. In order to increase or decrease the effect that a change in volume into the gate chamber 116 has on the change in flow through opening 114, the control area of diaphragm 117 must be decreased or increased respectively. This essentially increases or decreases the stroke by making the change of volume into gate chamber 116 work over a smaller or larger area respectively, and thus increasing or decreasing the stroke of valve stem 115 respectively.

When it is desired to stop flow through valve 101 during proportional flow, signals are sent to solenoids 111 and 113 to open gate outlet valve 112 and close gate inlet valve 110, thereby allowing pressurized fluid from gate chamber 116 to pass out outlet path 105 and outlet 103, but does not allow fluid from inlet 102 and inlet path 104 to enter gate chamber 116. As a result, the pressure on the control side of valve stem diaphragm 117 is relieved, thereby causing valve stem 115 to move upwardly to close valve opening 114. This position of solenoids 111 and 113 prevents fluid from flowing from inlet 102 to outlet 103.

During low flow in the valve 101 of Fig. 2, signals are sent to solenoids 111 and 113 to

open gate inlet and gate outlet valves 112, 113, a "low flow mode". As a result, fluid flows from inlet 102, through orifice of gate inlet opening 107, through gate chamber 116, out gate outlet opening 109 and subsequently out outlet 103, constituting a by-pass flow path (L). Because gate inlet opening 107 is in the form of a controlled-diameter and controlled-shape orifice, the flow rate through the path described above is of a low, controlled rate. As a result, the valve can be used during preset operations to provide controlled low flow without the need for an additional valve.

The embodiment of Fig. 2 is a slow-opening/fast-closing proportional valve. Because the orifice in the embodiment of Fig. 2 is at the gate inlet, the orifice slows the flow rate into the gate chamber 116 and thus slows the opening of valve 115, after gate inlet valve 110 is opened. Conversely, when gate inlet valve 110 is closed and gate outlet valve 112 is opened, the pressure of gate chamber 116 is exhausted rapidly, as gate outlet 109 is not a controlled-diameter or controlled-shape orifice. As a result, the valve stem 115 closes more rapidly than it opens.

Fig. 3 shows a second embodiment of the present invention, which is identical in design to the embodiment of Fig. 2 except for the location of the orifice. The embodiment of Fig. 3 is a fast-opening/slow-closing proportional valve. Thus, the controlled-diameter, controlled-shape orifice element 251 is at the gate outlet 209. In operation as a low-flow valve, the embodiment of Fig. 3 is identical to the operation of the valve of Fig. 2. In proportional flow, the valve stem 215 will open more rapidly than it will close, since the orifice is located at gate outlet 209.

Fig. 4 shows a third embodiment of the present invention, which is identical in design to the embodiments of Figs. 2 and 3 except for the location of the orifice. The embodiment of Fig. 4 is an equal-opening and -closing proportional valve. Thus, there are controlled-diameter, controlled-shape orifice elements 350, 351 at both the gate inlet 307 and gate outlet 309. As a result -- because the orifices allow approximately equal flow rates because of their equal sizes and shapes -- the proportional valve will open and close at the same rate. During low flow, the valve operates in a manner identical to that in the embodiments of Figs. 2 and 3.

Although Figs. 2-4 show the use of sized orifices 107, 209, 307, 309 to control flow rate through the gate chambers 116, 216, 316, the same effect could be achieved using a conventional valve structure (like that shown in Fig. 1), in which the valves 10, or 12, or 10 and 12, are rapidly pulsed open and closed by gate solenoids 11, or 13 or 11 and 13. As a result of such pulsing of the valves 10, or 12, or 10 and 12, the flow rate through the openings 7, or 9, or 7 and 9 is restricted (depending on the pulse rate), therefore providing the same effect as if there were a control orifice at the gate inlet, gate outlet or gate inlet and gate outlet. The same effect could be achieved by providing full-open and partially-open positions of the valves 10, or 12, or 10 and 12.

Figs. 5-7 show fourth through sixth embodiments of the present invention which are configured in the form of a diaphragm proportional valve. In the embodiment of Fig. 5, valve 401 includes an inlet 402 and an outlet 403 for, respectively, receiving and discharging a flow of fluid such as fuel. Inlet 402 leads to an inlet path 404, and outlet

path 405 leads to outlet 403. Inlet path 404 includes two fluid flow openings, valve inlet opening 406 and gate inlet opening 407. Gate inlet opening 407 in the embodiment of Fig. 5 is configured as a conventional valve opening. Gate inlet opening 407 is opened and closed by a gate inlet valve 410, which is reciprocated from opened to closed positions by a gate inlet solenoid 411. Gate inlet valve 410 is configured so as to seal against gate inlet opening 407 in its closed position. Outlet path 405 includes two fluid flow openings, valve outlet opening 408 and gate outlet opening 409. Gate outlet opening 409 is opened and closed by a gate outlet valve 412, which is reciprocated from opened to closed positions by a gate outlet solenoid 413. In the embodiment of Fig. 5, gate outlet opening 409 is configured as a controlled-diameter and controlled-shape orifice in an orifice element 451.

Valve 401 body contains a valve opening 414 which is opened and closed by a valve diaphragm 430. Valve diaphragm 430 has one side facing gate chamber 416 and another side which can seal against valve opening 414.

The device of Fig. 5 has three modes, proportional flow, low flow and closed. A proportional flow path of fluid is shown in dot-dash lines P. When it is desired to commence fluid flow through valve 401, signals are sent to solenoids 411 and 413 to open gate outlet valve 412 and close gate inlet valve 410, thereby venting pressurized fluid from gate chamber 416 to outlet 403. If there is a sufficient pressure difference between the fluid pressure at inlet 402 and outlet 403, pressure on lower side of valve diaphragm 430 will move valve diaphragm 430 upwardly, opening valve opening 414 and allowing

fluid to flow from inlet 402 to outlet 403. The degree to which valve opening 414 is opened depends upon the amount of differential pressure across the control diaphragm 430. The opening force on the main flow (lower) side of control diaphragm 117 is equal to the area of the diaphragm 117 exposed to the inlet pressure at 414 times the inlet pressure at 414, plus the area of the of the diaphragm 117 exposed to the outlet pressure at 408 times the outlet pressure at 408. This opening force is the net force acting on the main flow side of diaphragm 430 and is subtracted from the biasing force acting on the control (upper) side of the diaphragm 430. The biasing force is one of three forces, depending on the state of the gate valves 410, 412. If the inlet gate valve 410 is opened and the outlet gate valve 412 is closed, the biasing force is the inlet pressure at 406 times the area of the control side of the diaphragm 430. If the inlet gate 410 is closed and the outlet gate 412 opened, the biasing force is the outlet pressure at 405 times the area of the control side of the diaphragm 430. If both the inlet gate valve 410 and the outlet gate valve 412 are open, the biasing force is the inlet pressure at 406, minus the pressure drop across control orifice 450, times the area of the control side of the diaphragm 430. These three forces are referred to hereinafter as the "net inlet force," "net outlet force," and "net preset force," respectively. Note also that these three forces will be generally termed "biasing forces" and the net force on the opposite side of the diaphragm will be termed the "opening forces."

The net inlet force, net outlet force or net preset force and their relation to the opening force determine whether the valve opening 414 is open, and the amount which the valve opening 414 is opened. This is true whether the gates 410 and 412 are pulsed open for



discreet time intervals or held completely open. In order to optimize the control characteristics of the valve 415, both the opening and closing characteristics of the valve can be modified by changing the area on the main flow side of the diaphragm 430 exposed to the inlet pressure at valve opening 414. It has been found that when the area  
5 of the valve opening 414 is equal to the area of the control side of diaphragm 430 surrounding valve opening 414, there is no need for the use of a spring to bias the diaphragm 430. The limitation to such modification is the point where the net preset force is equal to the opening force on diaphragm 430. If the net preset force is greater than the net opening force, then the diaphragm 430 will deflect and not remain seated  
10 during preset flow, when both the inlet gate 410 and the outlet gate 412 are open.

Whenever controlled amounts of fluid flow are allowed to enter or exhaust from the gate chamber 416, the change in volume of gate chamber 416 is equal to the flow rate entering through orifice 450, or exhausted through outlet 409, times the elapsed time for this flow.  
15 In this way, the change of volume in the gate chamber 416 is essentially the integration (or summation) of the flow allowed to enter or leave the chamber. The increase in flow rate through valve opening 414 is proportional to the displacement of the diaphragm 430 caused by the change in the volume of gate chamber 416, resulting in the effective area of opening 414. In order to increase or decrease the effect that a change in volume into  
20 the gate chamber 416 has on the change in flow through opening 414, the control area of diaphragm 430 must be decreased or increased respectively. This essentially increases or decreases the stroke by making the change of volume into gate chamber 416 work over a smaller or larger area respectively, and thus increasing or decreasing the deflection of

diaphragm 430 respectively.

When it is desired to stop flow through valve 401 during proportional flow, signals are sent to solenoids 411 and 413 to close gate outlet valve 412 and open gate inlet valve 410, thereby allowing pressurized fluid from inlet 402 to enter gate chamber 416 but not to exit gate chamber 416. As a result, the pressure is increased on the control side of valve diaphragm 430, thereby causing valve diaphragm 431 to move downwardly to close valve opening 414. This position of solenoids 411 and 413 prevents fluid from flowing from inlet 402 to outlet 403.

During low flow in the valve 401 of Fig. 2, signals are sent to solenoids 411 and 413 to open gate inlet and gate outlet valves 412, 413. As a result, fluid flows from inlet 402, through orifice of gate inlet opening 407, through gate chamber 416, out gate outlet opening 409 and subsequently out outlet 403. Because gate outlet opening 409 is in the form of a controlled-diameter and controlled-shape orifice, the flow rate through the path described above is of a low, controlled rate. As a result, the valve can be used during preset operations to provide controlled low flow without the need for an additional valve.

The embodiment of Fig. 5 is a slow-opening/fast-closing proportional valve. Because the orifice in the embodiment of Fig. 5 is at the gate outlet, it takes a period of time before the pressure of gate chamber 416 is relieved after gate outlet valve 412 is opened. Conversely, when gate outlet valve 412 is closed and gate inlet valve 410 is opened, the pressure of gate chamber 416 is equalized rapidly, as gate inlet 407 is not a controlled-

diameter or controlled-shape orifice. As a result, the proportional valve closes more rapidly than it opens.

5 Fig. 6 shows a fifth embodiment of the present invention, which is identical in design to the embodiment of Fig. 5 except for the location of the orifice. The embodiment of Fig. 6 is a fast-opening/slow-closing proportional valve. Thus, the controlled-diameter, controlled-shape orifice 550 is at the gate inlet 507. In operation as a low-flow valve, the embodiment of Fig. 6 is identical to the operation of the valve of Fig. 5. In proportional flow, the valve will open more rapidly than it will close, since the orifice is located at  
10 gate inlet 507.

Fig. 7 shows a sixth embodiment of the present invention, which is identical in design to the embodiments of Figs. 5 and 6 except for the location of the orifice. The embodiment of Fig. 7 is an equal-opening and -closing proportional valve. Thus, there are controlled-diameter, controlled-shape orifices at both the gate inlet 607 and gate outlet 609. As a  
15 result -- because the orifices allow approximately equal flow rates because of their equal sizes and shapes -- the proportional valve will open and close at the same rate. During low flow, the valve operates in a manner identical to that in the embodiments of Figs. 5 and 6.

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Although Figs. 5-7 show the use of sized orifices 407, 509, 607, 609 to control flow rate through the gate chambers 416, 516, 616, the same effect could be achieved using a conventional valve structure, in which the valves are rapidly pulsed open and closed by

the gate solenoids. As a result of such pulsing of the valves, the flow rate through the gate openings is restricted (depending on the pulse rate), therefore providing the same effect as if there were a control orifice at the gate inlet, gate outlet or gate inlet and gate outlet. The same effect could be achieved by providing full-open and partially-open positions of the valves 10, or 12, or 10 and 12.

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Figs. 8 and 9 show an alternative embodiment which achieves the same results as the embodiments of Figs. 2-4, but which requires only one solenoid 711. In the embodiment of Figs. 8 and 9, the gate outlet opening 409 is resized to provide a small orifice which provides a controlled, very low flow rate. The gate inlet opening 407 is resized as a relatively large orifice which provides a controlled, high flow rate. Solenoid 711 is structured so as to provide three positions for the gate inlet valve 710: closed, partially-open (Fig. 9) and full-open (Fig. 8). The full-open position of gate inlet valve 710 results in a large flow rate into the gate chamber 716, through gate inlet opening 707, and a small flow rate out of gate chamber 716, through gate outlet opening 709. The gate chamber 716 essentially integrates the difference in the inlet and exhaust flows, and the resulting net flow rate into gate chamber 716 results in an accumulated pressure in gate chamber 716, which pressure acts on diaphragm to effect proportional flow control (in the manner described above with reference to Figs. 2-7). The partially-open position of gate inlet valve 710 is the low flow control position. In the partially-open position of gate inlet valve 710, the gate inlet opening 707 flow area is reduced, thereby reducing the flow rate through gate inlet opening 707 to a level approximately equal to the flow rate out gate outlet opening 709. As a result, no pressure is accumulated in gate chamber 716,

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diaphragm 730 is thus not displaced, and no proportional flow is achieved. The flow rate through gate inlet opening 707 and gate outlet opening 709 is the resulting controlled low flow rate. In the closed position of gate inlet valve 710, any accumulated pressure in gate chamber 716 is exhausted, with no net flow into gate chamber 716, thereby displacing the diaphragm and shutting off both proportional flow and low flow. This embodiment produces a simplified, cost reduced version that can be controlled by modulating the input gate only. The configuration of Figs. 8 and 9 would be used in a proportional flow control valve of the type shown in Figs. 2-4; in the valve structure shown in Figs. 5-7, the solenoid and valve would be located at the gate outlet, and the small orifice at the gate inlet.

It is to be understood that many variations are possible under the teachings of the present disclosure. For example, other mechanisms for providing proportional flow can be provided. In addition, the orifice need not be located at the inlet or outlet to the gate, but could be located elsewhere within the by-pass flow path (L). The present invention is not limited by the particular structures and methods described above, but is instead defined by the claims below.

Claims

1. Valve apparatus comprising a valve (101) and valve control means, the valve (101) comprising:
  - a valve inlet (102);
  - a valve outlet (103);
  - a valve opening (114);
  - a valve member (115) arranged to control the flow of fluid passing through the opening (114) between the valve inlet (102) and valve outlet (103);
  - a gate chamber (116) arranged such that the pressure of fluid therein acts to control the position of the valve member (115);
  - a gate chamber inlet (107) in fluid communication with the valve inlet (102);
  - a gate chamber outlet (109) in fluid communication with the valve outlet (103);and
  - at least one gate chamber valve (110, 112);wherein the valve control means is arranged to control the position of the at least one gate chamber valve (110, 112) such that in a proportional flow mode pressure in the chamber (116) acts to control the position of the valve member (115) in dependence on the relative pressure between the valve inlet (102) and outlet (103), characterised in that in a low flow mode the valve control means controls the gate chamber valve (110, 111) such as to permit fluid to flow from the valve inlet (102) to the valve outlet (103) via the chamber, the flow path (102, 103, 106, 105, 103) defining a by-pass flow path (L).

2. Apparatus as claimed in Claim 1 wherein the by-pass flow path (L) comprises an orifice (150) of known dimensions which determines flow rate through the chamber in the low flow mode, the dimensions of the orifice (150) being selected such that in the low flow mode flow is restricted such that the pressure in the chamber (116) permits the valve member to close the valve opening (114).
3. Apparatus as claimed in Claim 2 wherein the orifice (150) is in the at least one gate chamber valve opening (107).
4. Apparatus as claimed in Claims 1, 2 or 3 comprising an inlet gate chamber valve (110) and an outlet gate chamber valve (112) the valve control means being arranged to control the inlet and outlet gate chamber valves (110, 112) such that:
  - a) in a proportional flow mode the inlet valve (110) is open and outlet valve (112) is closed whereby at high flow rates fluid pressure in the chamber (116) causes the valve element (115) to restrict the flow through the valve opening (114) in dependence on said pressure in the chamber (116);
  - b) in a low flow mode both the inlet and outlet gate chamber valves (110, 112) are open such that fluid flows from the valve inlet (102) to the valve outlet (103) via the by-pass flow path (L), and the pressure in the chamber (116) permits the valve member (115) to close the valve opening (114); and
  - c) in a closed mode the inlet gate chamber valve (112) is closed and the outlet gate chamber valve is open such that the pressure in the chamber (116) permits the valve member (115) to close the valve opening (114).

5. Apparatus as claimed in Claim 4 comprising an orifice (251) of known dimensions located in the by-pass flow path (L) between the chamber (216) and the valve outlet (203), which orifice determines the flow rate through the chamber in the low flow mode.
6. Apparatus as claimed in Claim 4 comprising an orifice (150) of known dimensions located in the by-pass flow path (L) between the chamber (116) and the valve inlet (102), which determines the flow rate through the chamber (116) in the low flow mode.
7. Apparatus as claimed in Claim 4 comprising two orifices (350, 351) of known dimensions in the by-pass flow path (L), between the chamber (316) and the valve inlet (302) and between the chamber (316) and valve outlet (303) respectively, the orifices (350, 351) together determining the flow rate through the chamber (316) in the low flow mode.
8. Apparatus as claimed in any one of Claims 1, 2 or 3 comprising only one gate chamber valve (710), the valve control means being arranged to set the valve (710) to a closed position, an open position or, in low flow mode to an intermediary position, the gate chamber valve opening (707) comprising an orifice (750) which determines the flow rate through the chamber (716) when the gate chamber valve (710) is in an intermediary position, the dimensions of the orifice being selected such that in a low flow mode flow is restricted, such that the pressure in the chamber permits the valve member to close the valve opening.



9. Apparatus as claimed in Claim 8 wherein the gate chamber valve (710) is located in the gate chamber inlet, the control means being arranged to close the gate chamber valve (710) in the closed mode, and fully open the gate chamber valve (710) in the proportional flow mode.
10. Apparatus as claimed in Claim 9 further comprising a second orifice (751) located in the by-pass fluid flow path between the gate chamber outlet and valve outlet, the dimensions of the second orifice (751) being smaller than the first orifice.
11. A valve (1) for use in the apparatus of any one of Claims 2 to 10.
12. Apparatus as claimed in Claim 1 wherein the valve control means in a low flow mode causes the at least one gate chamber valve to be pulsed between two positions such as to partially restrict fluid flow through the chamber.

Fig.1.  
PRIOR ART

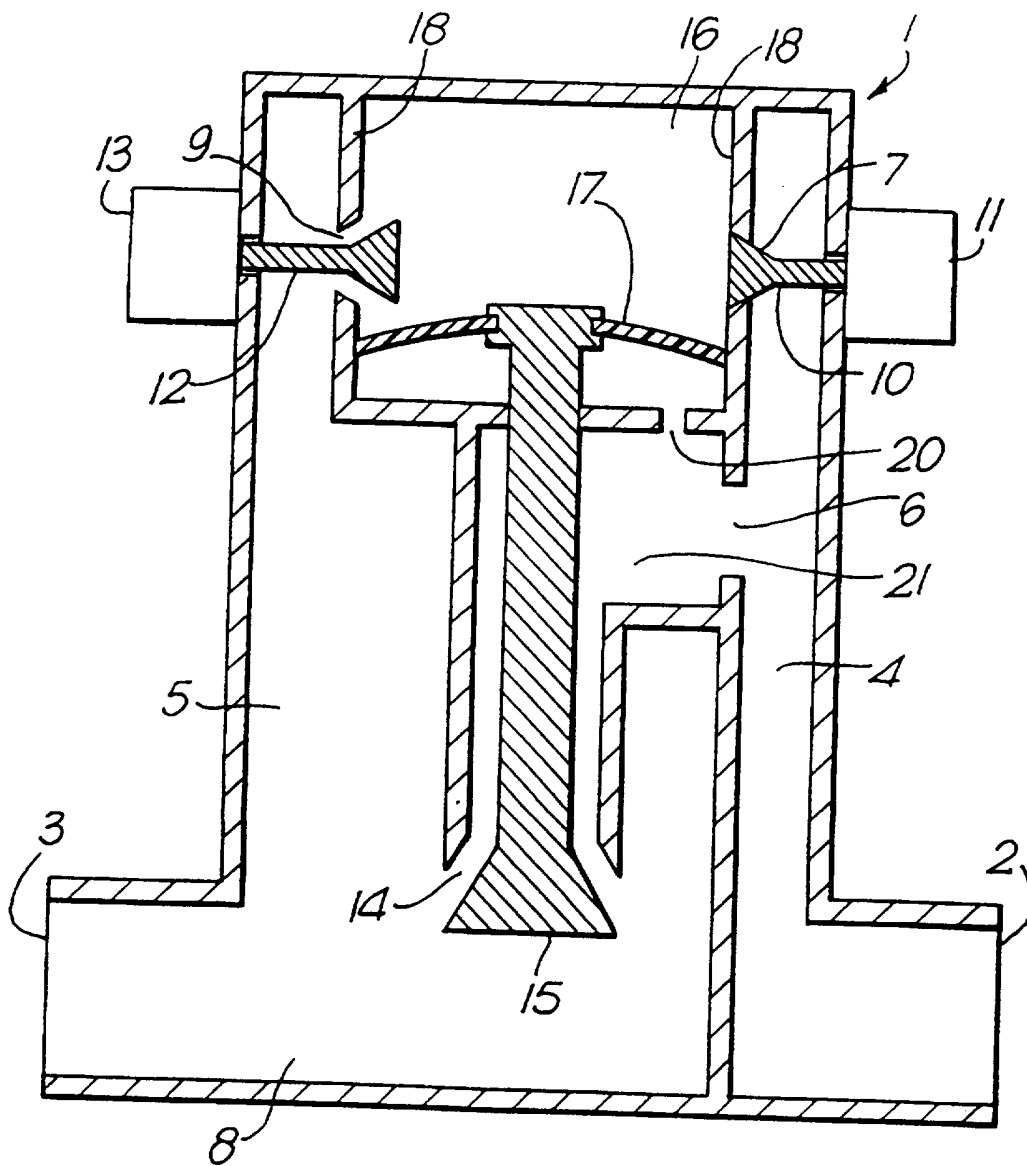


Fig.2.

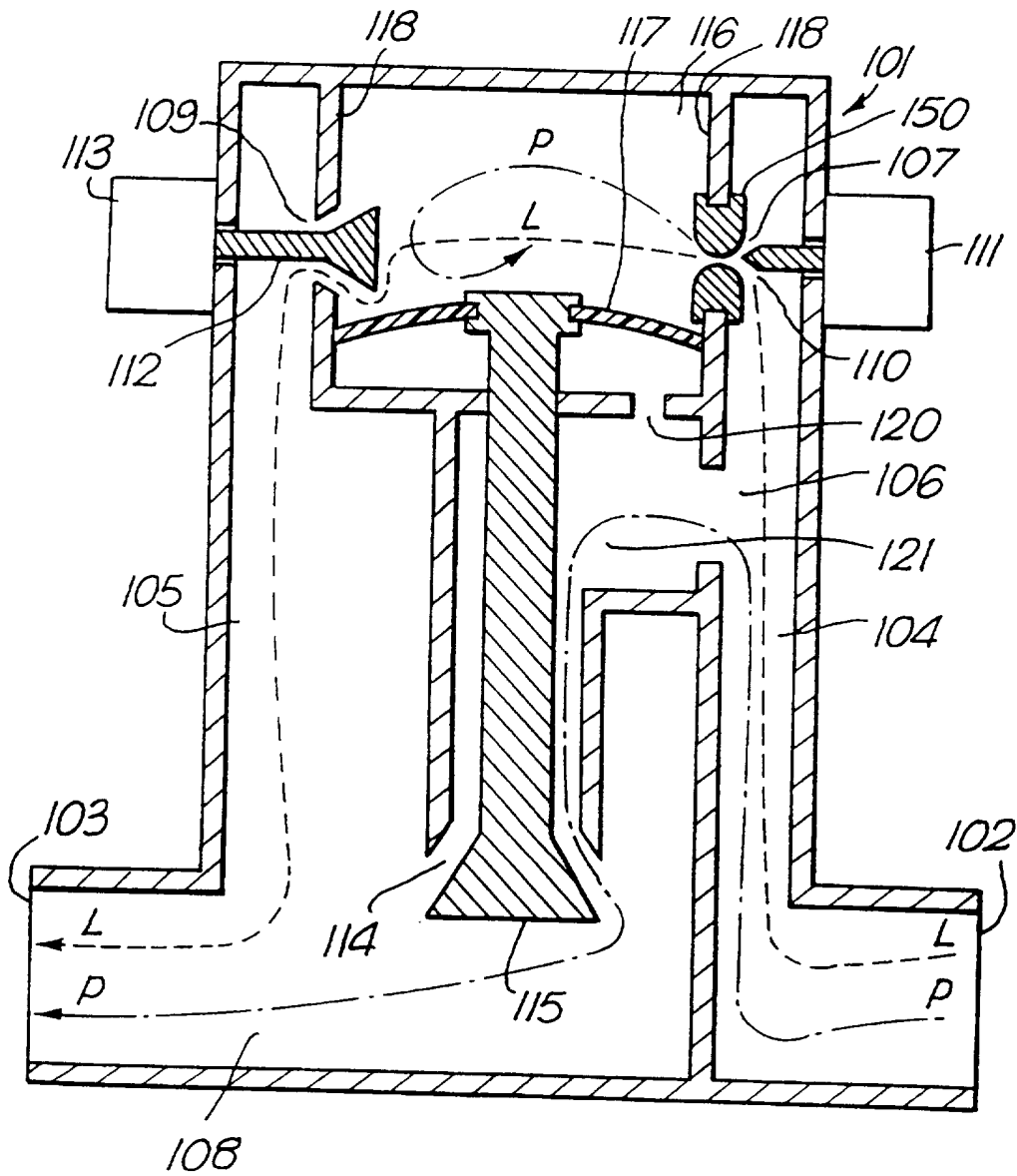


Fig.3.

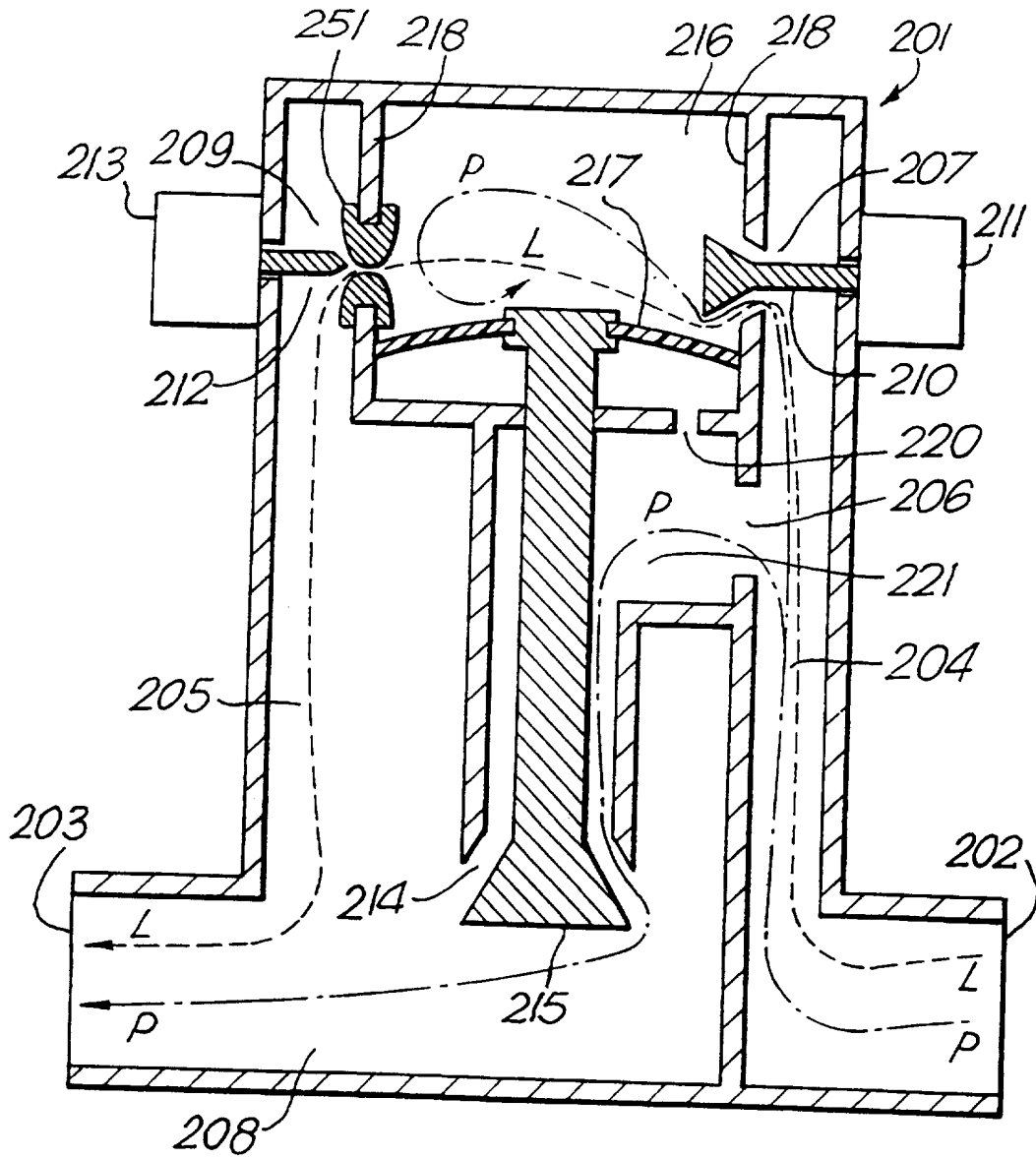


Fig.4.

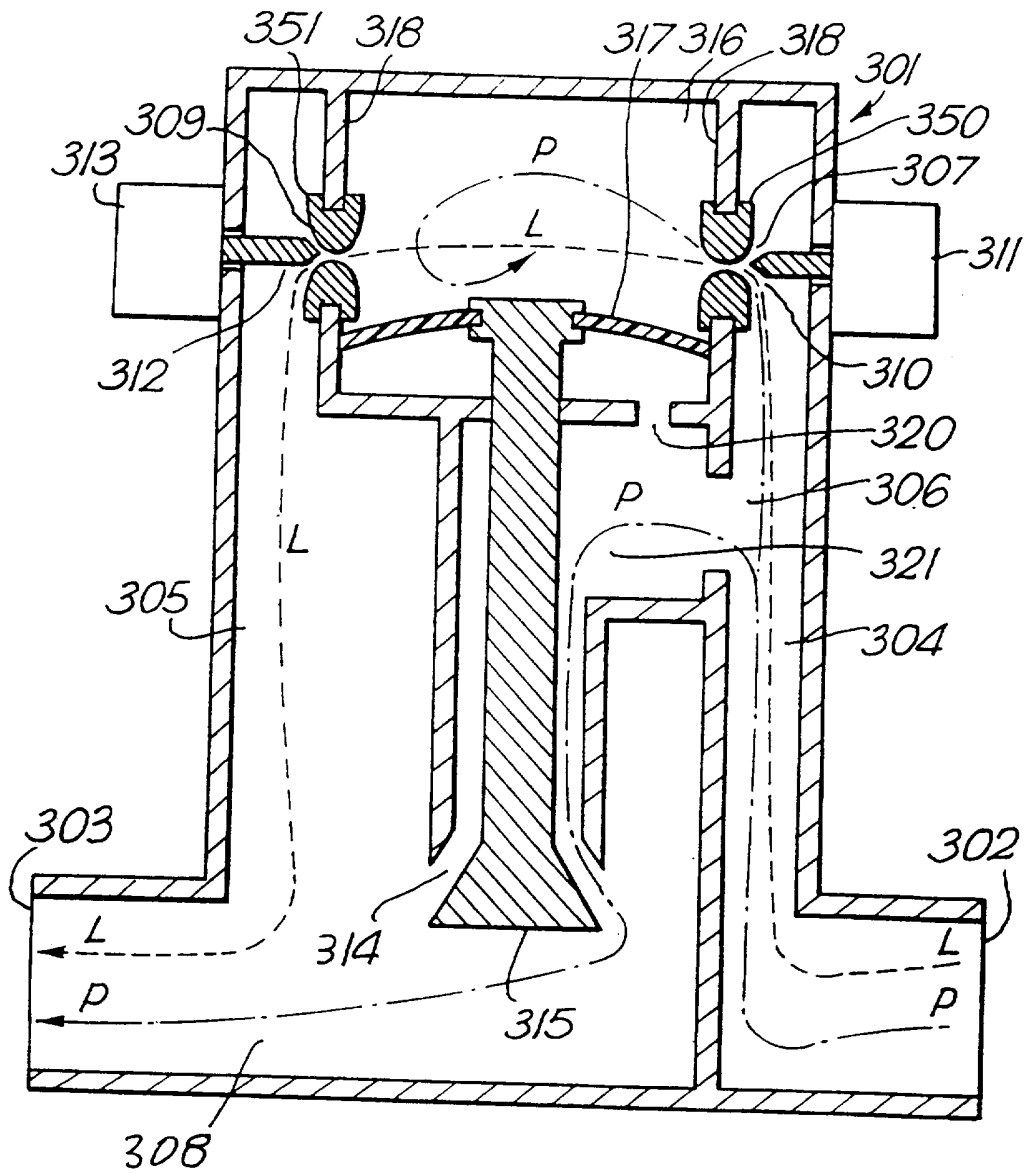


Fig.5.

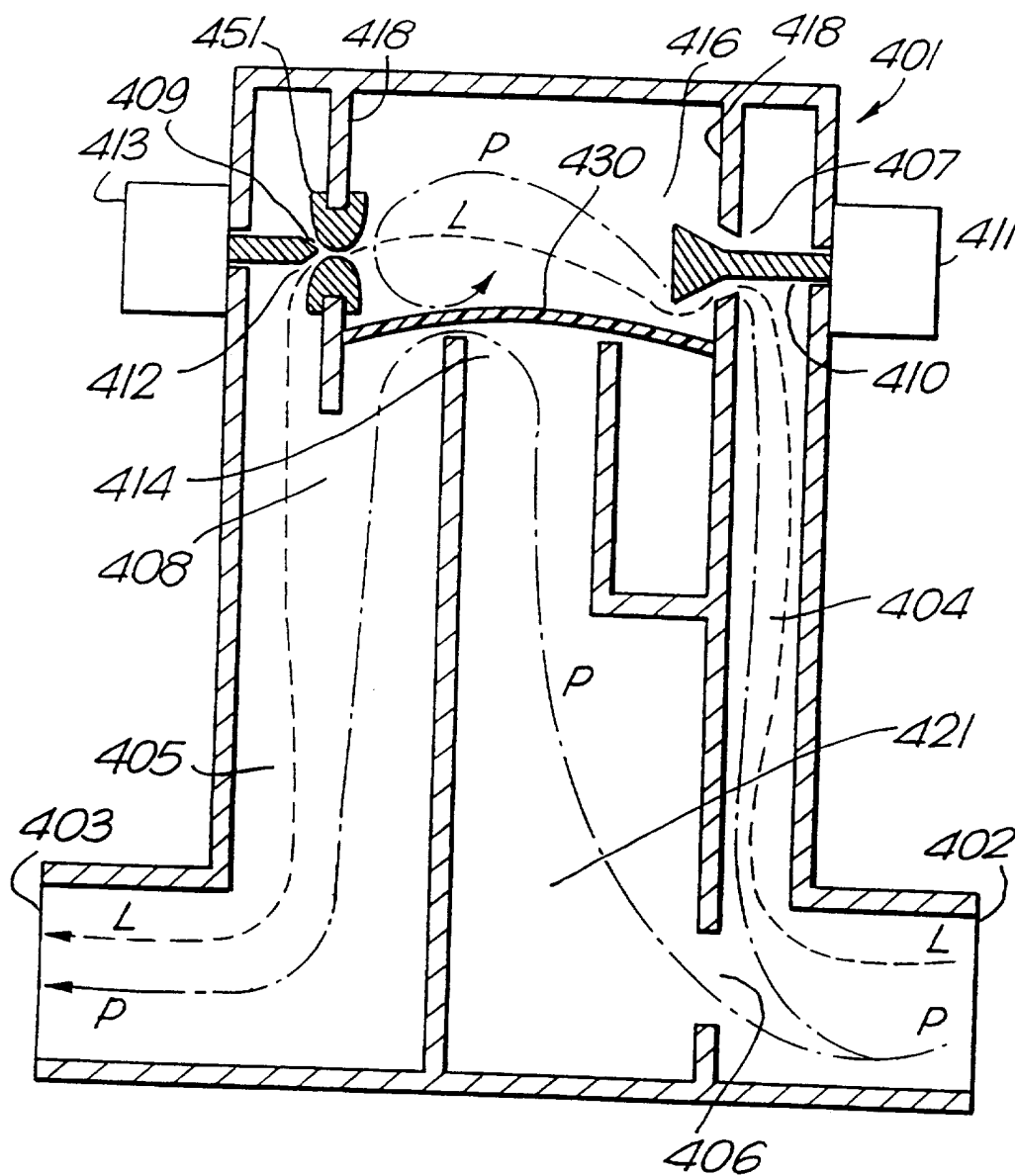


Fig.6.

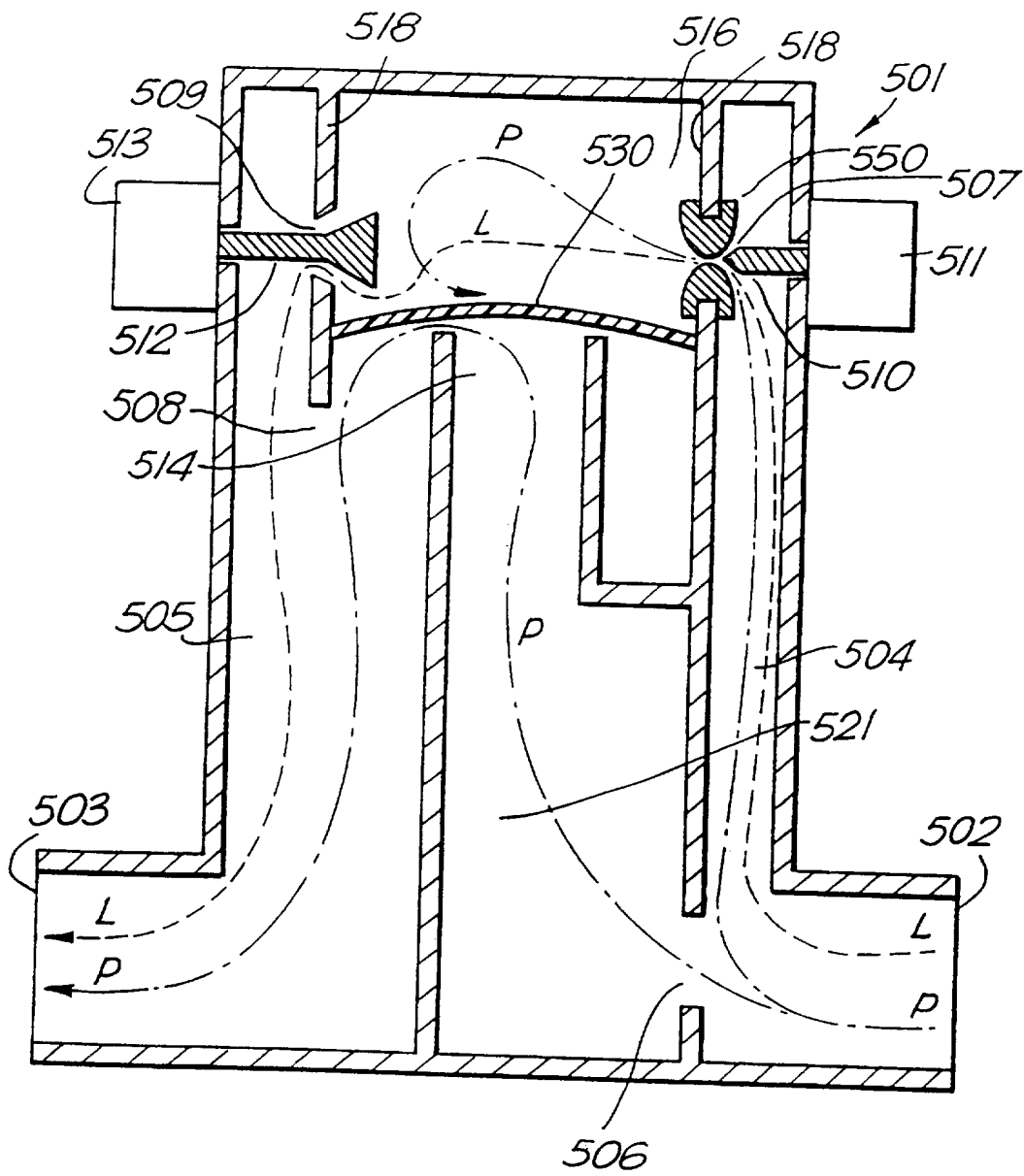


Fig.7.

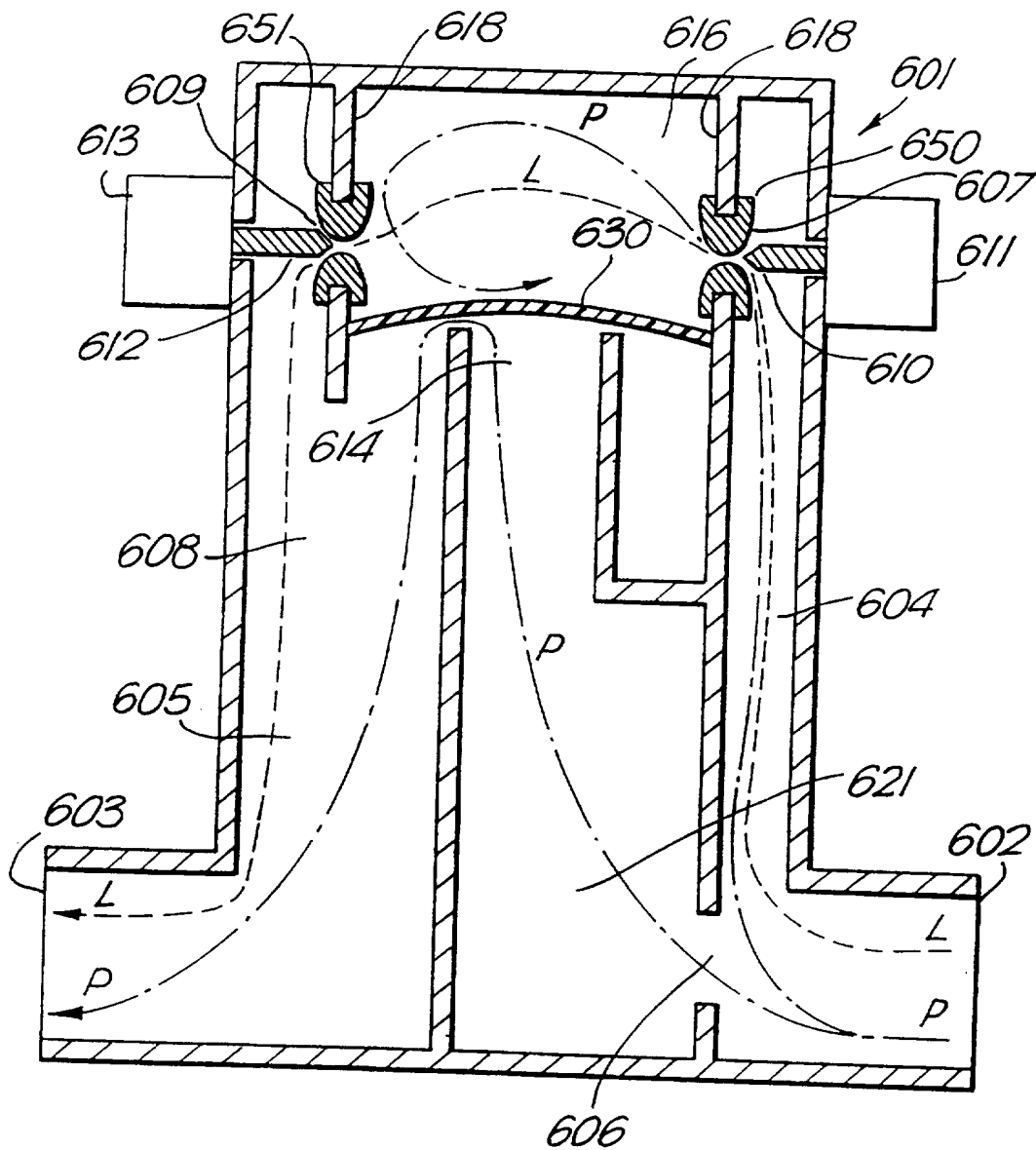




Fig.8.

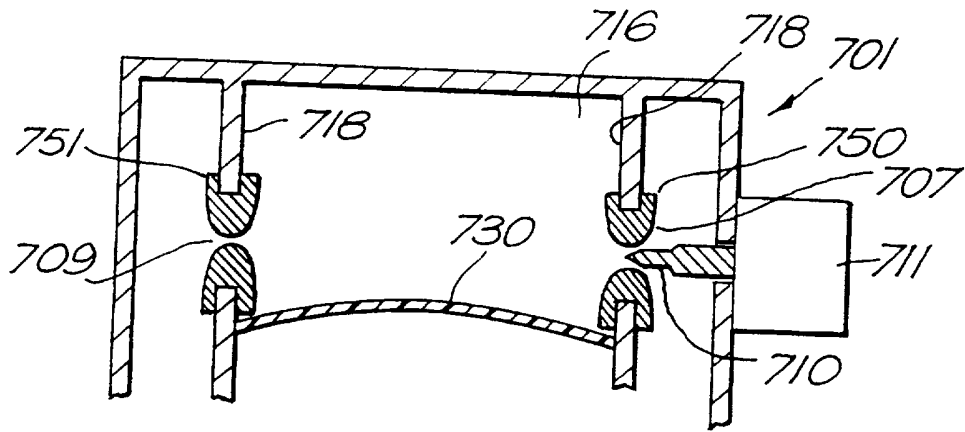
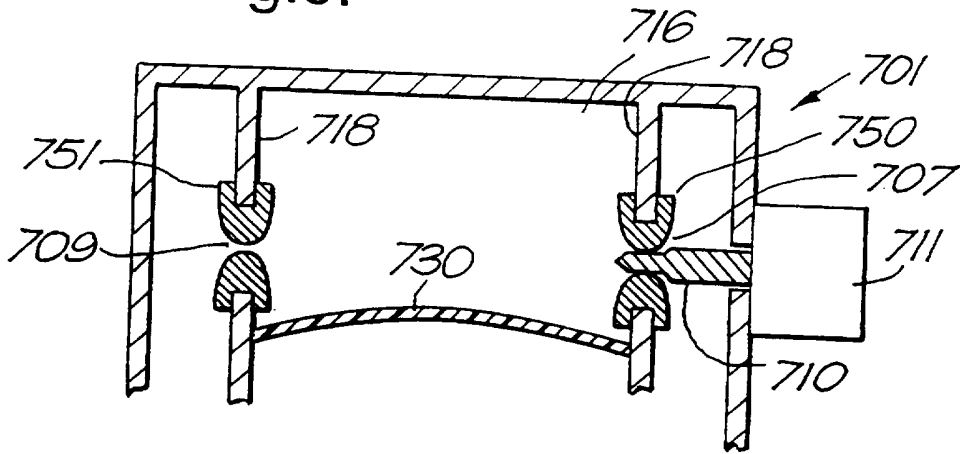


Fig.9.



# INTERNATIONAL SEARCH REPORT

Int. l. Application No  
PCT/GB 97/00468

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC 6 F16K31/40				
According to International Patent Classification (IPC) or to both national classification and IPC				
<b>B. FIELDS SEARCHED</b>				
Minimum documentation searched (classification system followed by classification symbols) IPC 6 F16K				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practical, search terms used)				
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>				
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
X	US 4 503 887 A (JOHNSON TERENCE L ET AL) 12 March 1985 see column 3, line 7 - column 4, line 5 ---	1-3,8, 11,12		
A	EP 0 343 288 A (KOPPENS AUTOMATIC FABRIEKEN BV) 29 November 1989 see page 4, line 3 - page 5, line 16; figures 1,2 ---	1-4,11, 12		
A	FR 2 155 549 A (NORTHEAST FLUIDICS, INC.) 18 May 1973 -----			
<input type="checkbox"/> Further documents are listed in the continuation of box C.				
<input checked="" type="checkbox"/> Patent family members are listed in annex.				
* Special categories of cited documents :				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; vertical-align: top;">                     *A* document defining the general state of the art which is not considered to be of particular relevance                      *E* earlier document but published on or after the international filing date                      *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)                      *O* document referring to an oral disclosure, use, exhibition or other means                      *P* document published prior to the international filing date but later than the priority date claimed                 </td> <td style="width: 50%; border: none; vertical-align: top;">                     *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention                      *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone                      *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.                      *&amp;* document member of the same patent family                 </td> </tr> </table>			*A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *&* document member of the same patent family
*A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *&* document member of the same patent family			
Date of the actual completion of the international search	Date of mailing of the international search report			
3 June 1997	13.06.97			
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016	Authorized officer  Christensen, J			

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 97/00468

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