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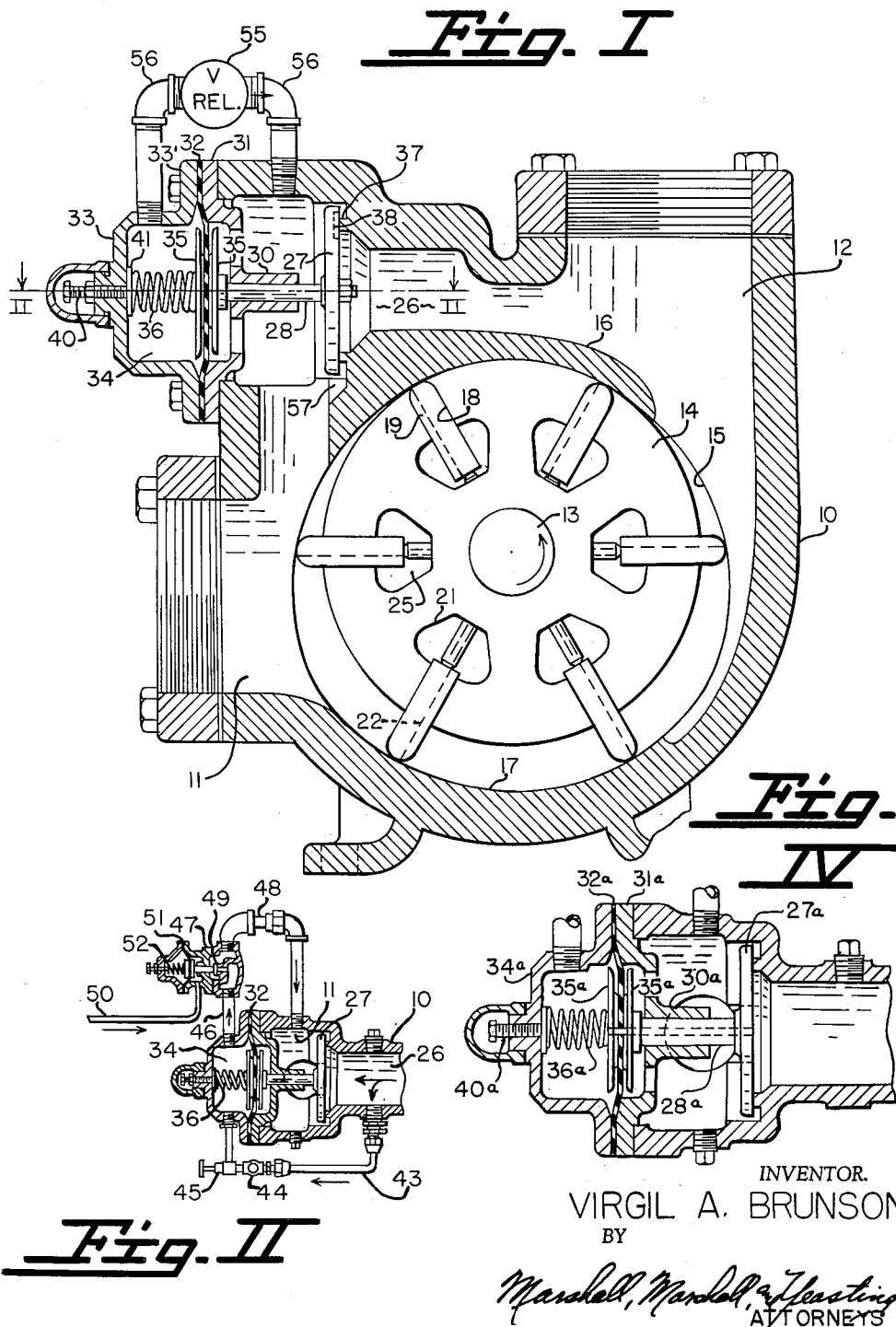
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PUMP DELIVERY CONTROL MECHANISM

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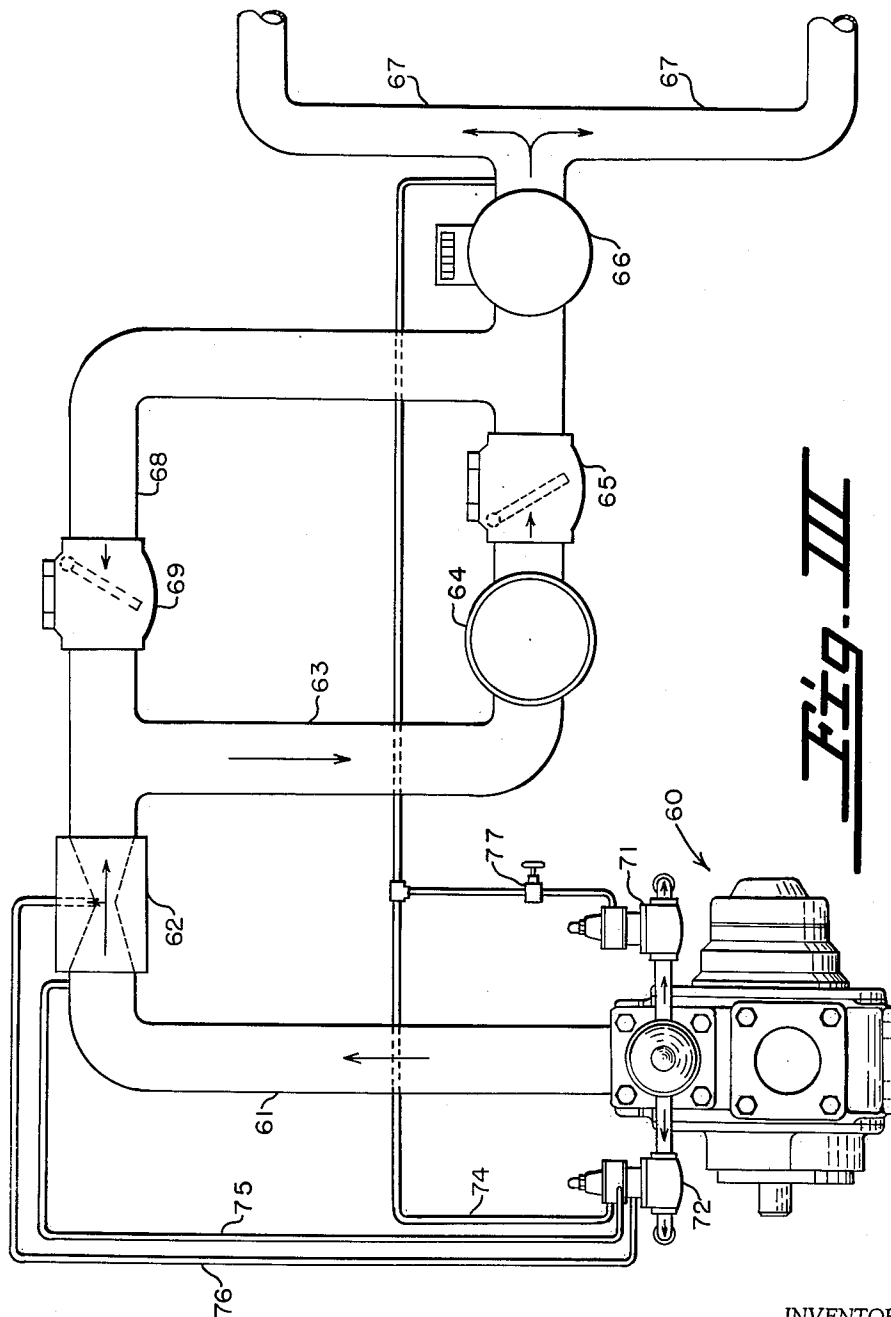


**Fig. III**

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1

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## PUMP DELIVERY CONTROL MECHANISM

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This invention relates to equipment for pumping fluids and in particular to means for controlling the output pressure of a pump in accordance with the pressure developed in some portion of the system receiving the pump discharge.

While positive displacement pumps have been used extensively for pumping liquids or fluids into confined spaces having ample storage capacity, such as tanks partially filled with air, the use of such pumps for pumping into systems having little or no storage capacity has not been satisfactory. A major difficulty when pumping into a closed system having little or no storage capacity is the difficulty of control of the pumping rate when the outlet of such system is throttled or closed.

The principal object of this invention is to provide a positive displacement pump with means for automatically controlling its output pressure in accordance with the pressure at some selected point in the system into which the pump is discharging.

Another object of the invention is to provide an integrally mounted bypass valve in the housing of a displacement pump.

A still further object of the invention is to provide an integrally mounted bypass valve in the housing of the pump and holding such valve in closed position by fluid under pressure obtained from the discharge port or the discharge passage of the pump.

A still further object of the invention is to provide an integrally mounted bypass valve in the housing of a positive displacement pump and arranging the control for such valve so that the valve is normally held in closed position by fluid pressure bled slowly from the discharge passage of the pump into a control chamber of the valve and in which the valve is opened or permitted to open by bleeding fluid from such control chamber.

A still further object of the invention is to provide a positive displacement pump with auxiliary control apparatus such that the pressure at the delivery end or other selected point of the system into which the pump discharges may be held substantially constant regardless of the rate of flow of liquid through the system.

These and more specific objects and advantages are apparent from the following description of a preferred form of the invention.

According to the invention the housing of a positive displacement pump is provided with a passage leading from its outlet port to its inlet port and such passage is closed by a valve controlled by a weak spring and a diaphragm exposed to the outlet pressure of the pump. Pilot valve control means are arranged to bleed pressure acting on the diaphragm back to the inlet side of the pump thereby reducing the pressure on the diaphragm and permitting the valve to open whenever it is desired to reduce the output pressure of the pump. The invention further contemplates the use of a pressure relief valve for discharging fluid from a space over the diaphragm whenever the discharge pressure of the pump tends to exceed a safe pressure.

A preferred form of the invention is illustrated in the accompanying drawings.

In the drawings:

FIGURE I is a vertical section of a positive displacement pump incorporating the improved control valve means.

2

FIGURE II is a horizontal section, at reduced scale, substantially along the line II—II of FIGURE I.

FIGURE III is a schematic diagram of an improved pumping system constructed according to the invention.

FIGURE IV is a fragmentary sectional view of the control valve showing an optional arrangement of control passages.

These specific figures and the accompanying description are intended merely to illustrate the invention and not to impose limitations on its scope.

While the improved pump pressure control means may be employed with any type positive displacement pump it will, for convenience, be described as it is incorporated in a rotary sliding vane type of pump. Such a pump comprises a housing 10 having an inlet port 11 and an outlet port 12. These ports may be fitted with threaded couplings or other means for attaching pipes to the pump. A shaft 13, extending transversely through the pump housing 10, carries a circular cylindrical rotor 14 that fits within a rotor chamber 15 in the housing 10.

The rotor chamber 15 includes, as a wall thereof, an interior partition 16 of the housing 10 having a cylindrical surface concentric with the shaft 13 at a radius equal to the radius of the rotor 14. Diametrically opposite the partition 16 the rotor chamber 15 is formed by a portion 17 of the bottom wall of the housing 10. This portion is concentric with respect to the shaft 13 at a radius sufficiently greater than the radius of the rotor 14 to provide pumping chambers in the space between the rotor 14 and the wall portion 17.

The rotor 14 has a plurality of radial slots 18 extending parallel to the shaft 13 to receive sliding vanes 19 which in cooperation with the exterior surface of the rotor 14 and interior surface of the chamber 15 provide a series of pockets or chambers for transporting fluid from the inlet port 11 to the discharge port 12.

The rotor 14 has axially extending pockets 21 at the base of each of the slots 18 and the forwardly facing sides of the vanes 19 are grooved as indicated by the dotted lines 22 to form communicating passages between the pockets or chambers formed ahead of the vanes 19 and the rotor pockets 21. The grooves 22 provide free communication between the pumping chambers ahead of the vanes 22 and the pockets 21 so that the vanes may freely slide radially in the slots. Furthermore, by letting each of the pockets 21 communicate with the chamber ahead of the vane the pressure in the chamber is employed to hold the vane against the exterior wall of the rotor chamber 15.

To further assist the centrifugal force, as the rotor turns, in throwing the vanes 22 outwardly into contact with the wall of the chamber 15 a plurality of push rods 23 extending diametrically through the rotor 14 are provided so that as one of a pair of vanes is pushed inwardly by contact with a contracting portion of the chamber wall the diametrically opposite vane is pushed outwardly to keep it in contact with an expanding portion of the wall of the chamber 15.

In accordance with the invention, a bypass duct 26 leading from the outlet port 12 past a disk valve 27 to the inlet port 11 is provided in the housing 10. The valve 27 is shown as a disk valve although other types such as piston valves, ball seat valves or angular seat valves may be employed as long as the outlet pressure of the pump tends to open the valve. The disk valve 27 is carried on a stem 28 that is axially slidable through a guide bearing 30 forming part of a guide fitting 31 that fits over an opening in the housing 10 in line with a portion of the duct 26.

A flexible diaphragm 32, which, like a piston, is a pressure responsive member, is clamped between an outer marginal face 31 and a rim 33' of a cup 33 en-

3

closing a diaphragm chamber 34. The central portion of the diaphragm 32 is clambered between a pair of disks 35 mounted on the end of the stem 28. A relatively light spring 36 enclosed within the diaphragm chamber 34 bears against the disks 35 and stem 28 to urge the valve 27 into engagement with its seat 36 to close the duct 26. Preferably, to form a tight seal the valve disk 27 is provided with a rubber insert 38 that bears against the valve seat 37.

The force with which the spring 36 bears against the valve stem 28 may be adjusted by an adjusting screw 40 that is threaded through the end of the cup 33 to bear on a spring seat 41 at the end of the spring 36.

In this arrangement the pressure of the fluid in the outlet port 12 of the pump acts against the face of the valve disk 27 enclosed within the valve seat 37 and this force is opposed by the force of the spring 36 and the pressure of any fluid in the diaphragm chamber 34 acting against the diaphragm 32. Preferably, the diaphragm 32 has an effective area in excess of the area of the valve disk 27 so that the fluid pressure required in the chamber 34 in order to assist the spring 36 in balancing the force on the valve disk 27 will be less than the fluid pressure in the outlet port 12 or the duct 26 ahead of the valve disk 27. The effective area of the diaphragm 32 may be less than the area of the valve disk 27 and the operating point of the valve may be controlled by hydraulic pressure in the diaphragm chamber 34 that is less than the desired discharge pressure if the spring 36 is made strong enough to overcome the excess force of the outlet pressure against the valve 27. For many applications it is desirable that the hydraulic pressure in the diaphragm chamber 34 be approximately equal to or slightly less than the discharge pressure in the outlet port 12 when the valve 27 is controlling the flow of excess fluid and thus controlling the outlet pressure.

According to one aspect of the invention, the hydraulic pressure required in the diaphragm chamber 34 is obtained from the discharge port 12 or the duct 26 by way of a small tube 43 that is tapped into the bypass duct 26 and which leads to the chamber 34. A check valve 44 and an adjustable throttling valve 45 are included in this tube or line 43 to regulate the rate at which fluid may flow from the bypass duct 26 into the diaphragm chamber 34. When the pump is first started the spring 36 urges the valve 27 into closed position and thus produces enough pressure in the bypass duct 26 and outlet port 12 to cause fluid to flow through the connecting tube 43, check valve 44, and throttling valve 45 into the diaphragm chamber 34 so that the pressure built up in the chamber then assists the spring in maintaining the valve 27 in its closed position. Without any further control the discharge valve 27 would not open under any slow increase in pressure but might open momentarily following a sharp or sudden increase in pressure which would tend to increase the force against the valve disk 27 before a counterbalancing pressure could be developed in the diaphragm chamber 34 in response to fluid flow through the throttling valve 45.

The actual discharge pressure in the outlet port 12 is controlled by bleeding fluid from the diaphragm chamber 34 into the inlet port 11 of the pump. As shown in FIGURE II this includes a pipe 46, a diaphragm controlled pilot valve 47, and pipes 48 leading to the suction or inlet port 11 of the pump. The diaphragm pilot valve 47 is arranged to open its port whenever the pressure in a control line 50 acting against its diaphragm 51 exceeds the force of a control spring 52 of the valve. The control tube or control line 50 may be connected to any portion of the discharge system of the pump 10 at which it is desired to maintain a constant pressure.

When the pump is in operation and the pressure at the selected point equals the desired pressure the valve 47

4

opens its port 49 to allow fluid to drain or leak from the diaphragm chamber 34 at a rate which is equal to or may momentarily exceed the rate at which the fluid passes through the throttling valve 45 into the diaphragm chamber so that the actual pressure exerted against the control diaphragm 32 is just sufficient to hold the valve disk 27 in throttling position and thus control the flow of fluid through the bypass 26.

As a safety feature to prevent stalling or damage to the pump in the event of throttling or closure of the discharge system being supplied by the pump and simultaneous failure of the control valve 47 an auxiliary relief valve 55 (FIGURE I) is connected in piping 56 leading from the diaphragm control chamber 34 directly to the inlet or suction port 11 on the low pressure side of the valve 27. The relief valve 55 is set for a pressure slightly greater than that corresponding to the maximum pressure ever desired from the pump and passes fluid from the diaphragm chamber 34 whenever the pressure in that chamber is raised above the control pressure by the force of fluid in the outlet port 12 acting against the valve 27 and tending to move the diaphragm 32. Ordinarily there is no flow of fluid through the relief valve 55, its sole function being to limit the maximum pressure that can be attained by the pump by limiting the pressure that can be obtained or maintained in the diaphragm chamber 34.

The relief valve 55 actually serves the same purpose as would a preloaded spring connection arranged between the diaphragm 32 and the valve disk 27 which would permit the valve disk 27 to move relative to the stem 28 whenever the pressure in the bypass duct 26 ahead of the valve 27 exceeded the maximum allowable pressure. The relief valve 55 is a preferred construction because of the limitations in space.

It may also be noted that any failure or leakage of the principal diaphragm 32 or obstruction of the pipe 43 or throttling valve 45 prevents the build up of pressure in the chamber 34 and therefore allows the valve 27 to open as soon as the discharge pressure overcomes the force of the spring 36. Thus failure of these parts cannot produce excessive pressures in the system.

In order to regulate the pressure that is maintained in the outlet port 12 for a given pressure in the diaphragm control chamber 34 throughout wide ranges of delivery rates from the pump which requires correspondingly wide ranges of flow through the bypass duct 26 past the valve 27 the valve disk 27 is arranged to operate in a generally cylindrical portion of the duct 26 having a greater diameter than the valve seat. At its maximum deflection the valve disk 27 does not move outside of the axial length of this cylindrical portion and since it maintains a fairly close clearance with the periphery of the cylindrical portion it is apparent that the effective area of the valve disk 27 against which the pump discharge pressure acts increases as soon as the valve disk moves away from its seat 37. Thus a lower pressure in the discharge or outlet port 12 is effective to overcome the spring pressure and the hydraulic pressure in the diaphragm chamber 34. The amount of this effect is controlled by relieving the cylindrical portion of duct surrounding the valve 27 on its side adjacent the inlet port 11 so as to provide a throttling region of substantial area as soon as the valve disk 27 lifts from its seat 37. This throttling passage through the region 57 may, if made comparatively small, cause the output pressure of the pump to decrease with decreasing delivery. Alternatively, by making this cutout portion of the cylindrical surface of greater extent the outlet pressure of the pump will increase with diminishing flow.

In many types of service satisfactory control of the pump may be obtained without resorting to adjustment of the throttling valve 45 in the line 43 feeding fluid from the discharge side of the pump to the diaphragm chamber 34. In these situations a construction similar

5

to that shown in FIGURE I modified according to FIGURE IV may be employed. In this arrangement a valve 27a is carried on a tubular valve stem 28a that is axially slidable through a bearing guide 30a in a guide fitting 31a. As in the structure shown in FIGURE I, a diaphragm 32a is clamped between the marginal areas of the fitting 31a and the rim of a cup 33a enclosing a diaphragm chamber 34a. The central area of the diaphragm is clamped between disks 35a mounted on the stem 28a.

The size of the axial bore through the tubular valve stem 28a is selected so that the restriction to fluid flow through the bore is generally the same as the restriction offered by the throttling valve 45. The bore through the valve stem thus takes the place of the valve 45 and the connecting pipes and fittings.

A spring 36a is included to urge the valve 27a toward closed position. The spring is selected for average conditions and is held between fixed seats in the chamber 34a and on the disks 35a.

To facilitate cleaning the bore of the valve stem 28a a removable cap screw 40a is tapped into the chamber housing 34a in line with the valve stem 28a so that, after removing the cap screw, a cleaning wire may be inserted through the opening and pushed through the bore of the valve stem to dislodge any foreign material from the bore.

The flexibility of control afforded by integral construction of the diaphragm control valve in the pump housing and the simplicity obtained by feeding the diaphragm chamber through a throttled connection to a pump discharge makes possible the accurate and simple control of rather complex delivery systems. Thus in the system shown in FIGURE III which is designed for use in the fueling of aircraft, a pump 60, constructed according to FIGURES I and II, discharges through a pipe 61 that includes a venturi 62 and thence through a pipe 63, a filter and separator 64, a check valve 65, and meter 66 to a pair of hose lines 67 leading to the aircraft fuel tanks. A branch pipe 68 equipped with check valve 69 is included in parallel with the pipe 63, filter 64 and check valve 65 so that fuel may be taken from the aircraft fuel tanks whenever it is necessary to defuel the plane. This is done by merely reversing the pump.

The control for the pump 60 in addition to the throttled lead from the pump discharge into the diaphragm control chamber and the relief valve 55 as shown in FIGURE I includes a first control valve 71 similar to the valve 47 of FIGURE II and a second control valve 72 also arranged to bleed fluid from a diaphragm control chamber 73, corresponding to the chamber 34, back into the inlet port of the pump. Control valve 72 is a conventional differential control valve containing several pressure responsive elements and is responsive to the difference in pressure in two lines and to the actual pressure in a third line. Its valve stem is urged to valve closed position by a spring generally similar to the spring 52 of the valve 47 in FIGURE II which is opposed by a diaphragm subjected to fluid pressure in accordance with the pressure to be maintained at a selected point in the system. In addition a second diaphragm connected to the valve stem and having chambers above and below it is included with the two chambers connected to related points in the system so that the diaphragm is responsive to the difference in pressure at these points. The pressure control diaphragm, acting in opposition to the control spring, is connected through a control line 74 to a junction between the meter 66 and the hose line 67 so as to be responsive to the pressure exerted at the inlet to the hose lines. The differential chambers of the valve 72 are connected through lines 75 and 76 to opposite sides of the venturi 62 so as to be responsive to the pressure drop across the venturi which in turn is related to the rate of flow of material through the venturi. The system is arranged so that the differential

6

pressure transmitted through the lines 75 and 76 to the control valve 72 acts in opposition to the pressure transmitted through the line 74 and thus causes the pressure at the discharge of the meter 66 to increase with an increase of the delivery rate of the pump. By suitably proportioning the size of the venturi 62 in relation to the pressure drop in the hose lines between the meter 66 and the plane fuel tank the system may be arranged so that the output pressure of the pump as measured at the discharge of the meter 66 increases so as to maintain a constant pressure at the delivery end of the delivery hose.

Occasionally it is required to provide a reduced discharge pressure at the nozzle at the end of the hose when adding the last increment of fuel to the fuel tanks. In this system this is accomplished by providing a valve 77 in the line between the line 74 and the control valve 71 and adjusting the valve 71 to maintain a pump discharge pressure just sufficient to overcome the friction losses and difference in elevation that occur during low rate delivery of fuel to the fuel tank. With the valve 77 open the discharge pressure is much less than it would be if controlled by the valve 72 so that the valve 71 by itself regulates the pump discharge pressure to the system and thus the rate of flow. For normal delivery the valve 77 is closed and the system then is under control of the valve 72 to regulate the pressure in accordance with the rate of flow desired.

The described system shows the use of the improved control to establish desired pressure and flow characteristics at points remote from the pump by suitably controlling the pump. The specific control systems and components are described as examples and not as limits of the invention.

Having described the invention, I claim:

1. In a pump control, in combination, a pump housing having inlet and outlet ports, means in the housing for forcing fluid from the inlet port to the outlet port, a passage in the housing leading from the outlet port to the inlet port, a valve in said passage for controlling the flow therethrough, said housing having an opening in a wall thereof in communication with said passage between said valve and said inlet port, a diaphragm closing said opening, means mechanically coupling the valve and the diaphragm, a cap enclosing the diaphragm, said diaphragm having an effective area at least as large as the effective area of the valve, throttling means for admitting fluid from the outlet port into the cap, conduit means connecting the spaces on opposite sides of the diaphragm, and control means responsive solely to a pressure to be controlled for controlling the flow of fluid from the cap through the conduit means to maintain a fluid pressure in the cap in accordance with the desired value of the pressure to be controlled.

2. In a pump control, in combination, a pump housing having inlet and outlet ports, means in the housing for forcing fluid from the inlet port to the outlet port, a passage in the housing leading from the outlet port to the inlet port, a valve disk in said passage for controlling flow therethrough, said housing having an opening in a wall thereof in communication with the passage between the valve and the inlet port, a diaphragm closing said opening, a mechanical connection between the diaphragm and the valve, a cap forming a chamber over said diaphragm, a spring in the cap urging the diaphragm toward valve closed position, conduit means connecting the chamber to the inlet and outlet ports, means in the conduit between the outlet port and the chamber for throttling the flow of fluid from the outlet port into the chamber, and control means sensitive only to the output pressure, said control means including a valve in the conduit means between the chamber and the inlet port for reducing the pressure in the chamber and therefore the force on the valve disk in accordance with a control signal applied to the control means.

7

3. In a pump control, in combination, a pump housing having inlet and outlet ports, means in the housing for forcing fluid from the inlet to the outlet port, a passage in the housing connecting said ports, a valve disk in said passage for opposing flow through the passage, said housing having an opening in a wall thereof communicating with said passage, a stem for said valve disk, a perforated member mounted in said opening and providing a bushing for said valve stem, a diaphragm covering said perforated member and engaging said stem for positioning the valve disk, a cap enclosing said diaphragm, a restricted conduit connecting the cap to the outlet port of the pump, a conduit including a pressure controlled valve connecting the cap to the inlet port, said pressure controlled valve being controlled solely by pressures to be regulated, and a pressure relief valve connected in parallel with the pressure controlled valve.

4. A pump control according to claim 1 in which the control means includes a pressure operated valve.

8

5. A pump control according to claim 1 in which the control means includes a pressure operated valve that is opened by the application of control pressure thereto.

6. A pump control according to claim 1 in which the throttling means admitting fluid from the outlet port to the cap is included in the means mechanically coupling the valve and diaphragm.

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