Aug. 1, 1967 N. A. LYSHKOW 3,333,548

POSITIVE DISPLACEMENT PUMP

Filed June 21, 1965 3 Sheets-Sheet 1

Fig. 1

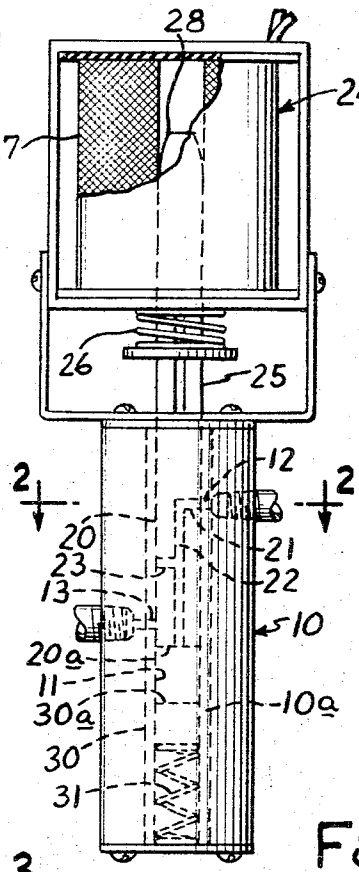


Fig. 4

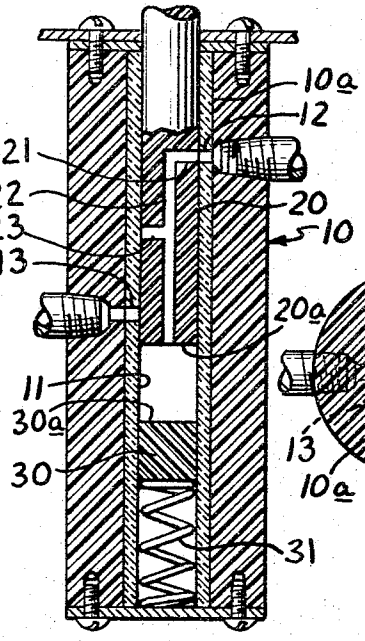


Fig. 2

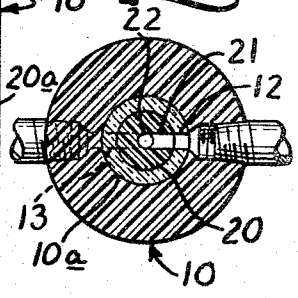


Fig. 3a

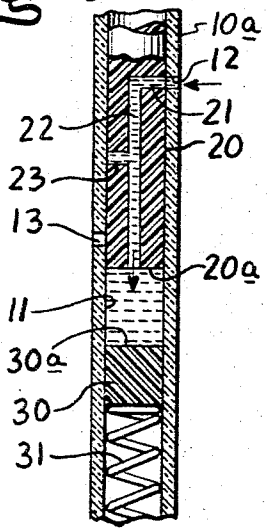


Fig. 3b

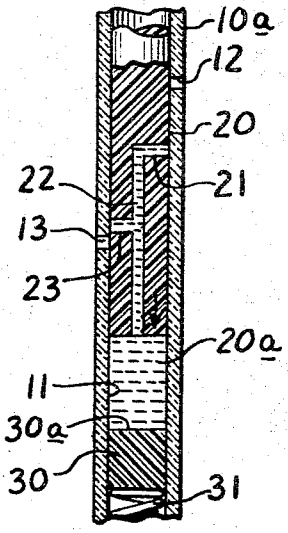
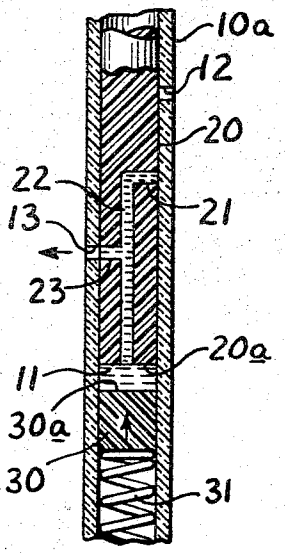


Fig. 3c



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Fig. 3d

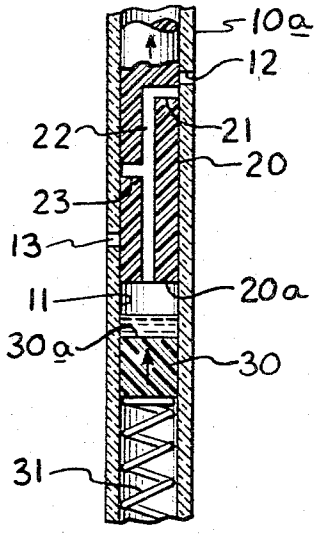


Fig. 5

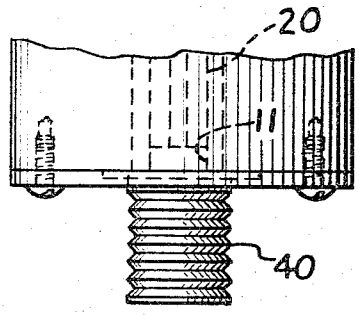


Fig. 6

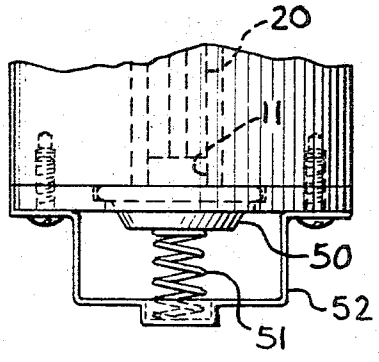
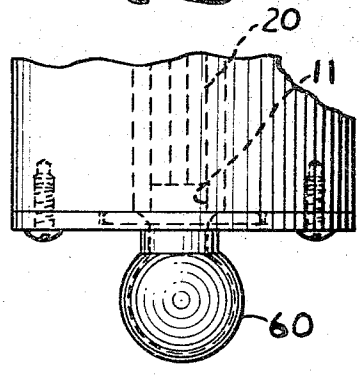


Fig. 7



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Fig. 8

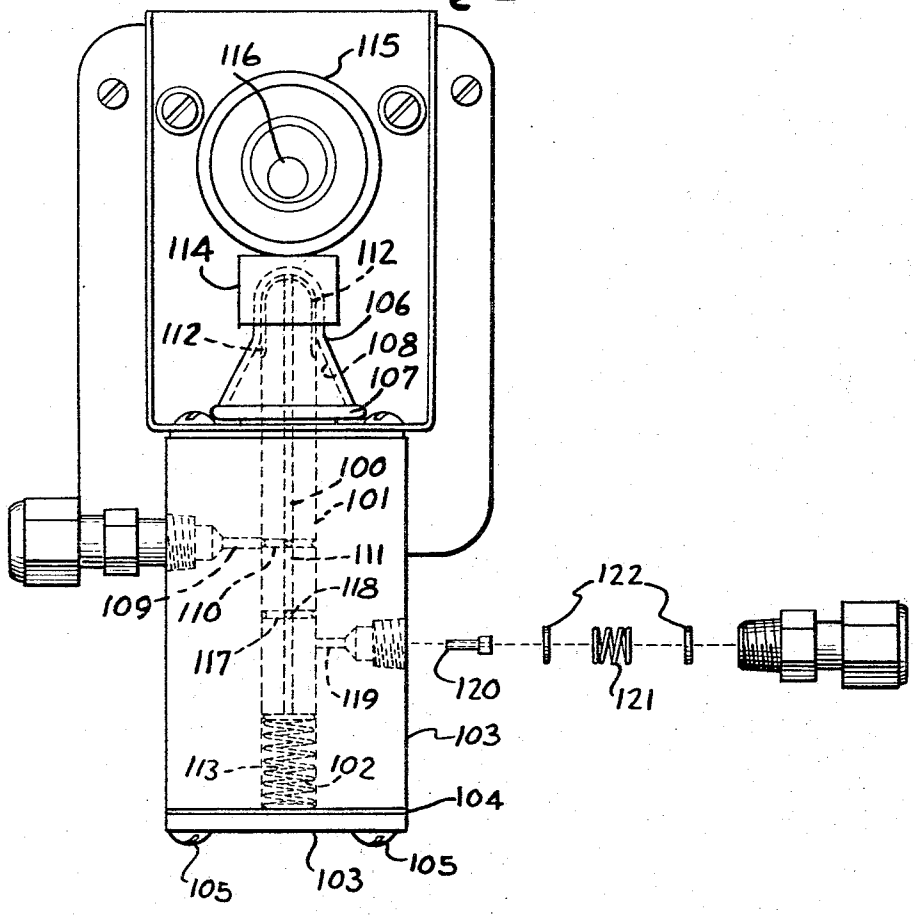
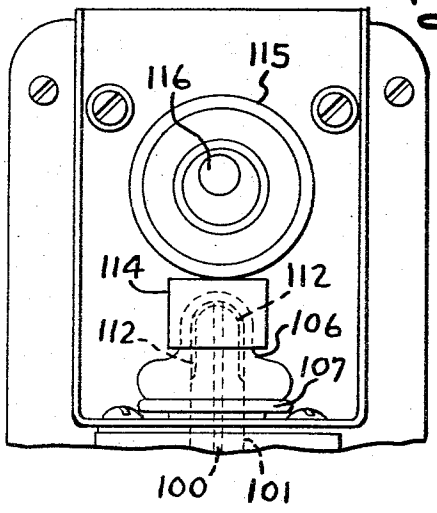


Fig. 9



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Patented Aug. 1, 1967

3,333,548

POSITIVE DISPLACEMENT PUMP

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3 Claims. (Cl. 103—154)

ABSTRACT OF THE DISCLOSURE

A positive displacement pump in which a piston opens an entrance port to admit fluid into a pump chamber, then closes the entrance port and increases the pressure on a biased flexible member so as to retract the same against the bias, and then opens an exit port so that the return movement of the biased flexible member discharges the fluid from the pump chamber through the exit port.

This invention relates generally to positive displacement pumps and, more particularly, to an improved positive displacement pump which is suitable for many different laboratory and industrial applications.

It is a primary object of the present invention to provide an improved positive displacement pump which is capable of providing relatively small fluid flow rates with a high degree of accuracy. It is a more specific object to provide such a pump which is capable of delivering fluid flow rates on the order of about 0.5 to 5 milliliters per minute with a high degree of accuracy, even over extended operating periods.

It is another object of this invention to provide an improved positive displacement pump of the foregoing type which permits the flow rate to be varied by a single relatively simple adjustment. A related object is to provide such a pump in which the flow rate adjustment can be made simply and accurately even by an unskilled operator.

It is a further object of the present invention to provide an improved positive displacement pump of the type described above which is economical to manufacture and which has a long operating life. In this connection, it is another object to provide such a pump which can be manufactured from a minimum number of parts so that it is inexpensive to manufacture and maintain.

Still another object of this invention is to provide an improved positive displacement pump of the above type which requires only a small volume.

Other objects and advantages of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is an elevation view of an improved positive displacement pump embodying the present invention;

FIG. 2 is a horizontal section taken along line 2—2 in FIG. 1;

FIGS. 3*a* through 3*d* are a series of fragmentary vertical sections of the pump of FIG. 1 showing the positions of the movable parts at various stages of an operating cycle;

FIG. 4 is a vertical section of the lower portion of the pump of FIG. 1 containing the cooperating pistons;

FIG. 5 is a fragmentary elevation view of a modified pump including an alternative bellows-type expansion-compression means;

FIG. 6 is a fragmentary elevation view of another modified pump including another alternative diaphragm-type expansion-compression means;

FIG. 7 is a fragmentary elevation view of a further modified pump including a further alternative elastic bulb-type expansion-compression means;

FIG. 8 is an elevation view of another positive displacement pump embodying the present invention with the movable parts shown in the intake position; and

FIG. 9 is a fragmentary view of the pump of FIG. 8 with the movable parts in the discharge position.

While the invention will be described in connection with certain preferred embodiments, it is to be understood that the invention is not intended to be limited to the disclosed embodiments but, on the contrary, it is intended to cover the various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

Turning now to the drawings, the illustrative pump includes a cylindrical housing **10** forming a pump chamber **11**. The fluid to be pumped is admitted to the housing **10** through an entrance port **12** and is subsequently discharged from the housing at the desired flow rate through an exit port **13**. The pump housing **10** is preferably lined with a glass tube **10***a* because of the low tolerances than can be achieved with that material, but it will be apparent that a number of other materials could be used in place of the glass. Also, the pump housing **10** is shown as having a cylindrical configuration, but the principles of this invention are equally applicable to numerous other geometric configurations.

In accordance with one important aspect of this invention, the pump includes means for switching the external fluid connection with the pump chamber alternately back and forth between the entrance and exit ports in the pump housing, and means responsive to the fluid connection of the pump chamber with the exit port for forcing fluid out of the pump chamber through the exit port. Thus, in the illustrative embodiment shown in the drawings, a primary piston **20** is mounted within the housing **10** for movement between the entrance port **12** and the exit port **13**. In order to provide a fluid seal between the piston side walls and the inside walls of the housing **10**, the primary piston is of cylindrical shape conforming to the interior shape of the housing **10**. Consequently, the piston **20** is capable of moving axially within the pump housing while maintaining a tight fluid seal along the piston side walls which slide over the inner walls of the housing. As will be apparent from the ensuing discussion, the primary piston **20** is positioned within the pump housing so that both the entrance port **12** and the exit port **13** are always blocked by the solid piston side walls except when one of the ports is in fluid communication with the passageways formed within the piston, as described in more detail below.

For the purpose of admitting fluid from the entrance port **12** into the pump chamber **11**, the primary piston **20** is provided with an interior passageway including a transverse leg **21** adapted to communicate with the entrance port **12** when the piston **20** is in a retracted or intake position, as illustrated in FIGURE 3*a* for example. From the transverse leg **21** the fluid is passed through a longitudinal leg **22** of the interior passageway opening into the pump chamber **11**. Thus, as long as the transverse leg **21** of the fluid passageway is in communication with the entrance port **12**, fluid will flow through the primary piston **20** into the pump chamber **11** until the pump chamber becomes filled.

In order to connect the pump chamber **11** with the exit port **13**, it is necessary to move the primary piston **20** longitudinally toward the pump chamber until a second transverse leg **23** of the fluid passageway communicates with the exit port **13**, as illustrated in FIGURE 3*c* for example. When the piston **20** is in this position, the transverse leg **21** is moved completely out of register with the entrance port **12** so that fluid can flow only between the pump chamber and the exit port. Conversely, when the transverse leg **21** is in communication with the entrance port of the pump, the transverse leg **23** is completely out of register with the exit port **13** so that fluid flow can occur only between the entrance port and the pump cham-

ber. Consequently, it can be seen that the fluid connection with the pump chamber can be switched alternately back and forth between the entrance and the exit ports by simply moving the primary piston **20** back and forth in the longitudinal direction.

In order to drive the primary piston **20** back and forth between the entrance and exit ports in the pump housing, a solenoid drive **24** is operatively associated with an upper extension **25** of the piston **20** for moving the piston in a first direction, and a coil spring **26** is disposed around the extension **25** bearing against a flange **25***a* for moving the piston in the other direction. When the coil **27** of the solenoid drive **24** is energized, it attracts a magnetic core **28** secured to the end of the piston extension **25** so as to move the piston **20** to the intake position shown in FIGURE 3*a*. The piston **20** remains in this position until the solenoid coil **27** is de-energized, at which time the compressed coil spring **26** drives the piston **20** to the discharge position shown in FIGURE 3*c*. Thus, by simply varying the frequency of energizing pulses supplied to the solenoid drive, the primary piston **20** can be moved back and forth between the intake and discharge positions at any desired frequency.

As the primary piston **20** is advanced between the intake position shown in FIGURE 3*a* and the discharge position of FIGURE 3*c*, a secondary piston **30** is retracted by pressure of the fluid within the pump chamber **11** against the end **30***a* of the secondary piston. The secondary piston **30** is biased toward the primary piston **20** by means of a coil spring **31** disposed around the secondary piston rod **32** and bearing against the outer end **33** of the secondary piston. As long as the primary piston **20** is somewhere between the entrance and exits ports, the fluid pressure is sufficient to overcome the biasing force of the spring **31** and, as a result, the secondary piston **30** is gradually retracted to the position shown in FIGURE 3*b*. Thus, FIGURE 3*b* shows the position of the secondary piston **30** and the other pump elements just before the transverse passageway **23** comes into register with the exit port **13**. As soon as the transverse leg **23** of the fluid passageway in the primary piston **20** comes into communication with the exit port **13**, the fluid pressure within the pump chamber **11** is decreased so that the compressed spring **31** advances the secondary piston **30** to force fluid out of the pump chamber through the exit port **13**. The force of the secondary piston **30** continues to discharge fluid from the pump chamber **11** as long as the passageway **23** remains in communication with the exit port **13**, as illustrated in FIGURE 3*c*.

As the primary piston **20** begins the next intake stroke back toward the inlet port **12**, the volume of the pump cavity **11** is suddenly increased. Since both the entrance and exit ports **12** and **13** are closed by the side walls of the piston, fluid cannot enter the increased volume and consequently, there is a brief reduction in pressure within the pump chamber **11** and the piston passageways until the passageway **21** comes into communication with the entrance port **12**. During this interval of reduced pressure, the secondary piston **30** is drawn upwardly a short distance, indicated as distance *a* in FIGURE 3*d*, toward the retracting primary piston. This slight overtravel of the secondary piston **30** serves to limit the degree of pressure reduction within the pump chamber and thereby reduces the possibility of air or other fluid leaking into the pump chamber during the intervals of reduced pressure. This feature is believed to be advantageous in extending the operating life and reliability of the inventive pump.

It will be appreciated that the fluid flow rate provided by the illustrative pump can be readily adjusted by simply varying the frequency of the energizing pulses supplied to the solenoid drive **24** so as to vary the frequency of the reciprocating primary piston **20**. The capacity of the pump can be varied by changing the dimensions of the pump chamber and/or the length of the piston stroke.

In FIGURES 5–7, there are illustrated various alternative expansion-compression means which can be substituted for the secondary piston **30** and spring **31** for discharging fluid from the pump chamber during the discharge stage of each pumping cycle. Thus, in FIGURE 5 an expansion-compression chamber is provided directly below a pump chamber **11** and primary piston **20** by means of a bellows **40**. As the primary piston **20** is advanced from the intake position of FIGURE 3*a* to the discharge position of FIGURE 3*c*, the increased fluid pressure within the pump chamber **11** expands the bellows **40**, and the bellows then subsequently contracts when the transverse leg **23** of the piston passageway comes into fluid communication with the exit port **13** so as to provide the desired discharge action.

In FIGURE 6, the desired expansion-compression chamber is provided by a diaphragm **50** and a spring **51** anchored to a rigid end plate **52**. Thus, as the fluid pressure within the pump chamber **11** is increased due to the downward movement of the piston **20**, the spring **51** is compressed so as to draw the flexible diaphragm **50** down into the recess defined by the end plate **52**. Then as the piston passageway comes into communication with the exit port **13** to reduce the fluid pressure, the spring **51** expands to drive the flexible diaphragm **50** upwardly toward the pump chamber **11**, thereby forcing fluid out of the pump chamber through the piston passageway and the main exit port.

In the alternative embodiment of FIGURE 7, an elastic bulb **60** forms the desired expansion-compression chamber. The bulb **60** is expanded by the increased fluid pressure during the discharge stroke of the primary piston **20**, and then compresses to drive the fluid out of the pump when the fluid pressure is eventually reduced by the fluid communication between the piston passageway and the exit port.

A further alternative embodiment of the present invention is illustrated by the positive displacement pump shown in FIGURES 8 and 9. In this embodiment, the main portion of the pump chamber is formed by a longitudinal passageway **100** extending through the entire length of the pump piston **101**, and a chamber **102** formed by the pump housing **103** adjacent the lower end of the piston **101** and in fluid communication with the longitudinal passageway **100**. The lower end of the pump chamber **102** is completely sealed against fluid leakage by means of a rigid end plate **103** and a sealing gasket **104** fastened to the bottom of the housing **103** by screws **105**. The upper end of the piston passageway **100** opens into a resilient diaphragm or nipple **106** mounted on a sealing disc **107** with the internal cavity **108** formed by the nipple **106** also forming a part of the pump chamber.

When the piston **101** is in the intake position illustrated in FIGURE 8, fluid is admitted into the pump chamber through an intake port **109** extending through the pump housing **103**. Fluid from the intake port **109** flows around a peripheral intake groove **110** formed in the surface of the piston **101**, and then through a radial passageway **111** into the main longitudinal passageway **100** which directs the fluid downwardly into the chamber **102** and upwardly into the cavity formed by the nipple **106**. Since the upper end of the piston **101** bears against the inner surface of the upper end of the nipple **106** a pair of grooves **112** extend from the end of the passageway **100** down into the nipple cavity **108** so that the passageway **100** is always in fluid communication with the cavity **108**.

For the purpose of driving the pump piston **101** back and forth between the intake and discharge positions, a mechanical driving arrangement is associated with the upper end of the piston, and the piston is biased upwardly thereagainst by a return spring **113** disposed within the pump chamber **102** and bearing against the lower end of the piston. Consequently, the piston is continuously urged upwardly against a rigid cap **114** which is designed to fit over the narrow upper end of the nipple

106 in bearing engagement with a cam 115 eccentrically mounted on a main drive shaft 116. As the drive shaft 116 rotates the eccentric cam 115, the cam drives the cap 114 and the piston 101 downwardly against the bias of the return spring 113. This reduces the volume of the chamber 102 and forces fluid from the chamber 102 upwardly through the passageway 100 into the nipple cavity 108 at increased fluid pressure, thereby flexing the side walls of the nipple 106 outwardly as illustrated in FIGURE 9.

In order to discharge fluid from the pump chamber, the piston 101 is provided with a second peripheral groove 117 communicating with a radial passageway 118 leading into the main longitudinal piston passageway 100. As soon as the peripheral groove 117 comes into communication with an exit port 119 formed in the pump housing, the fluid pressure within the pump chamber is decreased so that the flexed diaphragm or nipple 106 tends to resume its natural shape and thereby forces fluid out of the pump chamber through the exit port 119. As the eccentric cam 115 continues to rotate, the spring 113, which was compressed during the down stroke, expands to urge the piston 101 and the nipple cap 114 upwardly until the piston is return to its intake position shown in FIGURE 8. This completes one pumping cycle, and the frequency of these cycles can be adjusted by simply varying the angular velocity of the drive shaft 116.

In accordance with one aspect of this particular embodiment of the invention, an improved sealing means is provided between the pump entrance and exit ports and the side walls of the reciprocating pump piston. Thus, a small sleeve 120, which may be made of Teflon for example, is fitted into the exit port 119 and biased inwardly against the side walls of the piston 101 by means of a small spring 121. The spring 121 is compressed between a pair of end washers 122 when the external connecting member 123 is threaded into the pump housing. As the piston 101 is reciprocated back and forth between the intake and discharge positions, the outside wall of the piston simply slides over the abutting end of the sleeve 120 so as to maintain a fluid seal between the piston side wall and the exit port 119. The inner end of the sleeve 120 has a diameter larger than the longitudinal width of the discharge groove 117 formed in the piston so that the sleeve 120 does not slip into the groove 117 when the piston is in its discharge position with the sleeve 120 and groove 117 aligned with each other. A similar sealing arrangement is provided at the entrance port 109.

Since the piston of the pump shown in FIGS. 8 and 9 opens at both ends into fluid chambers which are sealed to the atmosphere and in continuous fluid communication with each other, the only seal required along the piston side walls is in the regions of the entrance and exit ports. The two fluid chambers 102 and 108 at opposite ends of the piston are in continuous fluid communication with each other through the longitudinal piston passageway 100, so any fluid leakage along the adjacent side walls of the piston 101 and the housing 103 simply supplements the main fluid flow through the passageway 100. Thus, this construction eliminates the necessity for maintaining an effective fluid seal along the entire length of the reciprocating piston except at the entrance and exit ports, where sealing is effected by the relatively simple and inexpensive arrangement provided by the sleeve 120 and spring 121.

While the present invention has been described above with particular reference to specific preferred embodiments, numerous modifications and variations of the same will be apparent to those skilled in the art. For example, the primary piston 20 of the pump of FIGS. 1–4 could be driven by means other than the solenoid and spring arrangement described above, such as the mechanical cam arrangement used in the embodiment of FIGURES 8 and 9. Moreover, means other than the exemplary diaphragm or nipple 106 could be used to provide the desired discharge action in the pump of FIGS. 8 and 9.

As can be seen from the foregoing detailed description, this invention provides an improved positive displacement pump which is capable of providing relatively small fluid flow rates with a high degree of accuracy. Indeed, it has been found that the pump of this invention is capable of delivering fluid flow rates on the order of about 0.5 to 5 milliliters per minutes with a high degree of accuracy, even over extended operating periods. Moreover, the inventive pump permits the flow rate to be varied by simply adjusting the frequency of the primary piston drive, so that the flow rate adjustment can be made simply and accurately even by an unskilled operator. Furthermore, the improved pump provided by this invention can be manufactured from a very small number of parts so that it is inexpensive to manufacture and maintain. The aforedescribed pump also has a relatively long operating life and occupies an extremely small volume.

I claim as my invention:

1. An improved positive displacement pump for pumping fluids, said pump comprising the combination of a housing including an entrance port for receiving the fluid to be pumped and an exit port for discharging the fluid, a piston mounted within said housing for movement between said entrance and exit ports and including a longitudinal passageway extending between opposite ends of the piston, said piston also including a first peripheral groove and cooperating first radial passageway for providing fluid communication between said entrance port and said longitudinal passageway when the piston is in a first position, and a second peripheral groove and cooperating second radial passageway for providing fluid communication between said longitudinal passageway and said exit port when the piston is in a second position, said pump housing forming a pump chamber adjacent one end of said piston in fluid communication with said longitudinal passageway, a diaphragm member forming a fluid chamber adjacent the other end of said piston and in fluid communication with said longitudinal passageway, driving means for periodically driving said piston from said first position to said second position so as to reduce the volume of said pump chamber and thereby increase the fluid pressure in the chamber formed by said diaphragm so that the diaphragm discharges fluid through said passageway and said exit ports when the piston is in said second position, and means for returning the piston from said second position to said first position between the successive fluid discharges effected by said diaphragm member.

2. An improved positive displacement pump for pumping fluids, said pump comprising the combination of a housing including an entrance port for receiving the fluid to be pumped and an exit port for discharging the fluid, a piston mounted within said housing for movement between said entrance and exit ports and including a first radial passageway adapted to communicate with said entrance port when the piston is in a first position, a second radial passageway adapted to communicate with said exit port when the piston is in a second position, and a longitudinal passageway providing fluid communication between said first and second radial passageways and extending to one end of said piston, said housing means forming a pump chamber adjacent said one end of said piston in fluid communication with said longitudinal passageway, a diaphragm member mounted in said pump chamber so as to form a flexible wall in said chamber, biasing means operatively associated with said diaphragm member for urging said diaphragm member toward said piston, driving means for periodically advancing said piston from said first position to said second position so as to increase the fluid pressure in said pump chamber to force said diaphragm away from the advancing piston against said bias, whereby the subsequent return movement of said diaphragm by said biasing means discharges fluid from said chamber through said longitudinal pas-

sageway and said second radial passageway when the piston is in said second position, and means for returning the piston from said second position to said first position between the successive fluid discharges effected by said diaphragm.

3. An improved positive displacement pump for pumping fluids, said pump comprising the combination of a housing including an entrance port for receiving the fluid to be pumped and an exit port for discharging the fluid, a piston mounted within said housing for movement between said entrance and exit ports and including a first radial passageway adapted to communicate with said entrance port when the piston is in a first position, a second radial passageway adapted to communicate with said exit port when the piston is in a second position, and a longitudinal passageway providing fluid communication between said first and second radial passageways and extending to one end of said piston, said housing means forming a pump chamber adjacent said one end of said piston in fluid communication with said longitudinal passageway, a diaphragm member mounted in said pump chamber so as to form a flexible wall in said chamber, biasing means operatively associated with said diaphragm member for urging said diaphragm member toward said piston, driving means for periodically advancing said piston from said first position to said second position so as to increase the fluid pressure in said pump chamber to force said diaphragm away from the advancing piston against said bias, whereby the subsequent return movement of said diaphragm by said biasing means discharges fluid

from said chamber through said longitudinal passageway and said second radial passageway when the piston is in said second position, means for returning the piston from said second position to said first position between the successive fluid discharges effected by said diaphragm, and sealing means associated with each of said entrance and exit ports, said sealing means comprising a sealing sleeve slidably mounted within the port and biased inwardly against the outside walls of said piston to prevent fluid from leaking from the ports along the piston walls.

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