

[54] **POSITIVE DISPLACEMENT PUMP**
[72] Inventor: **Rodney E. Schapel**, 322 Walnut St.,
Newport Beach, Calif. 92860
[22] Filed: **Oct. 21, 1969**
[21] Appl. No.: **868,025**

[52] **U.S. Cl.**.....**417/547, 417/901**
[51] **Int. Cl.**.....**F04b 21/04, F04b 15/08**
[58] **Field of Search**.....**417/901, 401, 545, 546, 547,**
417/548, 549, 550, 551, 552, 553

[56] **References Cited**

UNITED STATES PATENTS

48,401	6/1865	Hill.....	417/547
292,105	1/1884	Curtis et al.	417/552
551,157	12/1895	De Clercq et al.....	417/549

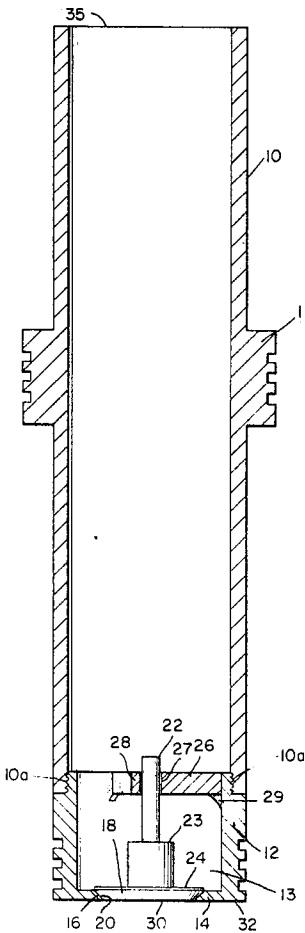
1,341,906	6/1920	Hutton	417/548
1,576,606	3/1926	Haskell	417/547 X
1,612,031	12/1926	Lanzerotti-Spina	74/569 X
2,277,641	3/1942	Harter	417/398 X
2,522,633	9/1950	Phillips	417/552 X

Primary Examiner—Robert M. Walker
Attorney—John Holtrichter, Jr.

[57] **ABSTRACT**

A positive displacement pump with the transfer (or outlet) valve seated in the piston head perpendicular to the piston axis and parallel to the inlet valve. The head space between the valves is thereby reduced to a minimum, eliminating the problem of residual liquid in the head space.

1 Claim, 5 Drawing Figures



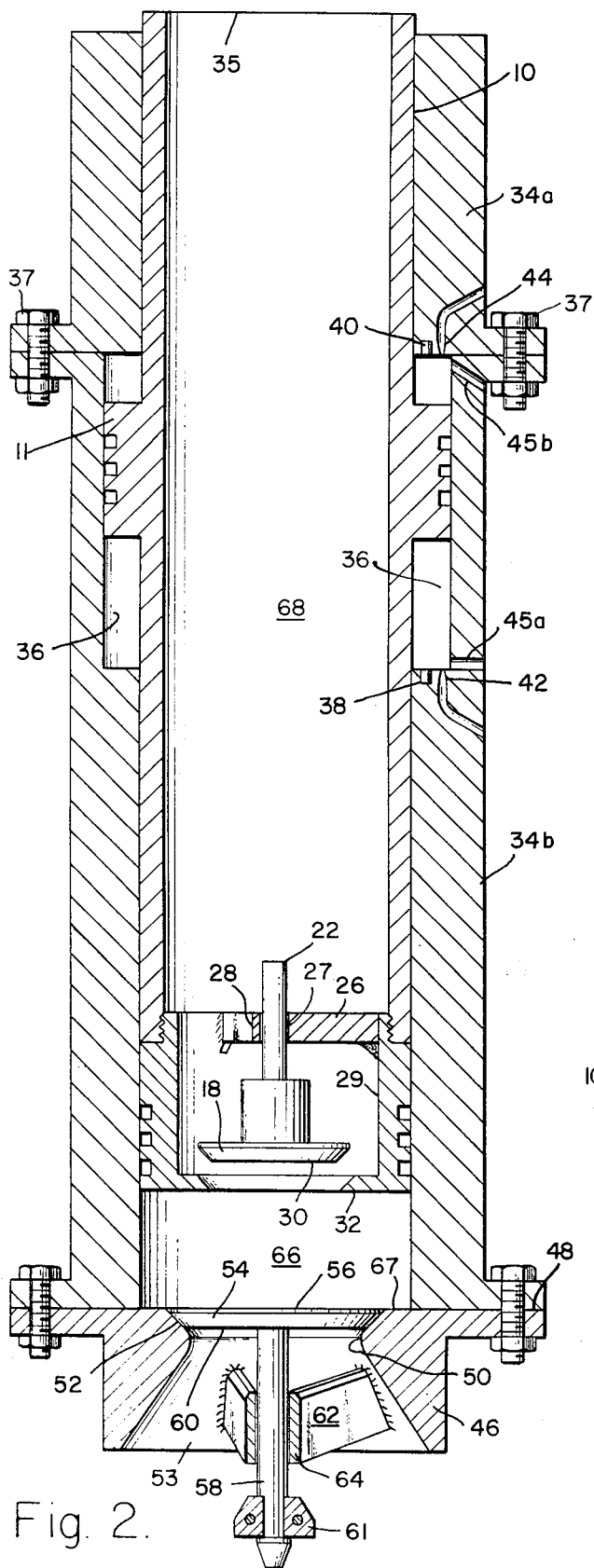


Fig. 2.

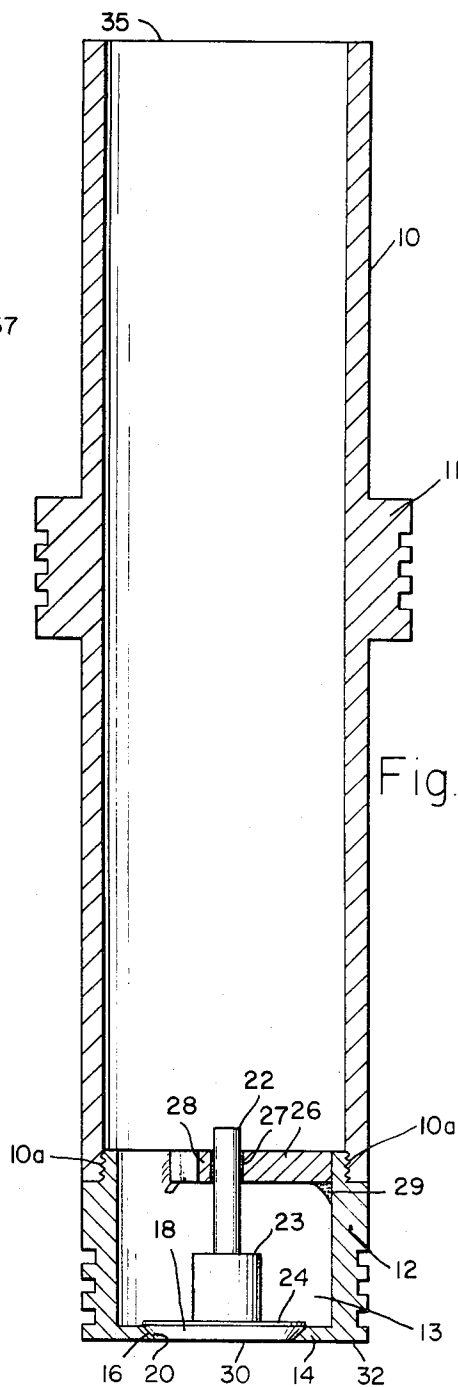


Fig. 1.

Rodney E. Schapel,
INVENTOR.
BY.

John H. Schapel

ATTORNEY.

Fig. 4.

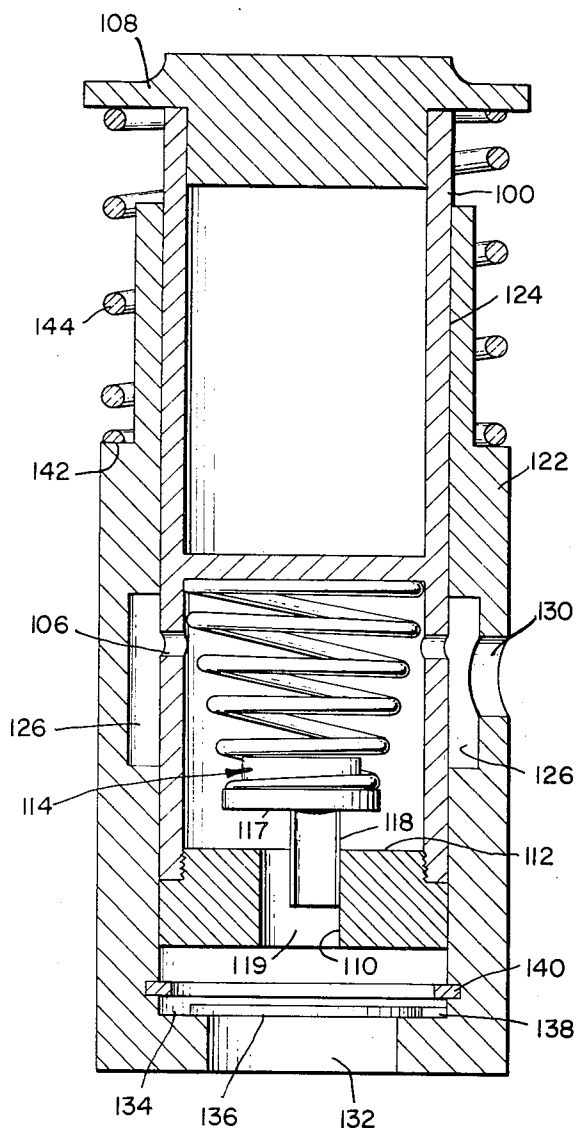


Fig. 3.

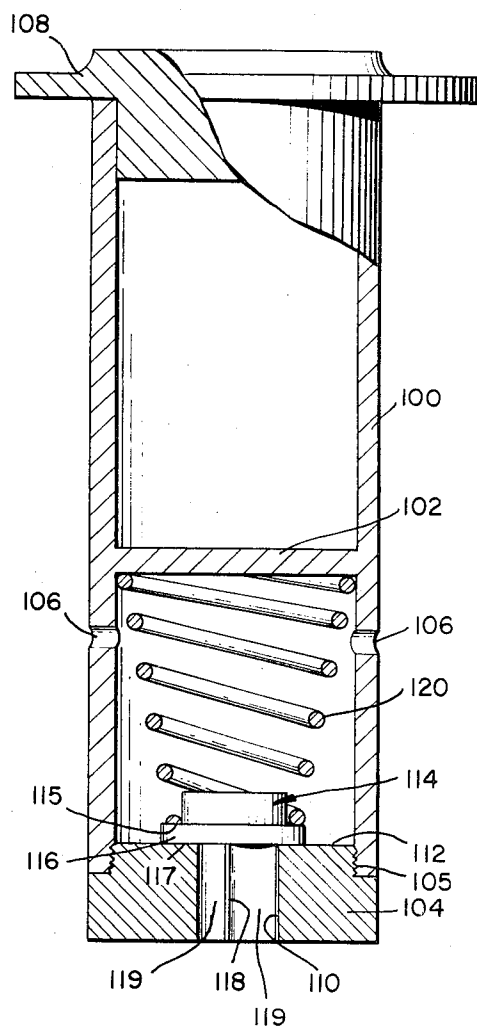
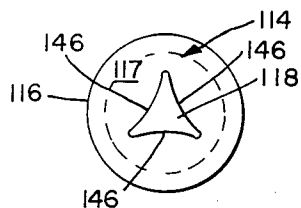


Fig. 5.



Rodney E. Schapel,
INVENTOR.

BY.

John Holthuis Jr.

ATTORNEY.

POSITIVE DISPLACEMENT PUMP

This invention relates generally to positive displacement pumps and particularly to cryogenic positive displacement pumps having minimum head space between valves.

In man's constant struggle to attain supremacy over his environment, he has achieved phenomenal results such as splitting the atom, orbiting the moon, and various other monumental accomplishments. To do all this, he has had to call on all of his available resources as well as develop new ones. In the course of his endeavors, man has delved into the realm of very low temperature physics to study the behavior of materials at very low temperatures. The results of such studies were useful in this country's space program, for example in determining how materials would behave in outer space, since the temperature in outer space is very low. The general field of electrical circuitry has also been aided by such studies, since it has been found that at temperatures near 0° K. certain materials behave as superconductors in that they can maintain the flow of current indefinitely without a power source.

To engage in the study of low temperature physics (cryogenics), as well as to put the resultant knowledge to use, man had to have at his disposal a means for creating a very low temperature environment. This usually meant immersing the workpiece or system in an environment of a liquefied gas such as liquid nitrogen, liquid helium, or other liquefied gases which liquefy at low temperatures. In the course of such work, man would often have to pump the cryogenic liquid from its container to the region where the workpiece or system under study was to be cooled.

In some instances, it was found desirable to use a positive displacement type pump for pumping the cryogenic liquid. However, a problem always persisted with such pumps. In conventional positive displacement pumps, the inlet and outlet valves are usually separated by a flow passageway. When both valves are closed, there is a fixed amount of space between them hereinafter and in the claims referred to as head space. During the operation of the pump, liquid is temporarily accumulated in the head space. The pumping action is such that when a piston is stroked in a direction causing a decrease in volume of liquid within the head space, the pressure on the liquid between the valves is increased. Since liquid is incompressible, the pressure developed by the piston is transmitted by the liquid to the inlet valve, closing it, and to the outlet valve, opening it, and thereby expelling the liquid. When the piston is returned, a suction effect is created on the inlet valve. The pressure of the incoming liquid opens the inlet valve, while the lack of pressure on the outlet valve keeps the outlet valve closed. Liquid thereby enters the pump.

A cryogenic liquid is obtained by cooling a gas under pressure. Such a liquid can be kept in such a state so long as the pressure is not decreased without a corresponding decrease in temperature, or the temperature increased without a corresponding increase in pressure. For a cryogenic liquid under a given pressure, there is a temperature above which it can no longer exist as a liquid. This is known as the saturation temperature. As the pressure is decreased, the saturation temperature is lowered so that if the pressure on a

cryogenic liquid is decreased to the point where the temperature is at the saturation point, any further decrease in pressure will cause the cryogenic liquid to vaporize.

When the liquid being pumped is cryogenic, it is usually at or near its saturation temperature so that a slight decrease in pressure will cause the liquid to vaporize. If there is residual liquid in the head space, some of it will vaporize due to the pumping action, because when the piston is returned, the pressure on the residual liquid is decreased. The resulting vapor then expands to fill the head space, increasing the pressure in the head space at the same time. Thus, the pressure on the inlet valve is increased, but not sufficiently to keep it closed. Thus, some more liquid is drawn into the head space and pumping continues. On the next stroke, some vapor is pumped out of the head space while some remains. On the next return of the piston, even more residual liquid vaporizes, while less new liquid is drawn in. This cycle will continue until the vapor pressure in the head space builds up sufficiently to maintain the inlet valve closed. Pumping then ceases. This is known as a vapor lock.

The conventional way of overcoming the problem of a vapor lock has been to keep the pump sufficiently far below the level of the liquid being pumped in order to maintain enough pressure on the outside of the inlet valve to overcome the vapor pressure built up in the head space, thereby insuring that a vapor lock would not occur.

This solution leaves much to be desired. Where the pump cannot be lowered, the liquid level must be raised or the pressure of the inlet fluid increased by other means. This can be a cumbersome proposition at best and a very costly one to boot.

Another problem encountered with positive displacement pumps, apart from pumping cryogenic liquids, involves overall size of the pump. For a given size piston and cylinder, there is usually a limit to how small the entire pump package can be. This limit is conventionally dictated by the size of the valves and the flow passage therebetween. If the valves are made too small, the flow capacity of the pump is reduced. Conversely, if the capacity of the pump is increased by increasing the valve size, the overall pump dimensions are increased.

It is therefore an object of the present invention to provide an improved positive displacement pump.

It is another object of the invention to provide a positive displacement pump having a minimum head space.

A further object of the present invention is to provide a positive displacement pump having maximum size valves while retaining minimum external housing dimensions.

Yet another object of this invention is to provide a positive displacement pump for pumping cryogenic fluids with minimum pressure exerted on the external side of the inlet valve.

These and other objects and advantages of the invention are provided by a positive displacement pump having minimum head space, comprising: a cylinder and cylinder head, with an inlet valve seated within the cylinder head; a piston rod having an inlet end and a piston actuating portion, the rod being movably mounted within and coaxial with the longitudinal axis

of the cylinder; a piston head adjacent said inlet end of said rod and having an aperture in a plane substantially perpendicular to the longitudinal axis of said cylinder and substantially parallel to the plane of said inlet valve seat so as to define a transfer valve seat; a transfer valve movably mounted in said piston head; and a transfer valve guide means mounted adjacent said transfer valve for guiding and retaining said transfer valve. The valves can be made almost as wide as the diameter of the piston without increasing the dimensions of the pump and at the same time increasing the capacity of the pump. The valve is seated in the piston so that its bottom surface is flush with the bottom of the piston. This positioning, in conjunction with an inlet valve seated in an inlet port within the cylinder or cylinder head, minimizes the head space in the pump because the flow passage between valves is part of the cylinder. Thus, when the piston is fully stroked, the bottom of the piston is almost in contact with the inlet valve, the piston thereby occupying the flow passage. Consequently, when cryogenic liquids are pumped, there is almost no residual liquid in the head space between valves. Therefore, vapor locks are avoided without resorting to immersing the pump in the liquid to be pumped.

The invention will be described in detail by reference to the drawings in which:

FIG. 1 is a cross sectional elevational view of a piston assembly according to one embodiment of the invention;

FIG. 2 is a cross sectional elevational view of an entire pump including the piston assembly of FIG. 1;

FIG. 3 is a cross sectional elevational view of a piston assembly according to a second embodiment of the invention;

FIG. 4 is a cross sectional elevational view of an entire pump including the piston assembly of FIG. 3; and

FIG. 5 is a bottom view of the transfer valve shown in FIGS. 3 and 4.

Referring now to FIG. 1, there is shown a piston assembly in detail in accordance with the teaching of this invention. A piston rod 10 in the form of a cylindrical tube with an outer flange 11 is shown threadably connected by threads 10a at one end to a piston head 12. The piston rod 10 may be in the form of a non-cylindrically shaped tube and may be connected to the piston head 12 in any manner, such as with screws or by a welded joint. The piston rod 10 and piston head 12 may alternatively comprise a single integral unit so long as the outer walls of the piston rod 10 and the piston head 12 are flush. The piston head 12 has an annular aperture 13 substantially therethrough interrupted by an internal annular flange 14 at the bottom end of the piston head 12 and substantially perpendicular to the longitudinal axis of the piston rod 10. The diameter of the inner wall 16 of the flange 14 increases linearly towards the rod 10 to define a valve seat 16. A disc shaped transfer valve 18 having a conical shaped side 20 for mating with the valve seat 16 is shown seated in the piston head 12 in the closed position. A valve stem 22, having a shoulder 23, extends from the large diameter end 24 of the transfer valve 18 partially into the tubular piston rod 10. A spider 26, having a cylindrical centerpiece 28 with an annular aperture therethrough defining a sleeve 27 for receiving the valve stem 22, is fixedly mounted to the inner wall 29 of the piston head 12.

When the transfer valve 18 is closed as shown, its smaller diameter end 30 is flush with the external bottom surface 32 of the piston head 12. When the transfer valve 18 opens, the shoulder 23 meets the bottom of the centerpiece 28, restraining the transfer valve 18 from further travel. The sleeve 27 guides the valve stem 22 and prevents the transfer valve 18 from cocking. The spider 26 is not absolutely necessary so long as means are furnished for guiding and retaining the transfer valve 18. For example, an annular retaining ring mounted on the piston rod 10 and at least 3 tabs on the perimeter of the transfer valve 18 could be used, the diameter of the circle described by the tabs being equal to the inner diameter of the piston rod 10. As an alternate valving arrangement for the transfer valve 18 and spider 26, a suitably configured flapper valve would be satisfactory.

FIG. 2 shows the piston assembly of FIG. 1 movably mounted within a tubular cylinder assembly comprising two connected sections 34a and 34b. As shown in FIG. 2, the transfer valve 18 is open. The upper end of the piston rod 10 defines the outlet port 35. The upper portion of the lower section 34b has an inner diameter defining a chamber 36 for receiving the piston rod flange 11. The upper section 34a is bolted with bolts 37 to the lower section 34b so as to confine flange 11 to the chamber 36 when the piston rod 10 moves in the cylinder assembly 34a and 34b. Sensors 38 and 40 are positioned at the bottom and top, respectively, of the chamber 36. These sensors 38 and 40 could be contact switches, for example, which cause external electric circuits to be completed upon contact with flange 11. Thus, when the piston 10 is fully stroked, flange 11 makes contact with the bottom sensor 38, causing an external electric circuit (not shown) to be completed. Completion of the circuit activates an external switch, for example magnetically, causing gas jet 42 to open. Gas jet 42 then emits gas, such as air or nitrogen for example (source of gas not shown), against the flange 11, thereby forcing the piston to return. When the piston rod 10 is returned, the flange 11 makes contact with the top sensor 40, completing a second external circuit (not shown), which in turn activates a second external switch causing a second gas jet 44 to open and the first gas jet 42 to close. Thus, when one gas jet is open, the other is closed. Gas jet 44 then emits gas (source not shown) against the other side of the flange 11, thereby restroking the piston 10. During the stroke, gas previously used to return the piston rod 10 is expelled through the bottom gas-exhaust hole 45a. During the return of the piston rod 10, gas previously used to stroke the piston rod 10 is expelled through the top gas-exhaust hole 45b. While a pneumatic actuating means is shown, the piston rod 10 could as well be actuated by other means such as a cam and cam follower or other means for causing reciprocating motion of the piston, in which case the cylinder assembly could be replaced by a single cylinder.

A cylinder head 46 is fixedly connected to the lower section 34b of the cylinder assembly at the interface 48. Cylinder head 46 might also be an integral part of section 34b instead of a separate piece. The cylinder head 46 has an annular aperture therethrough which is parallel to the longitudinal axis of the piston rod 10.

FIG. 3 is a cross sectional elevational view of a piston assembly according to a second embodiment of the invention. This embodiment is similar to FIG. 1, but the transfer valve 18 is shown in the open position. The valve stem 22 is shown extending through the piston rod 10 and the piston head 12. The spider 26 is shown in the open position, allowing the valve stem 22 to move freely. The transfer valve 18 is shown in the open position, allowing the flow passage between the piston head 12 and the transfer valve 18 to be open.

tially conical and whose diameter linearly decreases with depth into the cylinder head 46 to a level 50, defining a conical shaped inlet valve seat 52 thereby, and thereafter increases, defining an inlet port 53. An inlet valve 54, in the form of a conical disc, mates with the valve seat 52 when closed as shown, so that the large diameter end 56 of the inlet valve 54 is flush with the plane of the interface 48 and substantially perpendicular to the longitudinal axis of the piston rod 10. A valve stem 58, connected at one end to the small diameter end 60 of the inlet valve 54 and having a retainer 61 comprised of two sections screwably attached to one another so as to grip the valve stem 58 at its other end, extends outwardly of the inlet port 53. A three-fingered spider 62 (shown partly broken away) is mounted within the cylinder head 46 and has at its center a sleeve 64 designed for encompassing the valve stem 58. The retainer 61 and the inlet valve stem 58 may be a solid entity, the retainer 61 then being a flange. This would require the spider 62 to consist of two pieces mated together to define the sleeve 64. When the inlet valve 54 opens, the valve 54 and valve stem 58 can move up until the retainer 61 meets and is restrained by the sleeve 64, which also guides the inlet valve 54 back to the inlet valve seat 52. Other means for guiding and retaining the inlet valve 54 would be satisfactory so long as the inlet valve 54 is prevented from cocking. For example, a suitably configured flapper valve would suffice.

The operation of the pump shown in FIG. 2 is as follows: Initially the piston rod 10 is retracted, decreasing the pressure on the large diameter side 56 of the inlet valve 54. The pressure of the liquid near the inlet port is sufficient to open the inlet valve 54, thereby allowing the liquid to rush into a space 66, known as the head space, between the external bottom surface 32 of the piston head 12 and the upper surface 67 of the cylinder head 46. The liquid flows in until the piston rod 10 is stroked. This tends to create pressure on the trapped liquid; however, since liquid is incompressible, the transfer valve 18 is forced open on the stroke, permitting the fluid to rush into the cavity 68 within the piston rod 10. Simultaneously, the pressure created by the stroke is transmitted through the liquid to the inlet valve 54, causing it to close. The piston rod 10 is again retracted. This time the liquid accumulated in the cavity 68 of the piston rod 10 pushes against the shoulder-side of the transfer valve 18, closing the transfer valve 18. The accumulated liquid is raised in the process. Simultaneously, as the piston rod 10 is raised, the inlet valve 54 is opened as before, once more allowing more liquid to flow in. This cycle is repeated over and over, the liquid being pumped out through the outlet port 35 in the process.

The stroke of the piston rod 10 is such that when fully stroked the external bottom surface 32 of the piston head 12 is almost in contact with the interface surface 48, these two surfaces being separated by a clearance tolerance. In this way, the head space is reduced to a bare minimum. Thus, practically no residual liquid remains in the head space to flash, thereby insuring against a vapor lock.

For maximum mechanical efficiency, greatest volumetric efficiency and highest rate of flow of liquid through the pump, each valve must be allowed to open

far enough so that the liquid can flow through unimpeded in each case. For a typical operating pressure of 600 p.s.i., the capacity is approximately 15 gal/min.

Referring now to FIG. 3, there is shown another piston assembly in detail according to the present invention. Piston rod 100 in the form of a cylindrical tube, having a disc-like portion 102 cross sectionally situated about midway in the piston rod 100 and having a hollow collection chamber 103 below the disc-like portion 102, is shown threadably connected at its lower end to a piston head 104 by threads 105. A series of transfer holes 106 are circumferentially spaced in the wall of the piston rod 100 to communicate with the hollow chamber 103. A cam follower 108 in the form of a flat cap is mounted at the upper end of the piston rod 100. The piston head 104 may be mounted in any fashion, such as with screws or by a welded joint, or it may be an integral part of the piston rod 100 itself so long as the outer walls of the piston rod 100 and the piston head 104 are flush. The piston head 104 has an annular aperture longitudinally therethrough defining a valve sleeve 110 and an upper surface perpendicular to the valve sleeve 110 defining a transfer valve seat 112. A transfer valve 114 is shown in generally cylindrical form, having a spring retaining shoulder 115 near its upper end. Shoulder 115 is the upper surface of an annular flange 116 on the transfer valve 114. The lower surface 117 of flange 116 rests on the transfer valve seat 112. Valve stem 118 comprises the lower end of the transfer valve 114. The cross sectional diameter of the valve stem 118 equals the inner diameter of the valve sleeve 110 within a reasonable tolerance to allow relative longitudinal motion of the stem 118 within the sleeve 110. The stem 118 has three spaced longitudinal sections removed from the outer surface of the stem 118 thereby defining three spaced longitudinal flow passages 119 (only two being shown). When the transfer valve 114 is seated in the closed position as shown, the flange 116 rests on surface 112 and the stem 118 is positioned in the sleeve 110. When the transfer valve 114 is in the open position, liquid flows through the flow passages 119 in the stem 118 and passes up and around the flange 116. The liquid temporarily accumulates in the hollow chamber 103 of the piston rod 100 between the disc 102 and the piston head 104 until it is transferred through the transfer holes 106. The stem 118 serves as a valve guide for guiding the transfer valve 114 to its seat and for preventing it from becoming cocked or jammed when in the open position. A retaining spring 120, mounted on the top of the transfer valve 114 and supported there by the spring retaining shoulder 115 of the valve flange 116, spirals upward so as to be constrained by the disc 102. The retaining spring 120 is biased to force the transfer valve 114 back to the closed position and to force the valve stem 118 to remain in the valve sleeve 110. While a retaining spring is shown, an upper valve stem and spider could also be employed to guide and retain transfer valve 114, as could a retaining ring and 3 tabs. Furthermore, although transfer valve 114 and retaining spring 120 are shown, a suitably configured flapper valve could be used in their stead. This would eliminate the need for such a thick piston head 104.

FIG. 4 shows the piston assembly of FIG. 3 movably mounted coaxially within a tubular cylinder 122 with

the transfer valve 114 open. The cylinder 112 has a first inner diameter defining a sleeve 124 for the piston rod 100 and a second inner diameter, larger than the first, defining a transfer chamber 126. The motion of the piston rod 100 in the cylinder 122 is such that the transfer holes 106 always communicate with the transfer chamber 126. A hole in the wall of the cylinder 122 defines an outlet port 130, which communicates with the transfer chamber 126. A third inner diameter smaller than the first and located at the bottom of the cylinder 122 defines an inlet port 132. This third section of the cylinder is referred to as the cylinder head and might be a separate member screwably or boltably attached to the cylinder, for example. The internal annular shoulder 134 at the top of the inlet port 132 defines an inlet valve seat substantially parallel to the transfer valve seat 112. An inlet valve 136 in the form of a disc having three equally and circumferentially spaced tabs 138 rests on the shoulder 134 when closed as shown. When the inlet valve 136 is open, the tabs 138 are restrained by an annular retaining ring 140 fitted to the second inner diameter of the cylinder 122 at a point sufficiently above the shoulder 134 to allow unimpeded fluid flow through the inlet port 132. The tabs 138 press against the retaining ring 140, preventing the inlet valve 136 from cocking or jamming. While retaining ring 140 and inlet valve 136 with tabs 138 are shown, a suitably configured flapper valve would be a satisfactory alternative. The cylinder 122 has an external annular shoulder 142 near its upper end. A spring 144 is seated on the shoulder and presses up against the underside of the cam follower 108. A cam (not shown) is driven against the cam follower 108, causing the piston rod 100 to be stroked. The spring 144 returns the piston rod 100 to the unstroked position. While the piston rod 100 is described in this embodiment of the invention as cam operated and spring returned, other actuating means could be employed.

The operation of the pump depicted in FIG. 4 is as follows: When the piston rod 100 is returned by the spring 144, the pressure on the piston side of the inlet valve 136 is reduced. The liquid at the inlet port 132 can then exert sufficient pressure to open the inlet valve 136 and thereby enter the pump. When the piston rod 100 is stroked, pressure is exerted on the liquid in the pump. This pressure is transmitted to the inlet valve 136 which closes as a result. The pressure on the liquid is also exerted on the inlet side of the transfer valve 114, opening it. The liquid then passes into the hollow chamber 103 of the piston rod 100, is transferred through the transfer holes 106 into the transfer chamber 126, and expelled through the outlet port 130. On the return of the piston rod 100, the retaining spring 120 and the liquid above the piston head 104 combine to force the transfer valve 114 to close. The liquid in the hollow of the piston rod 100 can only go through the transfer holes and cannot go back towards the inlet valve 136. The return of the piston rod 100 results in a reduction of the pressure on the piston side of the inlet valve 136. The cycle then repeats.

When the piston rod 100 is fully stroked, the bottom of the piston head 104 comes within a reasonable tolerance of the retaining ring 140. The head space is then very small, consisting of the vacant space between the piston head 104 and the shoulder 134 and the space

in the flow passages 119. This space could be reduced further by trimming the edge of the piston head 104 to create a shoulder at the bottom which would accommodate the retaining ring 140 when the piston rod 100 is fully stroked. For a typical operating pressure of 40 p.s.i., the capacity is approximately one-half gal/min.

FIG. 5 is a bottom view of the transfer valve 114 shown in FIG. 3 and is included for greater clarity. The concave surfaces 146 of valve stem 118 comprise the inner boundaries of the three flow passages 119, two of which are shown in FIG. 3. Sleeve 110 shown in FIG. 3 forms the outer boundaries for the flow passages 119.

There has thus been shown and described a positive displacement pump having a minimum head space. Although specific embodiments of the invention have been described in detail, other variations of the embodiments shown may be made within the spirit and scope of the invention; for example: either transfer valve could be guided and retained by a retaining ring and 3 tabs; the piston head could be either an integral part of the piston rod or it could be attached to it; the transfer valve may have other shapes than those described so long as the minimum head space concept is not substantially compromised.

Accordingly, it is intended that the foregoing disclosure and drawings shall be considered only as illustrations of the principles of this invention and are not to be construed in a limiting sense.

What is claimed is:

1. A positive displacement pump having minimum head space comprising:

a cylinder including a cylinder head having an inlet valve seat;

an inlet valve movably mounted in said cylinder head, the head space side of said inlet valve being flush with the head space side of said cylinder head when said inlet valve is closed;

an inlet valve guide means mounted adjacent said inlet valve for guiding and retaining said inlet valve;

a piston rod having an inlet end and a piston actuating portion, said rod being movably mounted within and substantially coaxial with the longitudinal axis of said cylinder;

a piston head with a transfer valve movably mounted thereon, said piston head being attached to said inlet end of said rod and having an aperture in a plane substantially perpendicular to the longitudinal axis of said cylinder and substantially parallel to the plane of said inlet valve seat so as to define a transfer valve seat, said plane of said aperture substantially coinciding with said plane of said head space side of said cylinder head when said piston rod is fully stroked and said inlet valve is closed so that said head space is minimized, said transfer valve comprising a conically edged disc portion, said transfer valve seat comprising the conical edge of an annular flange which is inwardly extended from said piston head at the end of said piston head nearest said inlet valve, the small diameter side of said disc portion mating substantially flush with the side of said annular flange nearest said inlet valve, the plane of said small diameter side substantially coinciding with said plane of said head space side of said inlet valve

when said piston rod is fully stroked and said inlet valve is closed so that said head space is minimized, the edge of said disc portion mating with said conical edge of said annular flange when said transfer valve is closed; and
a transfer valve guide means mounted adjacent said transfer valve for guiding and retaining said transfer valve.

* * * * *

5

10

15

20

25

30

35

40

45

50

55

60

65