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PUMP

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FIG. 1.

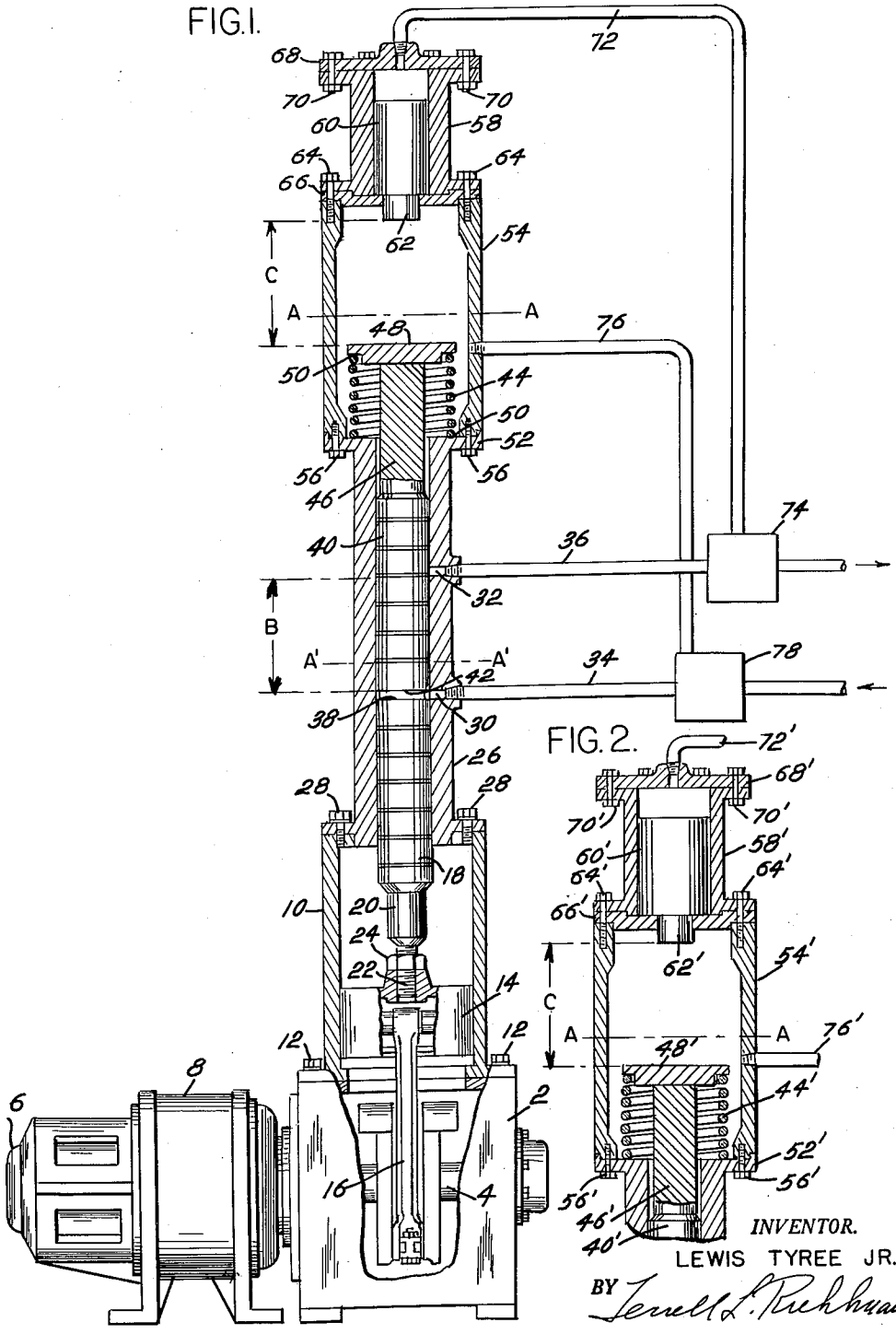



FIG. 2.




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# PUMP

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This invention relates to pumps, and more particularly to pumps of the free-piston type, such as may be used for pumping liquids at or near the boiling point, or for compressing gases through a large number of compression ratios. An example of one type of apparatus in which liquid pumps of this general type can be used is the apparatus shown in Patent 2,671,318, March 9, 1954, to Samuel C. Collins, Win W. Paget, and the present applicant. Examples of gas pumping will readily occur to those skilled in the art.

The pumping of liquids at or near the boiling point has always presented pumping engineers with grave problems. As a rule, the liquid being thus pumped can not be put under suction because any reduction in pressure of a liquid at the boiling point causes flashing of the liquid, and usually results in a vapor lock forming somewhere in the pumping system.

In the compression of gases, the number of compression ratios through which a compressor can compress a gas is usually limited by a number of factors, among these being: heating of the gas during compression and the necessity of cooling the gas (by intercoolers) to maintain compressor efficiency at a desirable level; the amount of gas remaining in the clearance volume of the machine and thus being present for re-expansion on the next suction stroke; and strength limitations in valve assemblies, which limit the permissible pressure differentials across valve assemblies. Where thermodynamic efficiency is not an important factor, a machine made according to this invention can advantageously be used to compress gases through a large number of compression ratios, because there is no clearance volume and there are no valve assemblies.

It is accordingly an object of this invention to provide a pump of the free-piston type for pumping liquids at or near the boiling point, and for compressing gases in one stage through a large number of compression ratios. This and other objects are accomplished in a free or floating piston type of pump having substantially zero clearance and being valveless, the valve function being provided by ports which are covered and uncovered at appropriate times.

In the drawings:

FIG. 1 is a view partly in elevation and partly in section showing one embodiment which the invention may assume; and

FIG. 2 is a similar view showing a modification of the invention.

It will be understood by those skilled in the art that the drawings are to some extent schematic in that they are limited to the bare essentials. As a matter of practical engineering, a pump made according to this invention will be jacketed for cooling. Where the fluid pumped is a liquefied gas far below atmospheric temperature, the jacket fluid may be the pumped liquid either before or after pumping. Where the fluid is gas being compressed, water, brine, or the like may be used for cooling. Furthermore, for pumping a boiling liquid, the inlet port will consist of a plurality of very large ports to permit easy inflow of liquid. Details such as these are design features which will be incorporated by any competent person skilled in the art.



In the embodiment shown in FIG. 1, a crankcase 2 is provided for the pump. A crankshaft 4 is rotatably mounted in the crankcase in suitable bearings, and is connected to be driven by an electric motor 6 through a suitable gear reduction 8.

A crosshead guide 10 is mounted on top of crankcase 2 and is secured thereto by threaded members 12. A crosshead 14 is reciprocably mounted in the crosshead guide 10, and is connected, by means of connecting rod 16, to be driven by crankshaft 4.

A closely fitting piston 18 is driven by crosshead 14 by means of a piston rod 20, here shown as integral with piston 18. The lower end of piston rod 20 is threaded as at 22, and a lock nut 24 secures the piston rod 20 against rotation relative to crosshead 14.

A cylinder 26 is secured to the upper end of crosshead guide 10 by threaded members 28, and is provided with inlet and discharge ports. As indicated above, any suitable number of such ports may be provided, but the embodiment shown indicates an inlet port 30 and a discharge port 32. Ports 30 and 32 are threaded to receive suitably threaded conduits 34 and 36 respectively.

Piston 18 is of course reciprocable in cylinder 26, and has a surface 38 at its upper end adapted to be exposed to the fluid which is to be pumped. The design of the pump, in the embodiment shown, is such that the piston is reciprocated by the connected mechanism through a given stroke at one end of which the piston uncovers inlet port 30 with surface 38 being immediately adjacent the inlet port, this being the position in which piston 18 is shown in the drawing; at the other end of the stroke, surface 38 is substantially alined with discharge port 32, piston 18 at this other end of its stroke not quite covering the discharge port 32.

Although the illustrated embodiment shows surface 38 just clearing port 30 at bottom dead center, it may be desirable in some applications of the invention to design the machine so that surface 38 drops below port 30 at bottom dead center. Such a provision will lengthen the time interval during which liquid is permitted to flow into the cylinder. This increased time interval will be advantageous even though liquid is subsequently pumped out again through port 30 until piston 18 has moved upward enough to block such flow. If desiried, a check valve, not shown, may be provided in inlet line 34 to prevent such outflow via port 30.

A free or floating piston 40 (also closely fitting) is provided, and is of course reciprocable in cylinder 26. Piston 40 has a surface 42 which is adapted to be exposed to the fluid which is being pumped. Pistons 18 and 40 are disposed in cylinder 26 in such a way that their respective surfaces 38 and 42 face each other. Moreover, surfaces 38 and 42 are carefully machined so as to be as nearly plane as possible, and as nearly parallel as possible. These features are especially desirable when the pump is to be a gas compressor, in order that the clearance volume may be reduced as nearly as possible to zero.

Resilient means 44 is connected to the free piston and normally biases it into a position in which its surface 42 is spaced from the discharge port and on the opposite side thereof from surface 38 when surface 38 is at bottom

dead center. In the embodiment shown, the "free" length of resilient means 44 is such that, with the system in equilibrium, surface 42 is disposed between ports 30 and 32. However, that is not the position shown in the drawing. As shown in the drawing, piston 40 is substantially at its lower limit of travel, although it will of course be understood that it is not practical to designate absolute limits of travel for a floating piston.

More specifically, piston 40 is provided with a piston rod 46 which extends out of the upper end of cylinder 26. A spring seat-providing member 48 is secured to the upper end of piston rod 46. The resilient means 44 referred to, here shown as a coil spring, is disposed between seat-providing member 48 and the upper end of cylinder 26. In the preferred form of the invention here shown, spring 44 is secured to member 48 and to cylinder 26 in a suitable manner, as for example by welds indicated at 50.

At its upper end, cylinder 26 is flanged as shown at 52, and carries a chamber 54 secured thereto by threaded members 56. In the embodiment shown, piston rod 46 extends into chamber 54, and seat-providing member 48 and spring 44 lie in chamber 54. In its free condition, spring 44 expands somewhat from the position shown in the drawing and extends the upper surface of member 48 substantially to the line shown at A—A.

Means are provided to increase the pressure in the cylinder just before the discharge port is uncovered. These means include an expansible chamber device comprising a cylinder 58 and a piston 60, piston 60 having a push rod 62. In the embodiment shown, cylinder 58 is secured to the upper end of chamber 54 by threaded members 64, and the push rod 62 extends through a suitable opening in an upper end wall 66 of chamber 54. A cylinder head 68 is secured to the upper end of cylinder 58 by threaded members 70, and has a threaded opening therein to receive a conduit 72. Conduit 72 communicates with the discharge conduit 36 through a surge chamber 74.

Reference was made above to the surface 42 of piston 40; at the end opposite surface 42, piston 40 is exposed to the inlet pressure. In the embodiment shown, this is accomplished through the medium of chamber 54. More specifically, chamber 54, into which piston rod 46 extends, is connected with inlet conduit 34 by way of a conduit 76 and a surge chamber 78.

*Operation of pump shown in FIG. 1*

Reference was made above to the line A—A as representing the reference plane to which the upper surface of member 48 moves when spring 44 is allowed to assume its free position. Under those circumstances, piston 40 is of course moved upward from the position shown in the drawing, and surface 42 assumes the position shown by line A'—A'.

Reference was made above to the means to increase the pressure in the cylinder just before the discharge port 32 is uncovered. Note that port 32 will begin to be uncovered as soon as piston 40 has moved through the distance B from its position shown in the drawing. Note that the dimension B is somewhat greater than the distance indicated as C on the drawing, dimension C being the distance from the top of member 48 as shown in the drawing to the lower end of push rod 62.

One more dimension should be referred to before the operation is discussed in detail, and that is the upper limit of the stroke of piston 18. Piston 18 is shown in the drawing at the lower limit of its stroke. When piston 18 is at top dead center, or the upper limit of its stroke, surface 38 is substantially alined with port 32. This does not necessarily mean that the axis of port 32 passes through the plane of surface 38; the important consideration is that piston 18 does not completely cover port 32 when it is at top dead center.

The cycle of operation will be described with surface 42 of piston 40 in the plane of the line A'—A' to serve as a starting point. The space in cylinder 26 between surfaces 38 and 42 is full of liquid. Piston 18 moves upward, and probably squeezes liquid back out through port 30 (unless line 34 be provided with a check valve) until port 30 is completely blocked by piston 18. Continued upward movement of piston 18 then moves the trapped liquid upward along with free piston 40.

Just before surface 42 of piston 40 begins to uncover port 32, member 48 contacts the lower end of push rod 62, and continued upward movement of piston 40 is against the resistance to movement of piston 60 which is offered by the pressure in the discharge line 36. Accordingly, the pressure of the trapped liquid between surfaces 38 and 42 is increased to substantially the pressure in line 36 and is at that pressure when port 32 begins to be uncovered.

It should be noted at this time that spring 44 is in tension during this phase of the operation. As soon as port 32 is uncovered, liquid begins to flow out through port 32 and into line 36, with piston 40 taking a position such that the force acting on surface 42 of piston 40, caused by the pressure in cylinder 26, equals the force of inlet pressure in chamber 54 acting on the upper end of piston 40 plus the force due to the tension in spring 44.

Piston 18 continues its upward movement until substantially all of the liquid between the surfaces is expelled. A substantially complete emptying of the space between surfaces 38 and 42 is assured by a proper finish of the surfaces and by proper design of spring 44, necessitating a slight further upward movement of piston 18 even after all of the liquid has been expelled, this further upward movement resulting in a corresponding slight additional upward movement of piston 40.

On the down stroke, the action of cylinder 58 and piston 60 plus the tension in spring 44 serve to keep the two surfaces 38 and 42 together until port 32 is again closed by piston 40; thereafter, the tension in spring 44 keeps the surfaces together and the two pistons 18 and 40 move downward substantially as a unit. Piston 40 will move downward even after surface 42 has reached the plane of line A'—A', because of the influence of two forces, one of these being the inertia of moving piston 40, and the other being the inlet pressure operating on the upper end of piston 40 aided by the substantially zero clearance volume.

The design is such that the compression of spring 44 produces sufficient force that piston 40 will not be able to move substantially, if any, below the position shown in the drawing, at which point the two surfaces 38 and 42 separate, whereupon liquid begins to flow into cylinder 26 by way of inlet port (or ports) 30. The pressure at the two ends of piston 40 is thereupon equalized, and piston 40 moves upward until surface 42 is again substantially in the plane of line A'—A'; which represents the free position of the resilient system which includes the spring 44. Liquid flows into cylinder 26 as piston 40 moves upward under the influence of the spring, filling the space between the surfaces 38 and 42, and the parts are in position to begin another cycle.

It will be appreciated by those skilled in the art that piston movement near the dead center positions is relatively slow, because of the nature of the crank-and-piston type of mechanism. In view thereof, considerable time elapses from the point at which piston 18 begins to uncover port 30 to the point at which this same piston again blocks the port. Such a long time interval is desirable to permit complete filling of the space between pistons with liquid. This time interval can be increased if desired by designing the mechanism to permit surface 38 to move below port 30 for the bottom dead center position.

The foregoing detailed discussion of the operation of my invention relates to its functioning as a liquid pump. The functioning of the machine as a gas compressor will be understood by those skilled in the art from the foregoing description, and accordingly need not be detailed here.

Looking now at the modification shown in FIG. 2, in

which the pump operates generally in the same manner as that disclosed in FIG. 1 and in which those parts of the pump that correspond to ones shown in FIG. 1 will bear the same reference numerals with the addition of a prime, spring 44' is not secured to the seat member 48' and the flange 52' as was the case in the embodiment of FIG. 1. A second departure is noted in that piston 60' is of a somewhat larger diameter than piston 40'. As was pointed out in the discussion of the operation of the pump shown in FIG. 1, with the spring 44 being secured to seat member 48 and flange 52, when piston 40 is moved to a point above the line A—A in FIG. 1, spring 44 acts in tension, with the result that when the piston 18 starts its downward or return stroke the force of the spring 44 in tension insures the surfaces 42 and 38 of pistons 40 and 18 respectively being maintained in abutting relation.

As the spring 44' in the modification of FIG. 2 acts in compression only since it is free to move relative to seat member 48' and flange 52', it is desirable to insure that the adjacent surfaces of piston 40' and piston 18 (shown only in FIG. 1) be maintained in abutting relation by having an additional force acting on the free piston 40' as the piston 18 initiates its return movement. Although it is recognized that the intake pressure acting through line 76' may many times be sufficient to maintain the pistons in such abutting relation, in the form of pump disclosed in FIG. 2 piston 60' is made larger in diameter than piston 40'. As a result the force acting downwardly through piston 60' is greater than the force acting upwardly on the more remote surface of piston 40', and thus on the initiation of the return stroke of the pump the action of the force acting through piston 60' plus the action of the intake pressure through line 76', if there be any, on the free piston 40' will serve to keep the surface of the latter more remote from the piston 60' and the adjacent surface of the driving piston 18 (see FIG. 1) together until the discharge port is again closed by the piston 40'. Thus I have provided in this form of my invention a unit in which the free piston and driven piston are maintained in abutting relation substantially throughout the return stroke of the pump without necessitating the use of tension springs.

It will be seen from the above description of the two forms of the pump herein shown that I have provided a pump of the free or floating piston type which is adapted to compress gases through a greater number of compression ratios and to pump liquids at or near the boiling point with a minimum danger of vapor lock. Other advantages will be apparent to those skilled in the art.

While there is in this application specifically described and shown two forms which the invention may assume in practice, it will be understood that these forms of the same are shown for purposes of illustration and that the invention may be modified and embodied in various other forms without departing from its spirit or the scope of the appended claims.

The present application is a continuation-in-part of my application Serial No. 421,551, filed April 7, 1954, now abandoned.

I claim:

1. A fluid pump comprising a cylinder having longitudinally spaced inlet and discharge ports, a piston reciprocable in the cylinder and having a surface to contact and exert pressure on fluid to be pumped, means associated with said piston to impart thereto intake and discharge strokes in the course of which the piston respectively establishes communication between the cylinder and inlet port and effects a displacement of fluid through the discharge port, a free piston reciprocable in the cylinder and having a surface to contact and exert pressure on the fluid to be pumped, the two pistons being disposed with said surfaces facing each other, resilient means connected to the free piston for biasing it in a direction opposite the direction of movement of the intake stroke of said first-named piston as the latter uncovers the inlet port, at least a part of the inlet port being between the two surfaces when the first named piston is at bottom dead center, means including an expansible chamber device acting on the free piston as the first-named piston approaches the discharge port and means connecting said expansible chamber device with said discharge port to increase the pressure in the cylinder at least to that pressure existing in the discharge port as the first named piston approaches the latter port.

2. A fluid pump comprising a cylinder having longitudinally spaced inlet and discharge ports, a piston reciprocable in the cylinder and having a surface to contact and exert a pressure on fluid to be pumped, means associated with said piston to impart thereto intake and discharge strokes in the course of which the piston respectively establishes communication between the cylinder and inlet port and effects a displacement of fluid through the discharge port, a free piston reciprocable in the cylinder and having a surface to contact and exert a pressure on the fluid to be pumped, the two pistons being disposed with said surfaces facing each other and said inlet port being between the two surfaces when the piston first mentioned is at the end of its return stroke, means acting on said free piston at a point remote from its said surface for automatically maintaining its said surface against said surface of the first piston through that portion of the intake stroke of said first piston between the initiation thereof and the point at which it uncovers said inlet port and for thereafter moving said free piston in a direction opposite the direction of movement of said first piston as the latter continues through its intake stroke, and means acting on said free piston to increase the pressure in the cylinder as said first-named piston approaches the end of its discharge stroke including an expansible chamber device and means connecting said expansible chamber device with said discharge port to increase the pressure in the cylinder at least to that pressure existing in the discharge port as the first named piston approaches the latter port.

3. A fluid pump as in claim 2 in which said expansible chamber device includes a piston of larger cross-sectional area than said free piston.

4. A fluid pump as set forth in claim 2 in which said second mentioned means includes means subjected to the inlet port pressure for urging said free piston toward said first piston throughout said portion of the intake stroke of the latter.

5. A fluid pump as set forth in claim 4 in which said second mentioned means also includes resilient means acting on said free piston for moving it away from said first piston as the latter uncovers said inlet port.

6. A fluid pump comprising a cylinder having spaced inlet and discharge ports, a piston reciprocable in the cylinder and having a surface to contact and exert a pressure on fluid to be pumped, means associated with said piston to impart thereto intake and discharge strokes in the course of which the piston respectively establishes communication between the cylinder and inlet port and effects a displacement of fluid through the discharge port, a free piston reciprocable in the cylinder and having a surface to contact and exert a pressure on the fluid to be pumped, the two pistons being disposed with said surfaces facing each other and said inlet port being between the two surfaces when the piston is at the end of its return stroke, and means acting on said free piston including an expansible chamber device for increasing the pressure in the cylinder as said first-named piston approaches the end of its discharge stroke and for automatically maintaining said surface of the free piston against said surface of the first piston through that portion of the intake stroke of said first piston between the initiation thereof and a point where it has covered said discharge port, said expansible chamber device including a piston of larger cross-sectional area than said free piston, and means connecting said expansible chamber device with said discharge port thus sub-

jecting said expansible chamber device to the pressure of said discharge port.


**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,396,602 | Posch | Mar. 12, 1946 |
| 2,739,643 | Voit et al. | Mar. 27, 1956 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 1,860 | Australia | Sept. 2, 1931 |
| 53,005 | France | Sept. 11, 1944 |
| | (1st addition to Pat. No. 860,009) | |
| 158,032 | Switzerland | Jan. 2, 1933 |
| 293,427 | Great Britain | June 20, 1929 |
| 421,301 | Great Britain | Dec. 18, 1934 |
| 521,508 | Canada | Feb. 7, 1956 |
| 698,977 | Great Britain | Oct. 28, 1953 |
| 1,060,300 | France | Nov. 18, 1953 |