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DIFFERENTIAL PRESSURE POPPET VALVE

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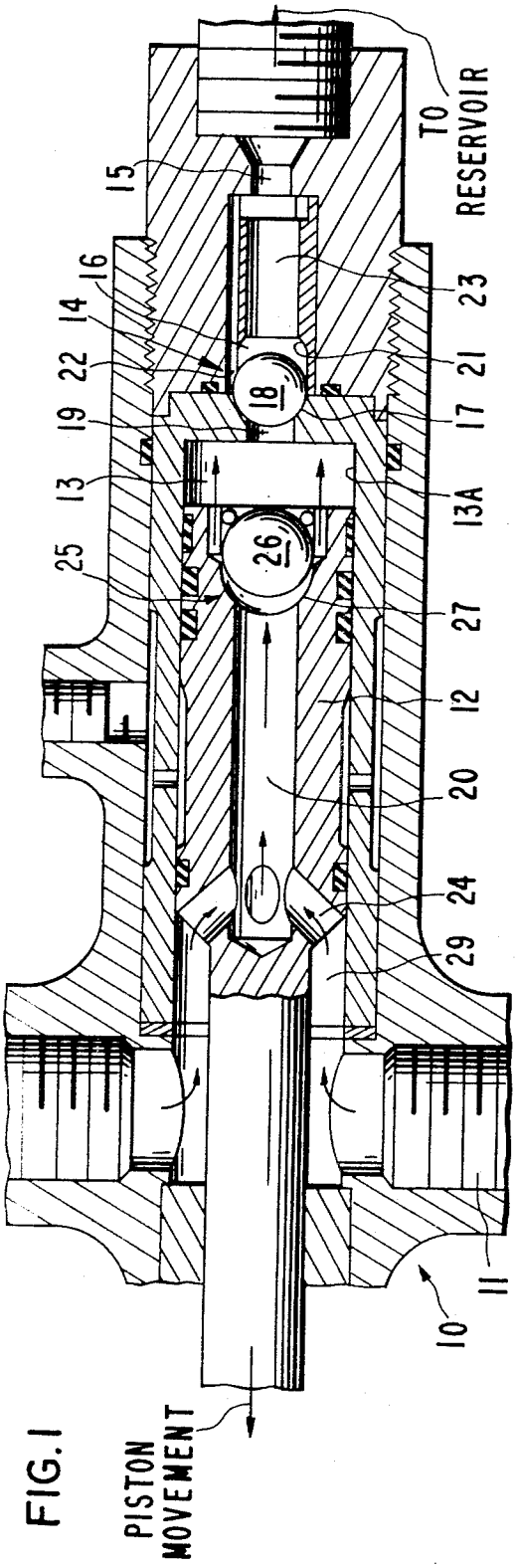

FIG. 1

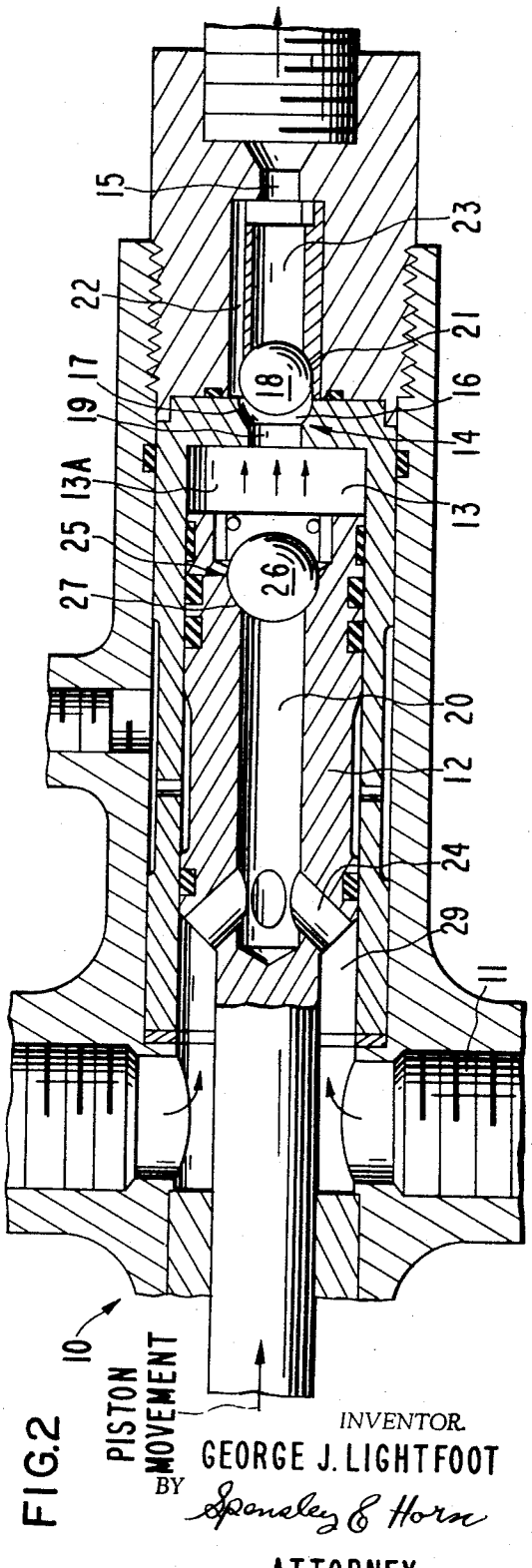

FIG. 2

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DIFFERENTIAL PRESSURE POPPET VALVE

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The subject invention relates to an improved discharge valve in a reciprocating pump. More generally, the invention covers a fluid control system having improved valves, particularly adapted for pumping fluids in cryogenic atmospheres.

Reciprocating pumps commonly use poppet valves to control the passage of fluids out of a pumping chamber into a discharge reservoir while at the same time preventing fluid flow from the discharge reservoir into the pumping chamber. Conventionally, these valve poppets are loaded against the valve seats either by springs or by gravity. Gravity loaded poppets have the disadvantage of requiring vertical mounting to allow the poppet to rest against the seat by the force of gravity. In many instances, however, particularly in space vehicles and the like, this is impossible to guarantee, and gravitation systems may vary or not exist. Springs and spring followers, on the other hand, are complex and subject to excessive wear. When you consider that the pump piston, and consequently the poppet, may be reciprocating at a rate of 20 cycles per second, it is readily apparent that the springs and spring followers will have a relatively short life. One type of prior art valve using a spring-loaded poppet is described in U.S. Patent 2,837,898, which issued on June 10, 1958, to P. M. Ahlstrand.

The improved discharge valve of this invention operates in the same manner as prior art poppet valves, but employs neither gravity nor springs for its energy source. Accordingly, the valve of the subject invention may be used in any gravitational orientation, and has a life which is not limited by the life expectancy of a spring or spring follower.

The discharge valve of this invention is used in a pump having a piston movable in a normal back-and-forth cycle capable of forcing a fluid through a cylindrical passageway. The improved discharge valve, which fits within the passageway and is adapted to control the discharge of fluid into a reservoir, comprises the following elements: a pumping chamber having a seat at one end adapted to seat a discharge blocking member (sometimes termed a "poppet"); a discharge reservoir; a discharge blocking member movably mounted between the pumping chamber and the discharge reservoir, the seat and the discharge blocking member being so sized that when the member is seated, the flow of liquid through the discharge valve is blocked; and at least two ports coupling the chamber to the reservoir to enable the difference in pressure on the chamber side or piston side and the reservoir side of the discharge blocking member to seat the member during the one cycle of pump operation, i.e., when the piston is moving in a direction away from the blocking member. In this manner, fluid is prevented from flowing from the reservoir into the passageway during the backstroke. The elements are also sized so that the pressure difference, at least in part, also holds the discharge blocking member away from the seat during a substantial part of the forward stroke of the cycle when the piston is moving towards the chamber. Therefore, during the forward stroke, fluid can flow through the valve into the reservoir.

The discharge valve and the fluid control system of this invention will be better understood from the more detailed description which follows making reference to the drawings in which:

FIGS. 1 and 2 show cross sectional views of the pump and discharge valve of the subject invention, FIG. 1 showing the pump during the downstroke and FIG. 2 during the upstroke.

Referring to the drawing, pump **10** has an inlet valve **11** for admitting fluid into the pump. The term "fluid" is a generic term including liquids and gases, and the pump of the subject invention is applicable to either. The fluid may be compressible. A piston **12** moves back and forth in a normal cycle, actuated by a reciprocating engine or motor, not shown, forcing fluids through the cylinder or cylindrical passageway forming a pumping chamber **13**, defined by wall **13***a*. When piston **12** abuts the left end of pumping chamber **13**, the piston is at bottom dead center; when piston **12** is at the right end, it is at top dead center. Discharge valve **14** is adapted to control the discharge of the fluid from the pumping chamber **13** through an outlet port **15** into a reservoir, not shown.

Discharge valve **14** comprises a chamber **16** having a first seat **17** at one end adapted to seat a discharge member, such as ball **18**. Although the preferred illustrated embodiment uses a spherical discharge member (ball **18**), this geometry is not required. A conical, cubical, or a member of other geometrical configuration capable of fitting snugly into first seat **17** so as to block the flow of liquid through the opening **19** is satisfactory. Accordingly, the term "discharge blocking member" is used to define all geometrical designs of such elements. However, for future ease of reference in this specification, the more restricted term "ball" will be used for discharge blocking member **18**.

Ball **18** is movably mounted in chamber **16**. Ball **18** and seat **17** (which is located at one end of pumping chamber **13** or similarly at one end of chamber **16**) are so sized that when the ball is seated in seat **17**, as shown in FIG. 1, the entire flow of liquid through discharge valve **14** is blocked. Discharge valve **14** has a second seat **21** at the opposite end of chamber **16**. The second seat **21** and ball **18** are so sized that when the ball is seated in second seat **21**, the flow of liquid into a first port **22** from pumping chamber **13** around ball **18** is permitted, but the flow of liquid through a second port **23** from the pumping chamber **13** is blocked by ball **18**. The cross-sectional area of first port **22** is smaller than that of second port **23**. (See FIGURES 1 and 2).

First port **22** and second port **23** extend from chamber **20** through outlet port **15** into the reservoir and thereby are in communication with the reservoir and pumping chamber **13**. The difference between the pressure on the piston or pumping chamber side and on the reservoir side of ball **18** holds the ball seated against first seat **17**, as shown in FIG. 1, during the backstroke (downstroke in vertical pump) of the piston cycle when the piston is moving in the pumping chamber **13** in a direction away from chamber **16**. Fluid is thereby prevented during that backstroke from flowing from the reservoir into chamber **16**. Note that when ball **18** is in seat **17**, fluid cannot flow through opening **19** from either the first port **22** or the second port **23**. Moreover, the pressure difference between the piston side and the reservoir side of ball **18** also holds the ball away from first seat **17** during a substantial part of the upstroke when piston **12** is moving from bottom dead center to top dead center in a direction towards chamber **16**, as shown in FIG. 2. Therefore, during that forward stroke (upstroke in horizontal pump), fluid is permitted to flow through valve **14**, through first port **22** and outlet **15**, into the reservoir not shown.

Preferably, first port **22** and second port **23** are parallel to wall **13***a* of the cylindrical passageway **13**. In the preferred illustrated embodiment, the first port **22** is located with respect to ball **18** so that first port **22** is open to

fluid passage from chamber **13** when the ball is in the second seat **21** during the upstroke, as shown in FIG. 2, but closed to such fluid passage during the backstroke when the ball is in the first seat **17**, as shown in FIG. 1. One way of achieving this function is to construct the second port **23** as a cylindrical passage, as shown in FIG. 2, of smaller diameter than ball **18** so that flow is blocked by ball **18** when the ball is in the second seat **21**. Proper operation of the first port **22** is achieved by sizing it to permit fluid passage through the port around ball **18** when the ball is in the second seat **21**, as shown in FIG. 2. Note that first port **22** is located laterally beyond the surface of ball **18**, permitting fluid flow around ball **18** when the ball **18** is in the second seat **21**. It should be understood that there may be a number of ports **22** and **23**, but it is preferred that only a single port **23** be employed and that this port be located centrally or more particularly co-axial with the pump axis.

The fluid control system using the novel discharge valve of this invention includes a cylindrical hollow piston **12** mounted in the cylindrical passageway or pumping chamber **13** defined by wall **13***a* so that piston can move in a normal back-and-forth cycle so as to force fluid from inlet port **11** through the pumping chamber, valve **14**, and out into the reservoir. The fluid moves as shown by the arrows through port **24** into the hollow interior chamber **20** of piston **12**. From the construction of the system as shown, it is apparent that fluid can move from inlet **11** through port **24** and on into the hollow chamber **20** of piston **12** irrespective of the position of the piston in the cylindrical passageway.

Piston **12** includes an inlet valve **25** located at the opposite end of the piston from port **24**. Inlet valve **25** includes an inlet ball **26** capable of moving between two positions during the backstroke illustrated in FIG. 1, fluid will pass through the inlet valve **25** from the hollow interior chamber **20** of piston **12** into pumping chamber **13**. When inlet ball **26** is in the second of the two positions during the forwardstroke shown in FIG. 2, against seat **27**, passage of fluid through the inlet valve **25** is prevented. Ball **26** is held in the first of the two positions shown in FIG. 1 by the pressure of the fluid in hollow interior chamber **20** against ball **26** during the backstroke of the piston cycle illustrated in FIG. 1 as the piston moves from top dead center to bottom dead center. Cage **27** holds ball **26** adjacent to piston **12** during the backstroke. However, cage **27** does not prevent fluid flow during the backstroke around ball **26** out of the hollow portion **20** of piston **12** and into pumping chamber **13**.

During the forwardstroke of the piston cycle, from bottom dead center to top dead center, ball **26** is held against seat **27** by the pressure of the fluid within the pumping chamber **13**. During that portion of the cycle, fluid is being forced by the combination of piston **12** and inlet ball **26** through opening **19**, discharge valve **14**, outlet **15**, into the reservoir.

It should be understood that inlet ball **26** need not be spherical; it too may have other geometries, adapted to fit in seat **27**, in the same manner as explained earlier in connection with discharge ball **18**.

The complete operation of the pumping system of this invention during the backstroke and forwardstroke of the piston will now be explained referring to FIGS. 1 and 2. During the backstroke, as shown in FIG. 1, no fluid is flowing into inlet **11**, nor coming out of outlet **15**. After the downstroke commences, ball **26** is held against cage **27**. The fluid within pumping chamber **13** and within the hollow portion **20** of piston **12** remains substantially still. The face of piston **12** moves behind a body of fluid in a direction towards bottom dead center through the still fluid. Fluid thus flows around ball **26** and into pumping chamber **13**. At the end of the backstroke, pumping chamber **13** is substantially filled with fluid. All during the backstroke, discharge ball **18** is held tightly against first seat **17** by the pressure differential between second port **23** and pumping chamber **13**. The motion of piston **12** towards bottom dead center creates a slight vacuum or reduced pressure in pumping chamber **13**. Accordingly, the pressure in chamber **13** is slightly less than the pressure in the second port **23**. Ball **18** is held tightly against seat **17** as a result of this differential pressure. Accordingly, fluid is prevented from flowing from the reservoir back through outlet **15** and the first or second ports **22** or **23**, into the pumping chamber **13**. Similarly, inertia of the fluid pressure of the fluid flowing around inlet ball **26** holds inlet ball **26** against cage **27** during the backstroke.

The situation is reversed during the forwardstroke, as shown in FIG. 2. As soon as piston **12**, controlled by a conventional reciprocating engine or motor not shown in the drawing, begins to move from bottom dead center towards top dead center, inlet ball **26** is forced against seat **27** by inertia of the pressure of the fluid in pumping chamber **13** against ball **27**. Accordingly, the hollow portion **20** of piston **12** is sealed. As piston **12** and ball **26** move towards top dead center, a lowering of pressure occurs in chamber **29**. This lower pressure along with other forces causes fluid to be sucked into inlet **11** and accordingly into the hollow portion **20** of piston **12**. Moreover, the fluid in pumping chamber **13** is pushed by the action of piston **12** and ball **26** (pinned to seat **27**) through the opening **19** at the end of the pumping chamber **13**. The pressure of this onrushing fluid forces discharge ball **18** away from first seat **17** and into second seat **21**. When ball **18** is in second seat **21**, the second port **23** is sealed so that no fluid flows through the second port **23** out through outlet **15**.

It should be apparent that it is intended in the embodiment shown that fluid does not flow through second port **23** either during the backstroke or during the forwardstroke. This port is merely to provide the necessary pressure on ball **18** to insure its seating in seat **17** during the backstroke. However, when ball **18** is in the second seat **21**, fluid is forced by the piston through the first port **22** (called the exit port) and through outlet **15** into the reservoir. Thus, during the forwardstroke, the contents of the pumping chamber are pumped through the exit port **22** and outlet **15** into the reservoir.

Once the piston **12** reaches top dead center, it begins to return towards bottom dead center and the entire cycle is repeated.

From the above description, it is seen that discharge ball **18** is controlled almost entirely by the differential pressures between the pumping chamber **13** and the second port **23**. No springs or other mechanical mechanisms are required to shift the ball from seat to seat at the proper times during the pumping cycle. Accordingly, a longer-life valve system is achieved. Furthermore, the pumping system of this invention may be utilized in any gravitational orientation since the action of discharge ball **18** is relatively insensitive to the forces of gravity.

The above specific structure is representative of only a preferred embodiment of the invention. Many modifications and improvements may be made by one skilled in the art without departing from the spirit of the invention, or from its true scope, as set forth in the claims which follow.

What is claimed is:

1. In a pump having a piston movable in a normal back-and-forth cycle of forcing a fluid through a cylindrical passageway which in part forms a pumping chamber, the improved discharge valve adapted to control the discharge of said fluid from said pumping chamber into a reservoir therefor, said discharge valve comprising:

a seat in the proximity of one end of said pumping chamber and adapted to seat a discharge blocking member;

a discharge blocking member movably mounted between the pumping chamber and reservoir, said seat

and said member being so sized that when said member is seated therein, the flow of liquid through said discharge valve is substantially blocked; and

first and second ports, at least, coupling said chamber to said reservoir to enable the difference in pressure on the piston side and the reservoir side of said member to seat said member during the downstroke of said cycle when the piston is moving in said direction away from said member, whereby fluid is prevented from flowing from said reservoir into said passageway and to enable the pressure difference to hold said member away from said seat during a substantial part of the upstroke of said cycle when said piston is moving towards said member, whereby fluid can flow through said first port into said reservoir, said second port being located centrally, and said first port being laterally spaced from said centrally located first port.

2. The improved valve of claim **1** further characterized by said discharge member being a spherical ball.

3. The improved valve of claim **1** further characterized by a second seat in opposed relationship to said first seat and adapted to seat discharge member, said second seat and said member being so sized that when said member is seated therein, the flow of liquid into said first port from said pumping chamber is permitted but the flow of liquid through said second port from said pumping chamber is at least partially blocked by said discharge member.

4. The improved valve of claim **1** further characterized by said first and second port being parallel to said passageway.

5. The improved valve of claim **3** further characterized by said first port being located with respect to said discharge member so that said first port is open to fluid passage when said discharge member is in said second seat and closed to fluid passage when said discharge member is in said first seat.

6. The improved valve of claim **4** further characterized by said discharge member being a ball, said second port being a cylindrical passage of smaller diameter than said ball and sized so as to be blocked by said ball when said ball is in said second seat, said second port providing the major control action for seating said discharge member in said first seat.

7. The improved valve of claim **6** further characterized by said first port sized to permit fluid passage therethrough around said ball when said ball is in said second seat.

8. The improved valve of claim **1** in which the second port is located co-axially to the pump axis and said passageway, and said first port is spaced laterally from said second port.

9. The improved valve of claim **1** in which said first port is of smaller cross-sectional area than said second port.

10. A fluid control system comprising:

a means defining a cylindrical passageway including a pumping chamber;

a cylindrical, hollow piston mounted in said passageway movable in a normal back-and-forth cycle capable of forcing a fluid through said said pumping chamber;

an inlet port to said cylindrical passageway at one end thereof located to permit the passage of fluid into one end of said hollow piston irrespective of the position of said piston in said passageway;

an inlet valve in said piston located at the opposite end of said piston, said inlet valve including an inlet ball movably mounted within said inlet valve, said inlet ball being capable of moving between two positions, when said inlet ball is in a first of said positions fluid will pass through said inlet valve from said piston into said pumping chamber, and when said inlet ball is in a second of said positions, passage of fluid through said inlet valve is prevented, said ball being held in said first position by fluid pressure against it during the forward portion of the piston cycle;

a discharge valve within said pumping chamber sized to control the discharge of said fluid into a reservoir therefor, said discharge valve including a pumping chamber having a seat at one end adapted to seat a discharge blocking member, a discharge blocking member movably mounted in said chamber, said seat and said member being so sized that when said ball is seated therein, the flow of liquid through said discharge valve is substantially blocked, and first and second ports coupling said chamber to said reservoir so that the difference between the pressure on the piston side and the reservoir side of said member seats said member during the downstroke of said cycle when the piston is moving in said passageway in a direction away from said chamber, whereby fluid is prevented from flowing from said reservoir into said passageway, and so that said pressure difference holds said member away from said seat during a substantial part of said upstroke of said cycle when said piston is moving towards said chamber, whereby fluid can flow through said first port into said reservoir, said second port being located centrally, and said first port being laterally spaced from said centrally located second port.

11. The fluid control system of claim **10** further characterized by said discharge member being a spherical ball.

12. The fluid control system of claim **10** in which said first port is of smaller cross-sectional area than said second port.

13. The fluid control system of claim **10** in which said second port is located co-axially to said passageway, and said first port is spaced laterally from said second port.

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137—512.1; 107—178