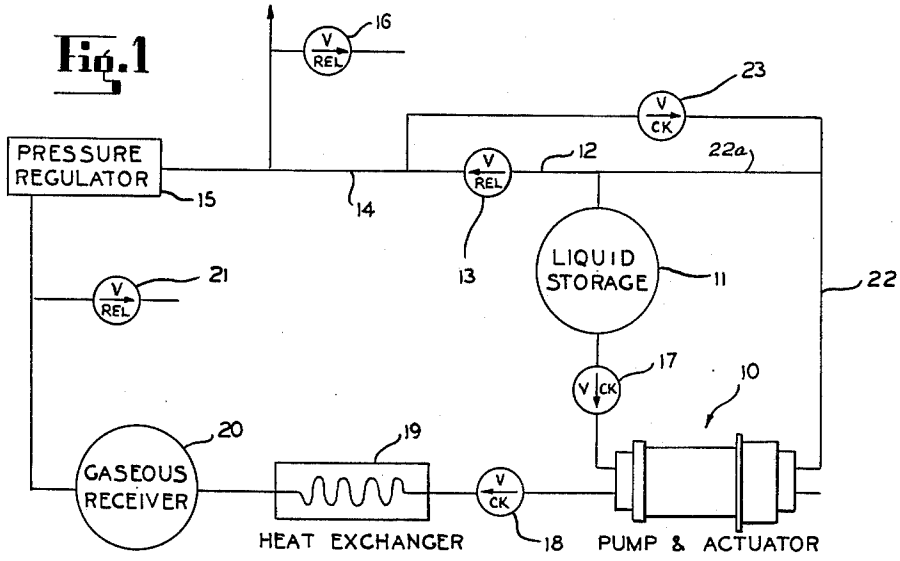
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LIQUID NITROGEN PUMP

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Fig. 1



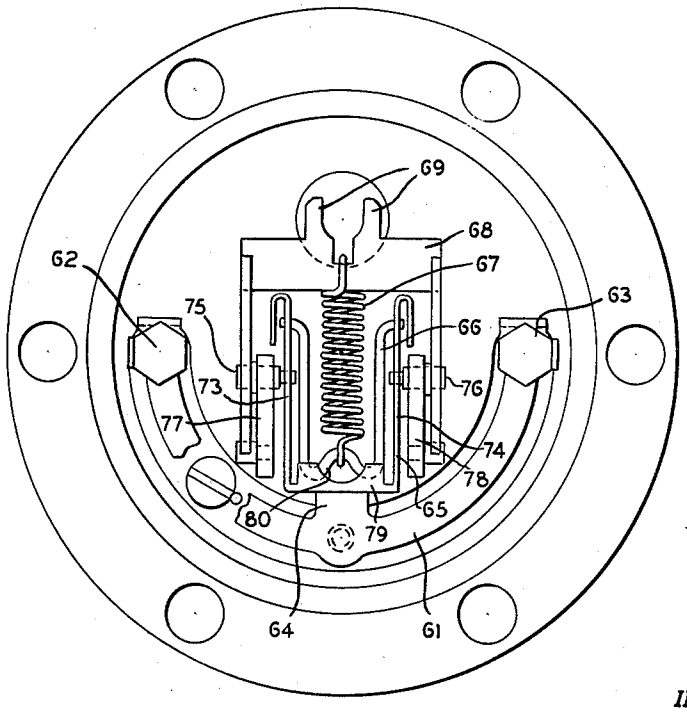


Fig. 3

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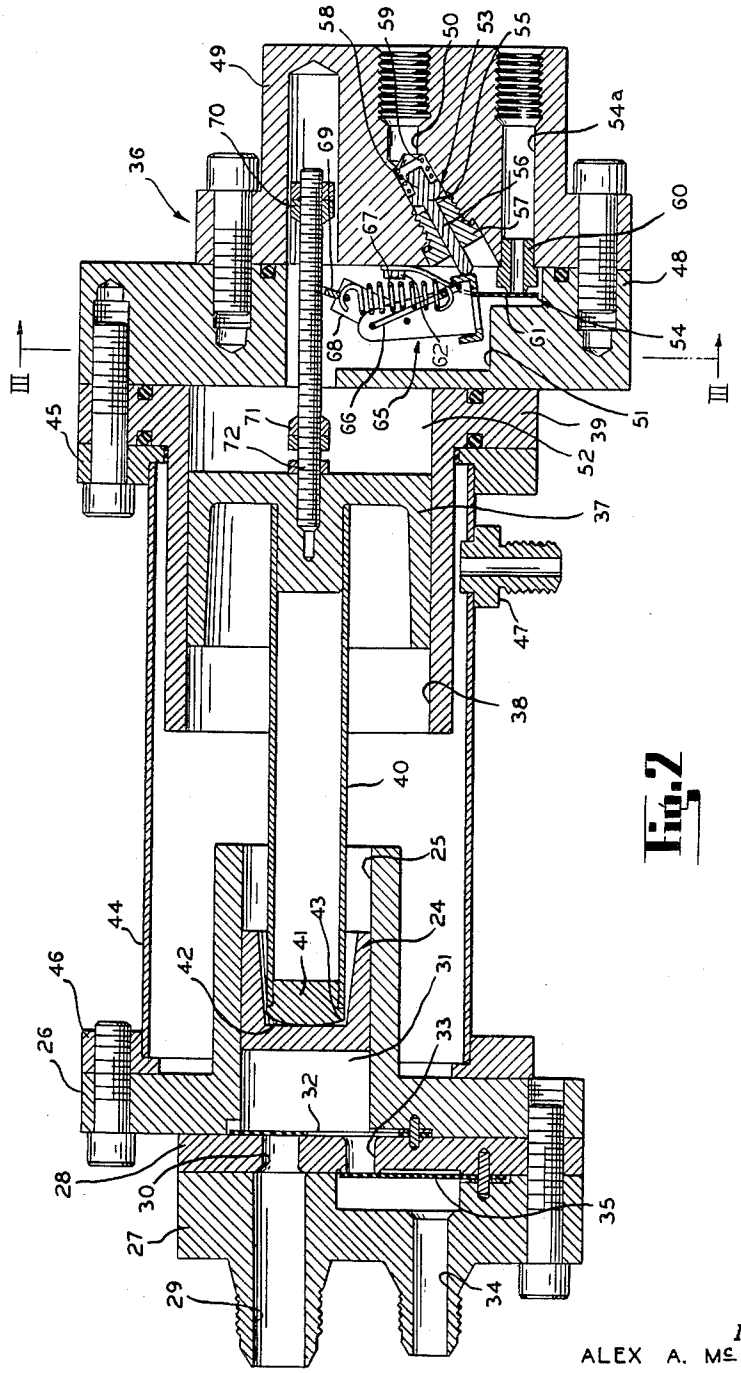


Fig. 2

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LIQUID NITROGEN PUMP

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This invention relates to a pump which is particularly designed for pumping liquid nitrogen but which has features applicable to the pumping of other fluids.

In certain systems, it is desirable to pump liquids having a very low boiling point. In rockets, for example, it has been found desirable to store nitrogen in liquid form to be used for various purposes. For certain purposes, a comparatively low pressure may be required while for others, a high pressure is required. To obtain the high pressure nitrogen, it is proposed to pump liquid nitrogen to a heat exchanger wherein it is converted to a gaseous state at high pressure.

The design of a pump for such a system presents various problems. In particular, it is necessary to prevent vaporization of the liquid within the pump in order to obtain efficient operation. It is desirable to use stored fluid as a source of power for actuating the pump.

This invention was evolved with the object of providing an improved pump for pumping a liquid having a low boiling point.

Another object of this invention is to provide a liquid pump in which vaporization is minimized.

A further object of this invention is to provide an improved pump actuator.

According to this invention, a reciprocating pump is provided which is so constructed as to minimize heat transfer to the pumping chamber, to minimize vaporization of the liquid. The pump is directly operated by a special fluid-powered actuator which forms an important feature of the invention.

Other objects, features and advantages of the invention will become more fully apparent from the following detailed description taken in conjunction with the accompanying drawings which illustrate a preferred embodiment and in which:

FIGURE 1 is a schematic diagram of a system utilizing a pump constructed according to the principles of this invention;

FIGURE 2 is a cross-sectional view through the pump of FIGURE 1; and

FIGURE 3 is a cross-sectional view taken substantially along line III—III of FIGURE 2.

Reference numeral 10 generally designates a pump constructed according to the principles of this invention. The pump 10 is particularly designed for use in a nitrogen system illustrated schematically in FIGURE 1, but it is to be emphasized that many features of the pump have general application.

In the system of FIGURE 1, nitrogen is stored in liqiud form in a tank 11. Gaseous nitrogen may be drawn off from the top of the tank 11 through a conduit 12 and through a relief valve 13 to a header 14 from which it may be applied to various devices and functions. The pressure in the header 14 may be maintained at approximately 200 pounds per square inch by means including a pressure regulator 15. A relief valve 16 may be provided to operate at a pressure of 225 pounds per square inch, for example, and prevent overpressurization of the header 14. To supply the pressure regulator 15 with gaseous nitrogen at relatively high pressure, liquid nitrogen is taken from the lower end of the liquid storage tank 11 to flow through a check valve 17 to the inlet of the pump 10, and from the outlet of the pump 10, the liquid nitrogen flows through a check valve 18 to a heat

exchanger 19. The nitrogen is vaporized in the heat exchanger and flows to a gaseous receiver 20 in which it may be stored at a relatively high pressure such as 500 to 750 pounds per square inch, for example, and from which it may be supplied to the pressure regulator 15. A relief valve 21 may be provided to prevent excessive pressure in the receiver 20.

Because of its availability, the gaseous nitrogen is preferably used as a means for pressurizing the liquid storage tank 11 and as a means for operating the pump 10. To pressurize the liquid storage tank 11, the top of the tank 11 is connected through conduits 22*a* and 22 and a check valve 23 to the header 14. To operate the pump 10, the pump 10 has an actuator section which is connected through a conduit 22 and a check valve 23 to the header 14.

To prevent overpressurization of the liquid storage tank 10 due to vaporization of the liquid nitrogen, a relief valve 13 with a predetermined pressure differential such as 10 pounds per square inch, for example, may be connected on one side through a conduit 12 to the top of the liquid storage tank 11, and on the other side to the header 14.

To provide additional capacity to the system, the gaseous receiver 20 may be charged initially with gaseous nitrogen at a high pressure such as 3000 pounds per square inch, for example, from an external source. As gaseous nitrogen is used from the header 14, pressure in the gaseous receiver 20 will be depleted until a certain predetermined pressure is reached such as 750 pounds per square inch, for example, at which time the pump 10 will begin pumping liquid nitrogen. The pump 10 will begin pumping liquid nitrogen. The pump 10 will supply enough liquid nitrogen to the heat exchanger 19 to maintain a pressure such as 500 to 750 pounds per square inch, for example, in the gaseous receiver 20 until the supply of liquid nitrogen is exhausted from the liquid storage tank 11.

Referrinng now to FIGURE 2, the construction of the pump 10 is illustrated in detail. The pump 10 comprises a piston 24 which is reciprocally movable in a cylindrical bore 25 of a pump cylinder 26 to which a pump head 27 is secured with a gasket member 28 between the head 27 and the cylinder 26.

The head 27 has an inlet passage 29, which receives the liquid nitrogen, and the gasket member 28 has a port 30 which establishes communication between the inlet passage 29 and a pumping chamber 31 within the bore 25. Communication between the inlet port 30 and the pumping chamber 31 is controlled by means of a reed valve member 32 which is urged by its own inherent resiliency against a lip about the inner end of the port 30. During the intake stroke, when the piston 24 moves to the right as viewed in FIGURE 2, the pressure in the chamber 31 is reduced to allow the liquid to flow through the port 30 past the valve member 32 into the chamber 31. During the pumping stroke, when the piston 24 moves to the left as viewed in FIGURE 2, the pressure buildup in the chamber 31 causes the valve member 32 to close the port 30. The liquid then flows through an outlet port 33 in the gasket member 28, and out through an outlet passage 34 in the head 27. An outlet reed valve member 35 is urged by its own inherent resiliency against a lip about the outlet side of the port 33, to permit passage of liquid through the port 33 only when the pressure differential exceeds a certain amount.

As above indicated, the pump 10 has an actuating section operated by pressurized fluid. This actuating section is generally designated by reference numeral 36 in FIGURE 2. The actuating section 36 comprises a piston 37 which is movable in a cylindrical bore 38 of an actuating cylinder member 39.

The bore 38 is coaxial with the pump cylinder bore 25 so that the pump piston 24 can be directly actuated from the actuating piston 37. For this purpose, the actuating piston 37 has an integral cylindrical portion of reduced diameter projecting toward the pump piston 24 and receiving, with a drive fit, one end of a tube 40. A button 41 is affixed in the other end of the tube 40 and has a surface portion 43 engaging a surface portion 42 of the pump piston 24.

The use of the tube 40 as the connecting means between the pistons is a specific feature of the invention. By using a tube instead of a solid piece, the rigidity is increased while the heat conduction between the pistons is decreased. It is very important to minimize the conduction of heat from the actuating section to the pump section, to prevent vaporization of the liquid in the pump section which would greatly decrease the efficiency and capacity of the pump. It is therefore important that the connecting means between the piston be as long as possible and have a minimum cross-sectional area. By using the tubular form, the connecting means can be quite long and yet have adequate rigidity and at the same time, minimum cross-sectional area. The wall of the tube 40 should be comparatively thin, preferably on the order of $\frac{1}{10}$ its diameter or less. The tube 40 should be of metal and preferably stainless steel.

According to a further specific feature of the invention one of the surface portions 42, 43 is convex to minimize the area of contact so that the contact may be described as being at a point of osculation, and thus minimize heat conduction. This feature is also desirable in permitting slight misalignments between the pump and actuating sections. In the illustrated arrangement, the surface portion 43 of the button 41 is convex.

Another feature of the invention is in the means for supporting the pump cylinder 26 and the actuating cylinder 39 in fixed relation. According to this feature, a sleeve 44 is used as the connecting means, one end of the sleeve being received by a ring 45 secured to a flange portion of the actuating cylinder 39, with the other end of the sleeve 44 being received by a ring 46 secured to a flange portion of the pump cylinder 26. The use of the sleeve 44 achieves advantages similar to those achieved by the use of the tube 40, in increasing rigidity to permit a longer length and in reducing cross-sectional area, both factors contributing to the reduction of heat transfer between sections.

It is possible that during operation of the pump, pressures may build up within the sleeve 44. To prevent this possibility, the sleeve 44 may be provided with an opening in its wall to receive a vent plug 47.

A plate member 48 is secured against the right-hand face of the actuating cylinder 39 and a head member 49 is secured against the right-hand face of the plate member 48. The head member 49 has an inlet passage 50 arranged to receive actuating fluid, as through a conduit 22 as described above in connection with FIGURE 1. The passage 50 is arranged to communicate with a chamber 51 in the plate member 48 which, in turn, communicates with a chamber 52 in the actuating cylinder bore 38. This communication is controlled by means of an inlet valve 53 disposed in the passage 50. The inlet valve 53 is opened when the actuating piston 37 approaches the limit of its travel to the right as viewed in FIGURE 2 to allow fluid under pressure to enter the chambers 51 and 52 and force the piston 37 to the left and thus produce pumping of the liquid. When the piston 37 approaches the limit of its movement to the left, the inlet valve 53 is closed and an outlet valve 54 is opened to allow fluid to flow from the chambers 52 and 51 out through an outlet passage 54*a* in the head 49.

The inlet valve 53 comprises a poppet valve member 55 having a shank portion 56 movable in a bore through a plug member 57 threaded in the passage 50, the valve member 55 having a head portion 58 arranged to seat against a valve seat formed at the end of the plug member 57. A coiled compression spring 59 acts on the head portion 58 to urge the valve to closed position. The shank portion 56 and the head portion 58 of the valve member 55 both have cutaway portions (not shown) to allow flow of fluid when the head 58 is moved away from the seat on the plug 57.

The outlet valve 54 comprises a ported plug 60 inserted in the outlet passage 54*a* and arranged to be engaged by a reed member 61. As best shown in FIGURE 3, the reed member 61 is a generally U-shaped element with the ends thereof secured by screws 62 and 63 to the inside face of the head 49. The center portion of the reed member 61 is arranged to engage the plug 60 and is provided with an upwardly extending projection 64 for actuation of the same in a manner to be described.

Means are provided for controlling opening and closing of the inlet and outlet valves 53 and 54 in accordance with movement of the actuating piston 37. In particular, the shank portion 56 of the inlet valve 53 and the projection 64 of the outlet valve reed 61 are actuated by a cradle 65 which is connected through a swing 66 and a spring 67 to an arm 68 having a projection 69 in the path of movement of a pair of spaced nuts 70 and 71 on an elongated screw 72 secured to the actuating piston 37.

In the illustrated position of the mechanism, the lower end of the cradle 65 is urged against the shank 56 of the inlet valve member, through the action of the spring 67, to maintain the inlet valve open. The piston 37 will thus move to the left as viewed in FIGURE 2. When the piston 37 approaches the limit of its movement to the left, the nut 70 will engage the projection 69 to move the arm 68 in a counter-clockwise direction and when it is moved to a certain position, the spring 67 will function with a snap action to rotate the arm 68 further in its counter-clockwise movement and simultaneously rotate the cradle 65 clockwise to allow the spring 59 to close the inlet valve and to simultaneously move the reed member 61 away from the plug 60 and thus open the outlet valve. The piston 37 will then move to the right and as it approaches the limit of such movement, the nut 71 will engage the projection 69 to effect movement of the arm 68 in a clockwise direction and after it reaches a certain position, the spring 67 will function to rotate the parts to the illustrated position to again open the inlet valve 53 and close the outlet valve 54.

This mechanism forms a highly important feature of the invention. Not only does it function to open and close the valves with a snap action, but forces are maintained on the valves until the instant of reversal so as to keep gas leakage to a minimum and so as to also prevent the possibility of the pump stopping in mid-stroke due to simultaneous opening of both the intake and exhaust valves.

Referring to FIGURE 3, the cradle 65 is in the form of a generally U-shaped element having legs 73 and 74 which are pivoted on coaxial pins 75 and 76 carried by lugs 77 and 78 which project inwardly from the inward face of the head 49. The cradle 65 has a bight portion 79 which is apertured to receive the projection 64 of the outlet valve reed 61 and which at one side is arranged to engage the shank portion 56 of the inlet valve.

The swing 66 is in the form of a U-shaped element with the upper ends of the legs thereof being turned outwardly to engage in aligned coaxial openings in the legs 73 and 74 of the cradle 65, so that the swing 66 is pivotal about an axis above the axis of the pins 75 and 76. The swing 66 has a bight portion 80 arranged to engage inside surfaces of flange portions of the bight portion 79 of the cradle 65, and also arranged to receive one end of the spring 67 which is a coiled tension spring.

The arm 68 is in the form of an inverted U-shaped element having legs pivoted on the pins 75 and 76 and having a bight portion notched to receive the upper end

of the spring 67. The projection 69 may be formed in two parts in straddling realtion to the screw 72.

With this arrangement, the arm 68 may be rotated in a counter-clockwise direction from the position shown in FIGURE 2 until the line through the opposite ends of the spring 67 passes through the axis of the aligned coaxial openings in the legs of the craddle 65. At this point, the spring 67 will still function to exert a force urging the craddle 65 in a counter-clockwise direction, due to the fact that a line from the lower end of the spring through the axis of pivotal connection of the swing 66 to the cradle 65 is to the right of the axis of the pins 75, 76. Then, with a further counter-clockwise movement of the arm 68, the spring 67 will function to move the arm 68 further in a counter-clockwise direction and then move the swing 66 together with the cradle 65 in a clockwise direction.

Accordingly, a substantial force will be exerted on the intake valve member until the instant of reversal. The operation is, of course, the reverse when the actuating piston 37 moves to the right as viewed in FIGURE 2.

A further feature of the invention is in the proportioning of the areas of the pump and actuating pistons in a manner such that the pump is inoperative until the liquid pressure at the discharge port drops below a certain value, which may be 750 points per square inch absolute in the system of FIGURE 1, for example. At this time, the actuating gas pressure of 216 pounds per square inch absolute is sufficient to force the pump to complete a discharge stroke and the toggle mechanism is tripped by the motion of the piston so as to close the actuating gas supplied to the actuating piston and vent the piston to a pressure of 16 pounds per square inch absolute. The pressure of the liquid supply of 216 pounds per square inch absolute then forces the piston to make a return stroke, filling the pumping piston cylinder with liquid and again tripping the toggle mechanism to reopen the actuating gas valve so that the cycle is repetitive. The special design of the toggle mechanism is very important, in this combination, since it prevents direct gas leakage and prevents the possibility of the pump stopping in midstroke due to simultaneous opening of both the intake and exhaust valves.

It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of this invention.

I claim as my invention:

1. In a pump for a liquid having a low boiling point, a pump cylinder having a cylindrical bore, a pumping piston reciprocable in said bore, an actuator cylinder having a cylindrical bore coaxial with said pump cylinder bore, an actuating piston movable in said actuator cylinder bore, and means for transmitting force from said actuating piston to said pumping piston comprising a rigid thin-walled tubing member forming a continuous and uninterrupted opening therethrough and engaged at one end with said actuating piston and at the other end with said pumping piston, the engagement of the rigid thin-walled tubing member with the pumping piston being through the medium of a button inserted in the rigid thin-walled tubing member and having a convex face contacting the pumping piston to provide a point contact constituting the sole point of engagement between said button and said pumping piston to minimize heat transfer and to accommodate misalignment therebetween.

2. In a pump for a liquid having a low boiling point, a pump cylinder having a cylindrical bore, a pumping piston reciprocable in said bore, an actuator cylinder having a cylindrical bore coaxial with said pump cylinder bore, an actuating piston movable in said actuator cylinder bore, a rigid thin-walled tubing forming an axially continuous opening therethrough and rigidly connected at one end to said pumping cylinder and means at the other end of said tubing contacting said actuating piston in operative relation thereto at a contact area substantially less than the cross-sectional area of said tubing.

3. In a pump for a liquid having a low boiling point, a pump cylinder having a cylindrical bore, a pumping piston reciprocable in said bore, an actuator cylinder having a cylindrical bore coaxial with said pump cylinder bore, an actuating piston movable in said actuator cylinder bore, a button element having a surface portion engaged with a surface portion of one of said pistons, and a rigid thin-walled tubing member connecting said button element with the other of said pistons, at least one of said surface portions being convex to engage the other of said surface portions at an osculating point, thereby to minimize heat transfer between said pistons and to accommodate misalignment of said pistons.

4. In a pump for a liquid having a low boiling point, a pump cylinder having a cylindrical bore, a pumping piston reciprocable in said bore, an actuator cylinder having a cylindrical bore coaxial with said pump cylinder bore, an actuating piston movable in said actuator cylinder bore, a button element having a surface portion engaged with a surface portion of one of said pistons, means connecting said button element with the other of said pistons, and a rigid thin-walled sleeve interconnecting said cylinders, at least one of said surface portions being convex to engage the other of said surface portions at an osculating point, thereby to minimize heat transfer between said pistons and to accommodate misalignment thereof.

5. In a pump for a liquid having a low boiling point, a pump cylinder having a cylindrical bore, a pumping piston reciprocable in said bore, an actuator cylinder having a cylindrical bore coaxial with said pump cylinder bore, an actuating piston movable in said actuator cylinder bore, a button element having a surface portion engaged with a surface portion of one of said pistons, and a rigid thin-walled tubing member connecting said button element with the other of said pistons, at least one of said surface portions being convex to engage the other of said surface portions at an osculating point, thereby to minimize heat transfer between said pistons and to accommodate misalignment of said pistons, and a rigid thin-walled sleeve interconnecting said cylinders.

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