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PUMP FOR A BOILING LIQUID

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FIG. 5

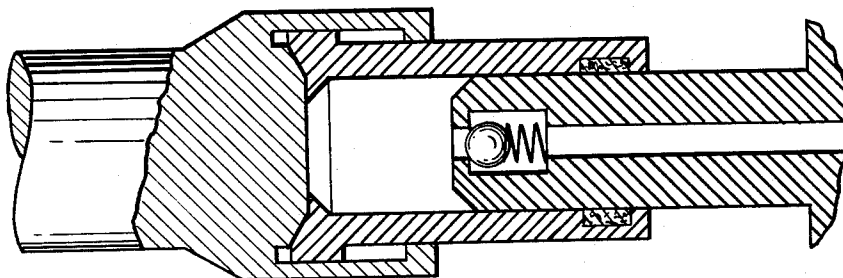


FIG. 4

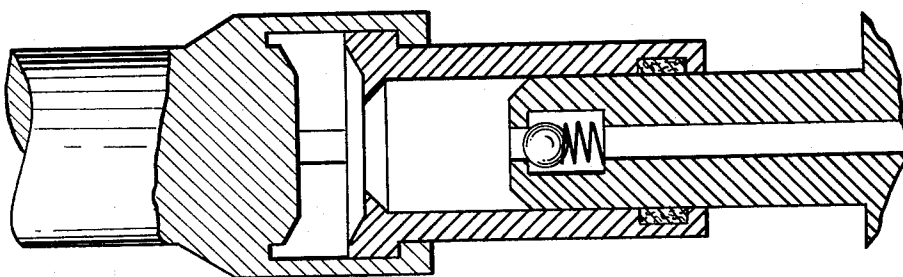


FIG. 3

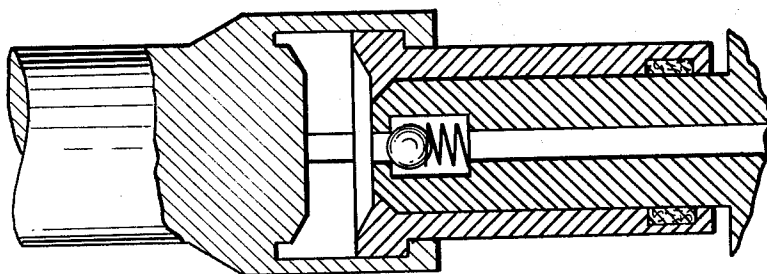
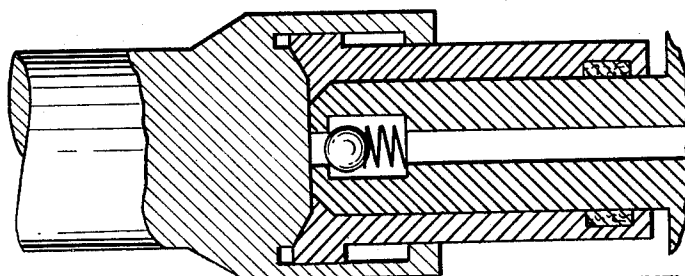


FIG. 2



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## PUMP FOR A BOILING LIQUID

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9 Claims. (Cl. 103—158)

The subject matter of this invention relates to a pump. More particularly, this invention relates to a reciprocating pump for raising the pressure of liquids, particularly boiling liquids.

The pump of this invention is especially adapted to use with cryogenic liquids, that is, for use with liquids of a temperature generally lower than  $-100^{\circ}$  F.

Although there have been a great many pumps proposed and used for liquids, particularly boiling liquids, certain problems have not been satisfactorily overcome. It is most desirable to have a pump which will pump liquid (which may be at its boiling point), to high pressure. The reciprocating pump of this invention will pump a liquid to a high pressure, at least a part of which liquid is boiling.

One problem encountered when liquid is pumped to a higher pressure is that at least a portion of said liquid, which is not discharged from the pump at the end of the pumping stroke, flashes to vapor during the reduction of pressure that follows said pumping stroke. This flashed vapor interferes with the proper operation of the pump and must be purged from the pump. Furthermore, the purging of flashed vapor allows for a continued substantially constant volumetric output of pumped liquid from the pump. Thus (for efficient operation) reciprocating pumps must purge themselves of vapor at the end of each pumping stroke. This invention relates to a simple reciprocating pump device with provision for simple and definite purging of all flashed vapors from the pump chamber, prior to each pumping stroke.

A second problem encountered in reciprocating pump structure relates to the question of priming the pump during the startup period. Provisions for this priming operation in the prior art are nonexistent, cumbersome, inefficient, or ineffective. The reciprocating pump of this invention includes the features of the preceding paragraph and a self-priming capability. As will be apparent from the detailed discussion of the operation of the reciprocating pump structure of this invention that will follow. In the reciprocating pump of the instant invention the liquid to be pumped does not have to be forced into the pumping chamber in order for the pumping operation to commence.

The pump of this invention contains the desirable features set forth in the preceding paragraphs, as well as other features, which features will become apparent in connection with the detailed description hereinafter.

It is an object of this invention to provide a pump which will pump to a higher pressure a cryogenic liquid a part of which liquid may be at its boiling point.

It is further an object of this invention to provide a reciprocating pump which has the capability of clearing itself of flashed vapor during operation.

It is a further object of this invention to provide pump structure which primes itself during startup.

It is further an object of this invention to provide the reciprocating pump of this invention with an efficient arrangement of independently functioning seals, so that communication between the pump chamber and the atmosphere is obviated.

Other objects and advantages of the liquid pump described in more detail hereinafter and shown in the drawing will become apparent in connection with the following description and drawing.

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Generally, the reciprocating pump structure which is the subject of this invention has a stationary piston located at the bottom of a liquid storage container, mounted about which there is a hollow cylinder which reciprocates toward and away from the bottom of the container as a result of motion imparted to it by a reciprocating drive shaft, which drive shaft extends out of the storage container to a drive mechanism. The stationary piston contains a discharge valve. A contact area between the reciprocating cylinder and the drive shaft forms an inlet valve through which liquid to be pumped and flashed vapors flow. The inlet valve opens at the end of the discharge or pumping stroke and remains open for the entire length of the upward or suction stroke of the reciprocating cylinder. The void in hollow cylinder forms a pump chamber which enlarges as the cylinder moves upward. Said pump chamber is continually filled with liquid through the inlet valve, as the cylinder moves on the upward (suction) stroke. The drive shaft, which is responsible for the motion of the reciprocating cylinder, reaches the top of its reciprocating stroke and starts downward before the inlet valve formed between cylinder and drive shaft closes. During the first portion of the drive shaft's downward stroke, the cylinder is stationary, as the result of a lost motion connection between the cylinder and drive shaft. This lost motion or dwell period in which the cylinder is stationary allows for an additional period of time for the pump chamber formed by the hollow cylinder to clear itself of flashed vapor. At the conclusion of the lost motion or dwell period, the inlet valve closes, as a result of relative motion between the drive shaft and the cylinder, and the liquid within the pump chamber is pumped to a higher pressure and discharged through the discharge valve in the stationary piston.

The invention will be described in more detail hereinbelow in association with the below described drawing.

FIGURE 1 of the drawing shows, partly in section, a reciprocating device for pumping liquid which is at least partially boiling; and

FIGURES 2 to 5 show the pump at various points during the course of its operation.

Referring to FIGURE 1, a container for liquefied gas is shown with a reciprocating pump device located therein. The liquid level within the container is maintained somewhat above the uppermost position of the top of cylinder E, to be described hereinbelow. Vapor outlet and liquid delivery lines V and L, respectively, are shown connected to the container; however, placement of said lines is not a part of this invention, and said lines are shown in particular locations in the drawing merely for illustrative purposes.

The piston G is located (an integral attachment is shown for convenience, but not required) on the bottom of the container which holds the liquid. Said piston G is located on the center line I—I. Drive shaft A of the liquid pump performs reciprocating straight line motion along the same center line I—I, which is the straight line path of movement of the shaft. The upstroke of shaft A within the container is the suction stroke and the downstroke the discharge stroke. Shaft A has attached to it a number of lifting fingers C (lost motion mechanism) which are in contact with the shoulder P of cylinder E during a part of the operation of the pump. There is sufficient clearance between fingers to allow liquid flow into the pump chamber to be described below. The surface B on shaft A is a sealing surface which mates with the surface D on cylinder E. These two surfaces, surface B and surface D, make up the inlet valve of the pump. Hollow cylinder E, which also moves along straight line path I—I, under the direction of shaft A through pressure from its lower face on the downstroke and lifting by its fingers C on the shoulder P on the up-

stroke, contains high pressure seals F. Seals F provide a seal between the inner surface of cylinder E and the outer surface of piston G to seal the pump chamber when in pumping position. The position of the high pressure seals F, as shown for example in the drawing, is not critical. Said high pressure seals could be provided for in another desired location, for example, on piston G abutting cylinder E, instead of as presently shown. The seals F help maintain cylinder E in position as a result of their friction contact of the opposing surface. Of course, spring loading of cylinder E, or another known system of support, may be substituted or added to the friction support of said cylinder E just described. The void J, bounded by the top of piston G, and the inner wall of hollow cylinder E makes up the pump chamber, which provides the volume to contain the liquid that is to be elevated in pressure on the discharge stroke of the reciprocating pump. The lower surface of the shaft A forms the upper boundary of the pump chamber when the inlet valve is closed on the downward or pumping stroke. A check valve M located within the outlet H of the piston G functions to allow the discharge of liquid that has been raised in pressure from the pump. Said ball and spring check valve also serves to seal off outlet H at other times, in the standard manner. The check valve M may be of any desired shape.

Although the piston G is shown as mounted on the bottom of the container, it could also be mounted in other locations such as on a side of the container, as long as the liquid to be pumped surrounds the pump chamber, and as long as the flashed vapors will rise from the pump chamber to exit through the inlet valve, as will be discussed hereinafter.

The container is shown as closed and sealed around shaft A by the use of seals K. Any desired type of seals may be used, and said seals may be located wherever desirable without departing from the scope of this invention, as long as the container is closed and sealed around said shaft.

The finger structure C, shown in the drawing, which allows for the lost motion period or dwell time in the pump operation of this invention, could be modified without departing from the scope of this invention. For example, the finger structure C could be located on cylinder E sliding on shaft A, if desired.

The shape of the upper surfaces of piston G and cylinder E provide for a mated fit, fitting projections N on cylinder E is in its lowermost position in recessed areas O in piston G. Projections N, which mate with recesses O, provide a surface upon which the liquid in the pump chamber can exert an upward force, so as to insure that cylinder E remains in mounted sealed position on piston G.

Standard stop structure (not shown) is included in the pump structure of this invention for limiting the distance traversed during the upward movement of shaft A.

The operation of the pump structure described above is as follows:

With shaft A and cylinder E in their lowermost positions, FIGURE 2, the pump is at the start of the suction stroke. The inlet valve formed by surfaces B and D is closed, as the surfaces are in contact. The seal at surfaces B and D is broken as shaft A starts to rise, since shaft A moves at the start of its upward stroke without moving cylinder E therewith. When the lifting fingers on shaft A contact cylinder E, the cylinder E will move with shaft A, (FIGURE 3). The liquid that was not discharged through ball check valve M during the previous pumping stroke, which liquid is warmer than the remaining liquid within the container, flashes to vapor as the shaft A starts to rise, due to the decrease in pressure, and said vapor rises within the pump chamber to exit through the inlet valve formed by surfaces B and D, said vapor rises due to its lower density with respect to the liquid entering through the inlet valve from the con-

tainer for the next purging stroke. This released vapor is thus replaced by liquid from the container. As previously mentioned as the shaft A continues upward the fingers C contact the shoulder P on cylinder E and pull it up with the shaft. As cylinder E moves upward, the void J increases in volume. During this upward movement of cylinder E, the two directional flow discussed above can exist through the inlet valve formed between sealing surfaces B and D. Vapor from boiling liquid in void J rises to the top of the cylinder and exits through the inlet valve as liquid is drawn in through the valve into the pump chamber. At the end of the suction stroke, FIGURE 4, there is a time delay, or dwell period, before the inlet valve closes during which cylinder E remains stationary as shaft A moves in a downward direction. This dwell period terminates when the surface B contacts the surface D, closing the inlet valve and moving cylinder downward with shaft A in the pumping stroke (FIGURE 5). This dwell period provides the time required for the pump chamber to clear itself substantially completely of vapor and fill up with liquid. As cylinder E and shaft A start down together all boiling within the pump chamber stops due to the increase in pressure.

The location of the inlet valve of this device contributes to the fact the device of this invention tends to clear itself of substantially all vapor during each stroke, since said inlet valve is located above the pump chamber and the vapor formed due to boiling rises. Said vapor is displaced by the liquid entering the pump chamber through said inlet valve.

The pump structure described will pump a boiling liquid with a minimum loss in volumetric efficiency. That is, substantially the same amount of liquid will be pumped to a higher pressure, during each pumping stroke. Because of the relation between the location of the inlet valve and the pumping void, the pump tends to clear itself at the end of each pumping stroke, and the volume of the pump thus remains substantially constant.

Since gas or boiling liquid vapor naturally flow out of the pump, and since liquid naturally flows into the pump as a result of gravitational pull, it is not necessary to force liquid into the pump to start it. Thus, the reciprocating pump of this invention is self-priming.

The seals F, whether their location be shown as in FIGURE 1 or in other desired locations, operate within the liquid inside the liquid container, and thus are always lubricated. Furthermore, if the seals F cease to be fully effective, any escape through said seals does not result in an escape into the atmosphere, but rather merely back into the liquid of the container since the seals F and the seals K are independent.

The shaft A, fingers C, cylinder E, piston G, etc., of the reciprocating pump structure described above are most usually composed of metal, but it is within the scope of this invention to form said parts of the reciprocating pump of any other desired material, such as plastic, glass, etc. The proportions generally shown in the drawing are merely illustrated and may be varied to meet flow and pressure requirements.

It is to be understood that the pump and method of pumping disclosed above may be modified and varied by one skilled in the art, without departing from the scope of this invention, within the scope of the claims as set forth hereinafter.

I claim:

1. A vertically disposed pump having a discharge passageway, outlet valve means in said passageway through which liquid is pumped under pressure comprising a fixed upstanding piston, said passageway disposed within said piston, a shaft above said piston mounted for pumping movement toward said piston and for suction producing movement away from said piston, a hollow movable cylinder for receiving the liquid to be pumped slideably receiving the shaft for movement therewith over a portion of the distance traversed by the shaft, said cylinder mount-

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ed in sealed relationship on the piston, said shaft and said cylinder having mutually confronting closure surfaces forming an inlet valve, which surfaces engage, closing the inlet valve during the pumping stroke, and lost motion means connecting the cylinder and the shaft allowing for a predetermined initial vapor purging movement of the shaft during the pumping stroke prior to closing the inlet valve.

2. A pump as set forth in claim 1, said lost motion means further allowing for upward movement of the shaft independent of the cylinder for ingress of the liquid to be pumped and egress of the vapor to be purged through the inlet valve.

3. A container for holding a liquid to be pumped to a higher pressure with a vapor space thereabove, liquid and vapor passageways connected to said container, an upstanding piston vertically mounted in said container, a discharge passageway disposed within said piston, outlet valve means in said passageway through which liquid is pumped under pressure, a shaft above said piston mounted for pumping movement toward said piston and for intake suction producing movement away from said piston, a movable, hollow cylinder forming a chamber for receiving the liquid to be pumped, said cylinder slideably receiving the shaft for movement therewith over a portion of the distance traversed by the shaft, said cylinder mounted in sealed relationship on the piston, said shaft and said cylinder having mutually confronting closure surfaces forming an inlet valve, which surfaces engage, closing the inlet valve during the pumping stroke, said vapor passageway connected to the container above the level of the closure surfaces when in engaged relationship, and lost motion means connecting the cylinder and the shaft allowing for a predetermined initial vapor purging movement of the shaft during the pumping stroke prior to closing the inlet valve.

4. A container as set forth in claim 3, said lost motion means further allowing for upward movement of the shaft independent of the cylinder for ingress of the liquid to be pumped and egress of the vapor to be purged through the inlet valve.

5. A vertically disposed pump having a discharge passageway, outlet valve means in said passageway through which liquid is pumped under pressure comprising an upstanding piston, said passageway disposed within said piston, a shaft above said piston mounted for pumping movement toward said piston and for intake movement away from said piston, a cylinder having a liquid receiving chamber therein, said cylinder movably mounted in operative relationship with said shaft, said cylinder mounted in sealed relationship on the piston, said shaft and said cylinder having mutually confronting closure surfaces forming an inlet valve through which liquid to be pumped passes to fill the chamber, which surfaces engage closing the inlet valve during the pumping stroke, lost motion means connecting the cylinder and the shaft which provide for a predetermined initial vapor purging movement of the shaft on the pumping stroke prior to closing the inlet valve, and a projection on said confronting surface of said cylinder to provide a surface upon which the liquid in said chamber can exert an upward force

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to maintain the mounting of the cylinder on the piston in sealed relationship.

6. A container for holding a boiling liquid with a vapor spaced thereabove, liquid and vapor passageways connected to said container, an upstanding piston vertically mounted in said container, a discharge passageway disposed within said piston, outlet valve means in said passageway through which liquid is pumped under pressure, a shaft above said piston mounted for pumping movement toward said piston and for intake movement away from said piston, a cylinder having a liquid receiving chamber therein, said cylinder movably mounted in operative relationship with said shaft, said cylinder mounted in sealed relationship on the piston, said shaft and said cylinder having mutually confronting closure surfaces forming an inlet valve through which liquid to be pumped passes to fill the chamber, which surfaces engage closing the inlet valve during the pumping stroke, said vapor passageway connected to the container above the level of said closure surfaces when in disengaged relationship, lost motion means connecting the cylinder and the shaft which provide for a predetermined initial vapor purging movement of the shaft on the pumping stroke prior to closing the inlet valve, and a projection on said confronting surface of said cylinder to provide a surface upon which the liquid in said chamber can exert an upward force to maintain the mounting of the cylinder on the piston in sealed relationship.

7. A pump consisting of a piston, a discharge passageway, outlet valve means in said passageway through which liquid is pumped, said passageway disposed within said piston, a shaft mounted for reciprocating movement above said piston, a hollow cylinder for receiving liquid to be pumped mounted in sealed relationship on said piston and slideably connected to said shaft for motion with said shaft, said shaft and said cylinder having mutually confronting surfaces forming valve means for allowing flashed vapor and liquid to be pumped to pass therethrough, and lost motion means connecting said cylinder and said shaft allowing movement of said shaft without associated movement of said cylinder, in order to provide for venting of substantially all vapors through said valve.

8. A pump as set forth in claim 7, said lost motion means connecting the cylinder and the shaft, said lost motion means comprising a plurality of fingers mounted on said shaft in removable engagement with a shoulder element mounted on said cylinder.

9. A pump as set forth in claim 7, including a projection on said confronting surface of said cylinder to provide an area upon which the liquid received in said cylinder can exert an upward force to maintain the mounting of the cylinder on the piston in sealed relationship.

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