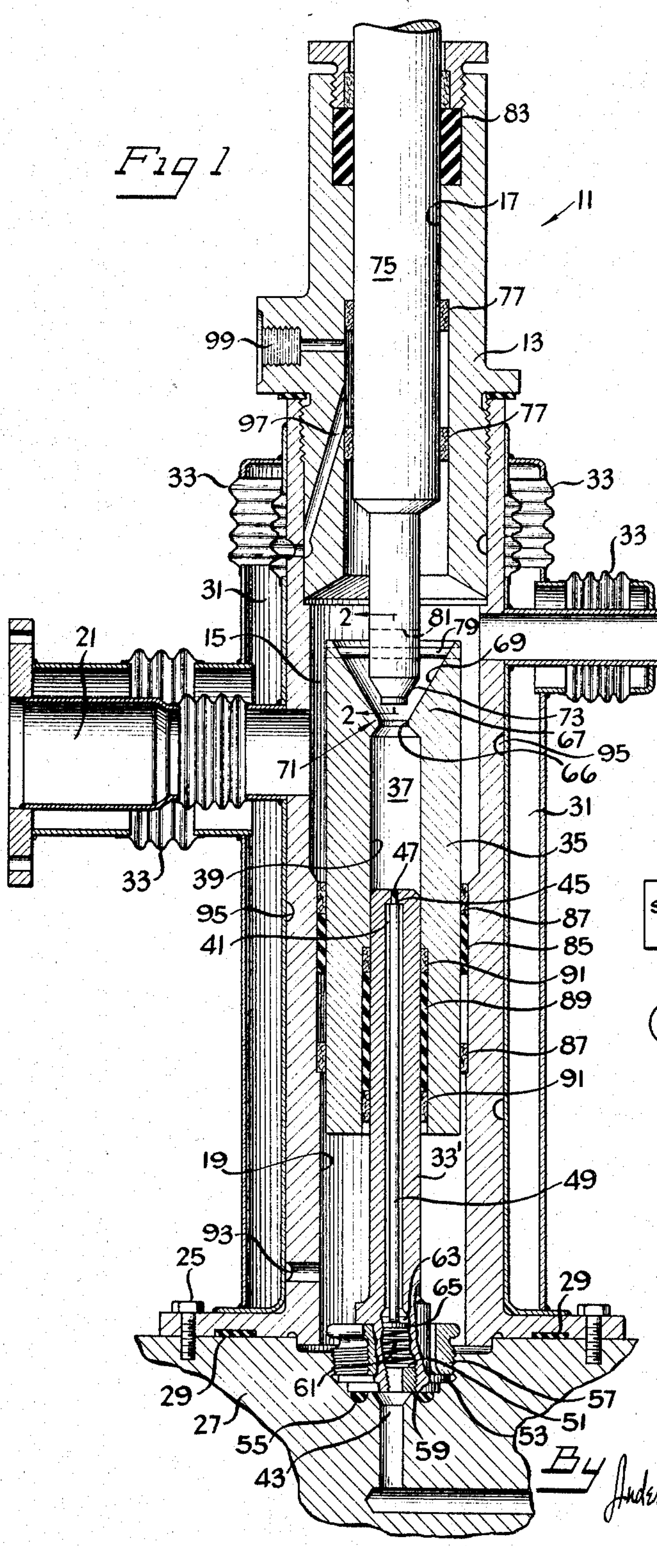
Aug. 2, 1966 | L. TYREE, JR | 3,263,622

PUMP

Filed June 1, 1964 | 2 Sheets-Sheet 1

Fig 1



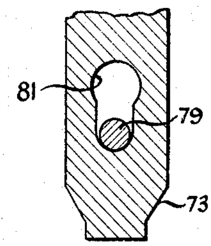


Fig 2

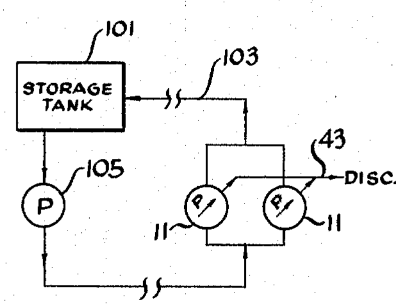


Fig 3

Inventor
Lewis Tyree, Jr.
By Anderson, Luedeka, Fitch, Even & Tabin
Atty's

PUMP

Filed June 1, 1964 2 Sheets-Sheet 2

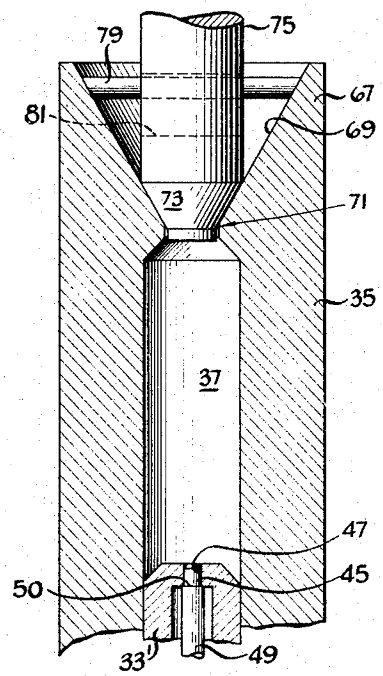


Fig 4

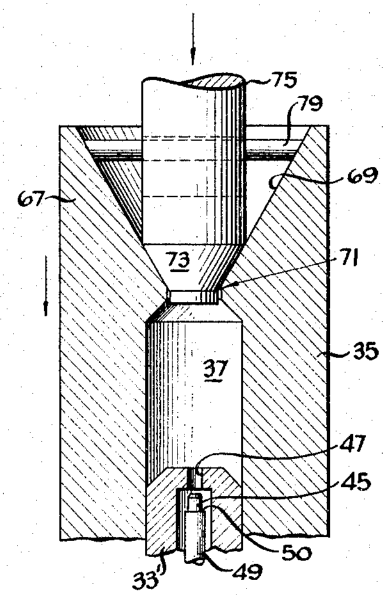


Fig 5

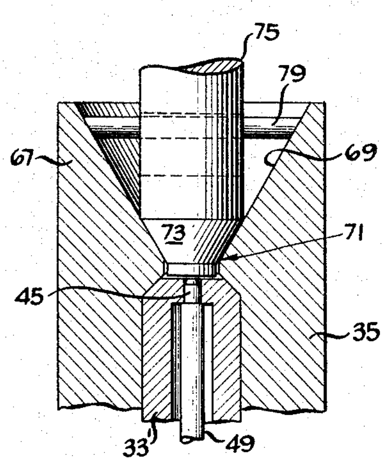


Fig 6

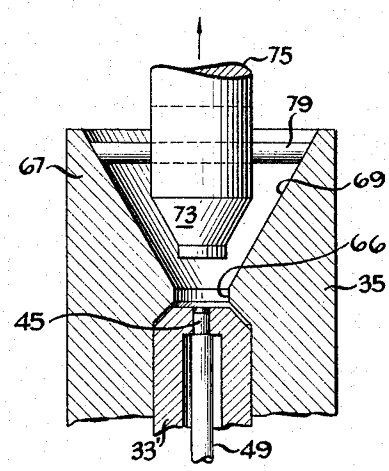


Fig 7

Inventor
Lewis Tyree, Jr.
By Anderson, Luedeka, Fitch, Even & Tabin
Atty's

United States Patent Office 3,263,622
Patented August 2, 1966

3,263,622
PUMP

Lewis Tyree, Jr., 9955 S. Hamilton Ave., Chicago, Ill.

Filed June 1, 1964, Ser. No. 371,666
16 Claims. (Cl. 103—153)

This invention relates to positive displacement, reciprocating pumps. More particularly, the invention is directed to pumps such as these which are designed for pumping cryogenic liquids, and especially for pumping cryogenic liquids near their boiling points.

One important criterion for a pump of this type, as for any pump, is that it should have good volumetric efficiency. By volumetric efficiency is meant the percentage of the potential volume of liquid in the pumping chamber that is actually pumped. In pumping cryogenic liquids, especially cryogenic liquids which are at or near their boiling point, the problem of achieving good volumetric efficiency becomes more difficult. To achieve good volumetric efficiency, the pumping chamber of the pump must be nearly completely filled with liquid. Cryogenic liquids are generally in the liquid state only at temperatures below ambient or room temperature, and they tend to flash to vapor at every opportunity, either as a result of heat gained or of a drop in pressure.

If a portion of the pumping chamber is occupied by vapor on the intake stroke, this of course means that the entire pumping chamber is not filled with liquid. Less liquid will accordingly be discharged, resulting in lower volumetric efficiency. Even if the cryogenic liquid to be pumped is a few degrees below its boiling point, it has a substantial tendency to vaporize because every pumping process is accompanied by some heat build-up in the pumping chamber. The temperature of the fluid in the pumping chamber rises as its pressure is raised during the discharge stroke. This rise in temperature results in a transfer of some heat to the walls of the pumping chamber. This heat is referred to as the residual heat of the pumping chamber and is subsequently returned to the incoming cryogenic fluid on the next intake stroke, raising its temperature. If the residual heat of the pumping chamber is allowed to gradually increase, the amount of vapor created will also increase. Eventually it is possible that the entire pumping chamber might be filled with vapor instead of liquid. In such a case, the pump would act only as a compressor. Thus, an increase in residual heat is clearly harmful to efficient cryogenic pumping and should be held within practical limits in order to achieve good volumetric efficiency.

Furthermore, not all of the fluid is exhausted from the pumping chamber on the discharge stroke. The volume of fluid remaining in the chamber at the end of a discharge stroke is referred to as the clearance volume of the pumping chamber. At the beginning of the intake stroke, some flashing of the liquid remaining in the clearance volume may occur and thus partially fill the pumping chamber with vapor. Such a reaction is, of course, undesirable. To minimize this effect it is desirable to design the pumping chamber to have a very low clearance volume and to minimize flashing of the residual liquid therein.

Another factor which impairs volumetric efficiency is incomplete filling of the pumping chamber with fluid at each stroke. In reciprocating, positive displacement pumps having relatively high delivery capacity, reciprocating motion is rapid, and the pumping chamber has only an instant of time in which to be filled. Accordingly, a pumping chamber designed to assure as complete filling as possible on every intake stroke is desired.

Another problem common to pumps of this general design, when used to pump cryogenic fluids, is vapor-

locking. Especially when liquids at or near their boiling point are being pumped, the possibility of vapor-build-up within the pumping chamber becomes likely. If a cryogenic pump employs a check-type valve as its intake valve, vapor-locking becomes a distinct possibility. Such a valve requires some pressure on behalf of the incoming fluid to open it; if vapor pressure is built up within the pumping chamber, the incoming fluid pressure may not be sufficient to open the valve and vapor-lock will occur. Vapor-locking can quickly result in over-heating of the pumping chamber and consequent injury to the pump. Therefore, pumps for handling cryogenic liquids are desired which have positive protections against vapor-locking.

In pumps which are designed to operate at high discharge pressure, the sealing of the pumping chamber is an important consideration. Because in a positive displacement, reciprocating pump there is generally a sliding fit between mating surfaces of the pump members that define a variable volume pumping chamber, the high-pressure seal is most efficiently and practically located between these sliding surfaces.

Any effective high pressure seal will produce some frictional heat. Moveover, the use of pressure-responsive seals in pumps of this type has become fairly common. Such seals, when subjected to higher pressures in the pumping chamber, rub harder against the surfaces being sealed and provide a more effective seal. However, the higher the pressure to which the seal is subjected, the more frictional heat which is generated.

Frictional heat is a particular problem for pumps handling cryogenic liquids because, if it is allowed to reach the pumping chamber, the intake liquid is undesirably heated and partially vaporized. In such an instance, the volumetric efficiency of the pump is impaired, for the reasons previously discussed. These problems are further complicated when the pump is to be adapted to pump fluids of extremely low viscosity which are quite difficult to contain. Moreover, whatever type of sealing material which is chosen, the operating temperature of the seal must be maintained within a fairly constant temperature range because operation at temperatures considerably above the planned temperature causes excessive seal wear and premature seal failure. A pump design which alleviates these problems is desired.

A principal object of the present invention is to provide a reciprocating, positive displacement pump which is simple in mechanical design and which will pump fluids with increased volumetric efficiency. Another object is to provide a pump of this type which will pump fluid at high discharge pressures and relatively high capacities. A further object is to provide a pump of this type which is inherently incapable of vapor-locking. A still further object is to provide a pump which has a very low clearance volume so that the pumping chamber retains a minimum amount of residual liquid at the end of the discharge stroke. These and other objects of the invention are more particularly set forth in the following detailed description and in the accompanying drawings wherein:

FIGURE 1 is a vertical sectional view of a pump embodying various features of the invention;

FIGURE 2 is an enlarged fragmentary sectional view taken along line 2—2 of FIGURE 1;

FIGURE 3 is a schematic view of a system using two of the pumps shown in FIGURE 1;

FIGURE 4 is a diagrammatic view of the pumping chamber of the pump illustrated in FIGURE 1 at the beginning of the discharge stroke;

FIGURE 5 is a view similar to FIGURE 4 at a later point during the discharge stroke;

FIGURE 6 is a view similar to FIGURE 4 at the very end of the discharge stroke; and

FIGURE 7 is a view similar to FIGURE 4 after the intake stroke has begun.

The present invention provides a pump which simultaneously solves each of the above-indicated problems and which can be used to pump cryogenic fluids under boiling point conditions with increased volumetric efficiency. The pump has an intake valve designed so that vapor-locking is inherently avoided and so that the action of the pump durinug the intake stroke dynamically induces the filling of the pumping chamber. The pump construction is such that the two surfaces of the respective ends of the cylindrical pumping chamber are in face-to-face relationship and closely adjacent at the end of the discharge stroke, thus minimizing the pump clearance volume and the amount of residual liquid.

Moreover, the pump discharge passageway is located adjacent the high pressure seal. This arrangement utilizes the effluent, high pressure liquid to absorb the frictional heat generated at the high pressure seal and effectively keeps the high pressure seal within a fairly narrow and low operating temperature range. Moreover, this arrangement prevents the frictional heat from reaching, and undesirably affecting, the intake fluid in the pumping chamber.

Now referring more particularly to the drawings, a pump **11** designed for pumping cryogenic fluids is illustrated in FIGURE 1. The pump **11** includes a pump casing **13** having a central sump **15** and upper and lower co-axial, vertical, cylindrical passageways **17**, **19** which open into the sump **15**. A horizontal inlet **21** and outlet **23** are also provided in the casing **13** which are in communication with the sump **15**. The pump casing **13** is suitably mounted, as by bolts **25**, on a pump base **27**, and sealed thereto by an appropriate gasket **29**. A vacuum jacket **31** is disposed adjacent the outer surface of the pump casing **13** and insulates the pump **11** from the higher temperature of the surrounding atmosphere. Appropriate expansion joints **33** are provided to allow for differential thermal contraction.

A pair of pump members, a pump plunger **33'** and a hollow pump cylinder or sleeve **35**, define a pumping chamber **37** and are disposed in the lower vertical passageway **19** of the pump casing. The plunger **33** is stationary and is mounted concentrically within the lower passageway **19**. A central bore **39** in the hollow cylinder **35** allows the cylinder to fit downward over the top of the plunger **33'** and occupy the annular space between the plunger and the inner wall of passageway **19** of the pump casing **13**.

The stationary plunger **33'** contains a central drilled hole **41** which serves as the beginning of a discharge passageway **43** from the pumping chamber **37** to the outlet (not shown) of the pump **11**. A discharge valve **45** is located at the upper end of this drilled hole **41**, at the junction between the discharge passageway **43** and the pumping chamber **37**. The valve **45** is a poppet valve and comprises a cylindrical valve port **47** and an elongated cylindrical valve stem **49** having a tip of reduced diameter. As best seen in FIGURES 4–7, an annular surface **50** provided by the reduction in diameter seats against the bottom of surface in which the valve port **47** is formed when the valve **45** is closed. Because of the relatively small diameter of the plunger **33'**, the valve stem **49** is elongated so that a spring mechanism **51** that biases the valve **45** to the closed position can conveniently be accommodated at the bottom of the plunger **33'** in an enlarged portion thereof.

The plunger **33'** terminates in a flange **53** which extends outwardly from the enlarged portion of the plunger. The plunger **33'** is seated atop an O-ring **55** in a threaded cavity provided in the pump base **27** and secured therein by a bushing **57** which screws into the cavity and bears against the flange **53**. The valve spring mechanism **51** comprises a hollow plug **59** and a compression spring **61**. The spring **61** is held within a small valve chamber **63**, counterbored at the bottom of the plunger hole **41**, by the plug **59** which screws into threads at the bottom of the valve chamber **63**. The compression spring **61** bears upward against a flat bottom plate **65** carried at the end of the valve stem **49**, seating the reduced tip of the stem **49** in the valve port **47**.

To define the upper limit of the pumping chamber **37**, the internal bore **39** in the slidable cylinder **35** is necked inward to an opening **66** of lesser diameter. Immediately above this neck, the bore **37** in the slidable cylinder flares outward to provide a funnel-like upper portion **67** having a conical inner surface **69**. This funnel-shaped upper portion **67** serves to dynamically induce the filling of the pumping chamber **37** on the intake stroke, as will be described more fully hereinafter.

The pumping chamber **37** is closed at the top by an intake valve **71**. The opening **66** is the intake valve port, and lower part of the conical surface **69** serves as the seat for the intake valve **71**. A stem **73** for the intake valve **71** is fashioned from the bottom portion of a piston rod **75** that is disposed in the upper vertical passageway **17** of the pump casing **13**. Through a drive connection (not shown) to the upper end of the piston rod **75**, the piston rod is driven in reciprocating motion. Bushings **77** are provided within the lower section of the upper vertical passageway **17** to maintain correct alignment between the piston rod **75** and the inner wall of the passageway **17** and, more importantly, to maintain alignment between the intake valve stem **73** and the intake valve seat.

Attachment of the piston rod **75** to the slidable cylinder **35** is made through a lost-motion connection. A horizontal connecting pin **79** diametrically spans the sides of the funnel-like end portion **67** of the slidable cylinder **35**. The ends of the pin **79** are mounted in suitable holes drilled in the wall of the cylinder **35**. As best seen in FIGURE 2, a key-hole shaped opening **81** is provided in the piston rod **75**, a short distance above its lower end. It is in this opening **81** that the central portion of the connecting pin **79** resides establishing a lost-motion connection between the piston rod **75** and the slidable cylinder **35**. When the piston rod **75** begins its downward discharge stroke, the intake valve **71** closes, transmitting power through the mating conical surfaces to force the slidable cylinder **35** downward. Location of the key-hole opening **81** is such that the top of the pin **79** never touches the upper interior surface of the opening **81**.

A low pressure stuffing box **83**, provided in a cylindrical recess near the top of the upper vertical passageway **17**, seals the upper end of the sump **15** against loss of fluid therethrough. Likewise, low pressure packing **85** is provided between a pair of bushings **87** that guide the slidable cylinder **35** within the lower vertical passageway **19** in which it resides. The bushings **87** assure proper alignment of the intake valve port **66**, whereas the low-pressure packing **85** seals the bottom of the sump **15** against fluid loss.

The seal which is of the most interest from the standpoint of the frictional heat generated thereat is the high pressure seal. This seal is provided by high pressure packing **89** which is disposed between a pair of bushings **91** in a cylindrical recess provided in the lower portion of the central bore **39** in the slidable cylinder. This high-pressure packing **89** seals the pumping chamber **37** against fluid loss.

The pump **11** is designed to efficiently pump cryogenic fluids at pressures up to about 12,000 p.s.i. To efficiently operate at pressures in this high pressure range, especially with fluids having fairly low viscosities, such as liquid nitrogen, it is necessary to have a good high pressure seal. Good high pressure seals for a sliding fit mean creation of frictional heat. Any suitable high pressure packing may be used, as for example, commercially available chevron-type packing. This type of packing is what is termed heavily loaded packing because the higher the pressure which is applied to it, the greater is the frictional force with which it bears against the surfaces being sealed.

Regardless of the type of high-pressure packing chosen, it is important to maintain the temperature of the packing within a fairly narrow operating range. Because of differential thermal expansion of the materials of which the pump members being sealed are made and the material of which the packing is made, it is important that the high-pressure seal operates at a fairly constant, relatively cool temperature. If the temperature of the high-pressure packing **89** is allowed to rise above the desired temperature range, as may easily happen because of the frictional heat to which it is subjected, greater than normal wear on the packing **89** occurs, the high-pressure seal loses its effectiveness, and more fluid is lost therethrough.

It should also be understood that, no matter how effective the high-pressure packing **89** is in sealing this sliding joint, it will not be perfect, and some fluid will escape therethrough. The fluid lost is commonly referred to as "blow-by," and it is the purpose of the seal to keep the blow-by at as low a level as practical. The blow-by which escapes through the high pressure packing **89** and reaches the bottom of the lower vertical passageway **19** is removed through an exit **93** in the side wall of the pump casing **13**. The exit **93** leads to a helical passageway **95** formed in the outer surface of the pump casing **13**. Thus, an upwardly leading passageway, between the vacuum jacket **31** and the pump casing **13** is provided which conducts blow-by, via an upper passageway system **97**, to an exit port **99** where it enters a conduit (not shown). This conduit carries the blow-by back to the source of fluid supply, keeping fluid losses in the pump at a low level.

Because the pump **11** is designed to operate with a feed of cryogenic fluid at a temperature near its boiling point, which are the prevailing conditions in a large, unrefrigerated supply tank **101** (see FIG. 3), both the inlet **21** and the vapor return outlet **23** are provided. Through the inlet **21**, the sump **15** is flooded with cryogenic fluid. If the pump **11** is operated in close proximity to the storage tank **101** of the cryogenic fluid, the vapor fraction, which invariably accompanies liquid near its boiling point, may be allowed to return to the storage tank **101** directly through the supply line or to pass with the liquid through the pump. In such instances, the vapor return outlet **23** may be eliminated.

One way of operating the pump **11** at a remote location from the supply vessel is depicted in FIGURE 3. In this embodiment, a pair of pumps **11** in parallel are used in a location substantially distant from the storage vessel **101**. In this case, an auxiliary vapor return line **103** is provided for connection to the pump outlets **23**. Moreover, it is preferred to use an auxiliary, low pressure, high capacity pump **105** positioned close to the storage tank **101**. Such a pump **105** is commonly referred to as a fore pump. The function of the fore pump **105** is to circulate cryogenic fluid from the storage tank **101** through a continuous exterior circuit. Included in this circuit, as illustrated in FIGURE 3, there may be the sumps **15** of a plurality of high pressure pumps **11**. Disposition of the inlet **21** at a lower vertical level than the vapor outlet **23** enhances the complete filling of the pumping chamber **37** and the return of the vapor fraction to the storage tank **101**. The fore pump **105** is operated to circulate a greater amount of fluid than the pumps **11** in the circuit are pumping.

In operation of the pump **11**, circulation of cryogenic fluid through the inlet **21** and into the sump **15** is first established. The pump drive is then actuated so that the piston rod **75** begins to reciprocate. In the position illustrated in FIGURE 1, the piston rod **75** has just completed the intake stroke and is about to reverse direction.

FIGURE 4 shows the pumping chamber **37** just after the piston rod **75** has reversed direction and begun its downward discharge stroke. In this view, it can be seen that the intake valve stem **73** has been seated too close to the intake valve **71** at the top of the pumping chamber **37**. Inasmuch as all the force that moves the slidable cylinder **35** downward is transmitted to it through the mating conical surfaces of the intake valve **71**, a good seal at the intake valve is assured.

In FIGURE 5, the pumping chamber **37** is shown after the piston rod **75** has driven the slidable cylinder **35** some distance downward. As can be seen, the volume of the pumping chamber **37** decreases during this discharge stroke. The pressure on the fluid contained in the chamber **37** accordingly increases so any vapor which was present at the beginning of the stroke is compressed to liquid. As soon as the pressure pumping chamber overcomes the pressure in the discharge line **43** (e.g., pumping may be into a closed cylinder), the poppet valve **45** opens. Discharge of fluid immediately begins through the central hole **43** in the stationary plunger **33'**, through the bottom hollow plug **59** and out through the pump base **27**.

FIGURE 6 shows the pump **11** at the end of the discharge stroke where the piston rod **75** has reached the bottom of its stroke and the discharge valve **45** has closed. The bottom horizontal surface of the piston rod **75** is face-to-face with the upper horizontal surface of the stationary plunger **33'**, in which the discharge valve port **47** is located. Proportioning of these elements is such that the vertical clearance between these two faces is about 0.020 inch. Accordingly, the clearance volume of the pumping chamber **37** is only about 1 percent of the total volume of the chamber **37** at the beginning of the discharge stroke.

As the piston rod **75** begins to move upward at the beginning of the intake stroke, the intake valve **71** immediately opens, as illustrated in FIGURE 7. The cylinder **35** does not move until the intake valve **71** is completely open and the piston rod **75** has traveled a sufficient distance upward so that the connecting pin **79** is engaged by the bottom of the key-hole opening **81**, as shown in FIGURE 2. Because the sump **15** is always kept substantially full of cryogenic fluid, as a result of the circulation of an excess of fluid therethrough by the fore pump **105**, the funnel-like portion **67** of the slidable cylinder moves upward through a body of cryogenic fluid. During this upward movement, the conical surface **69** of the cylinder acts as an inducer to produce dynamic induction of cryogenic fluid into the continually enlarging pumping chamber **37**. This effect is similar to that which a funnel exhibits when it is dragged through a water bath, i.e, the liquid velocity at the funnel exit is higher than the velocity of the funnel. In the pump **11**, the neck of the slidable cylinder **35** is akin to the funnel exit. The surface area of the conical surface **69** is preferably at least as large as the cross sectional area of the pumping chamber **37** to assure effective filling.

This funnel-like configuration of the upper cylinder portion **67** not only dynamically induces the filling of the pumping chamber **37**, but also it increases the velocity head of the fluid entering the pumping chamber **37**, which is then converted to static head. This effect accordingly promotes the filling of the pumping chamber **37** with cryogenic fluid in the liquid form. As a result, at the end of the intake stroke, the pumping chamber **37** is filled with cryogenic fluid, substantially entirely in liquid form, in time for the discharge stroke to begin.

Thus, the advantageous features of the design of the slidable cylinder **35** reduces the need for sub-cooling of the cryogenic liquid before pumping, a device employed by other cryogenic pumping systems. Sub-cooling is generally effected by vaporizing some of the liquid from the bottom of the storage tank to raise the pressure therein and sub-cool the remaining liquid. Such sub-cooling by partial vaporization is undesirable in terms of overall economy and is only a temporary measure, effective until equilibrium conditions are re-established.

If the pump 11 is intended to be used to handle cryogenic fluids, it is preferred to construct the structural elements of the pump out of stainless steel, although other suitable materials may also be used. Relative to "Teflon," stainless steel also has good thermal conductivity. A stainless steel plunger 33 is suitable to conduct the frictional heat from the high pressure packing 89 radially inward to the discharge passageway 43. In any respect, it is preferred that the plunger 33 be constructed of a metal, or of a material having a thermal conductivity the approximate equal of a metal.

Location of the discharge passageway 43 adjacent the high pressure seal, allows the high pressure, low temperature discharge stream of cryogenic fluid to be used as a heat sink for the purpose of cooling the packing 89. A relatively high quantity of cryogenic fluid is discharged through this passageway when the pump 11 operates near its rated capacity, i.e., about two gallons per minute for a pumping chamber 37 with a 1⅜-inch diameter and a length or stroke of 3⅛ inch. Thus, the discharge stream provides a heat sink of ample capacity to easily absorb the frictional heat generated by the high pressure packing 89 and maintain the packing 89 within the desired temperature range. When liquid nitrogen is being pumped at rated capacity, the packing 89 is maintained at about −250° F. Thus, a heavily loaded packing may easily be used.

Although the single cylinder pump 11 is designed to produce a discharge of about two gallons of liquid per minute at pressures up to about 12,000 p.s.i.g., when the piston rod 75 is connected to a crank shaft rotating at about 100 r.p.m., it is also suitable for operation at speeds of up to about 700 r.p.m. Pumping cryogenic liquids at 2 gallons per minute and at pressures up to about 12,000 p.s.i., can be accomplished with high volumetric efficiency. Although the volumetric efficiency of the pump 11 is not as good at the higher speeds possible, it is considered an improvement over the volumetric efficiency of comparable pumps operating in this pressure range.

With these conditions of operation in mind, the importance of completely filling the pumping chamber 37 on each intake stroke is apparent. Furthermore, the limited entrance area there is through the intake valve and the fraction of a second in which the pumping chamber 37 must be filled on the intake stroke, the dynamic induction which is provided by the design of the pump 11 is of considerable advantage. The combination of features in this design that provides both a low clearance volume and excellent filling of the pumping chamber results in very good volumetric efficiency and makes the use of the pump 11 especially advantageous in handling cryogenic liquids at temperatures near their boiling point.

Various of the features of the invention are set forth in the following claims.

What is claimed is:

1. A positive displacement reciprocating pump for handling cryogenic liquids, which pump comprises first and second cooperating pump members which are movable relative to each other and which define a pumping chamber, means disposed between said members effective to seal said pumping chamber, said first pump member having a discharge passageway formed therein in fluid communication with said pumping chamber, and discharge valve means closing said discharge passageway, a portion of said discharge passageway being located in close thermally conducting relation to said sealing means so that heat frictionally generated by said sealing means is absorbed by the discharge stream of cryogenic liquid and carried away from said pumping chamber.

2. A positive displacement reciprocating pump for handling cryogenic liquids which pump comprises first and second cooperating pump members which are slidable relative to each other and which define a pumping chamber of variable volume, means disposed between said members effective to seal said pumping chamber, said first pump member having a discharge passageway formed therein in fluid communication with said pumping chamber and discharge valve means closing said discharge passageway, a portion of said discharge passageway being located in close thermally conducting relation to said sealing means so that heat frictionally generated by said sealing means is absorbed by the discharge stream of cryogenic liquid and carried away from said pumping chamber.

3. A positive displacement reciprocating pump for handling cryogenic liquids which pump comprises a hollow pump cylinder, a pump plunger partially disposed in the hollow bore of said pump cylinder, said plunger being proportioned so that said plunger and said cylinder are slidable relative to each other and define a pumping chamber of variable volume, means disposed between said plunger and said cylinder effective to seal said pumping chamber, said plunger having a discharge passageway formed therein in fluid communication with said pumping chamber and discharge valve means closing said discharge passageway, a portion of said discharge passageway being located in close thermally conducting relation to said sealing means so that heat frictionally generated by said sealing means is absorbed by the discharge stream of cryogenic liquid and carried away from said pumping chamber.

4. A positive displacement reciprocating pump for handling cryogenic liquids which pump comprises a hollow pump cylinder which has a cylindrical bore, a cylindrical pump plunger of good thermal conductivity being partially disposed in the bore of said pump cylinder, said plunger being proportioned so that said plunger and said cylinder are slidable relative to each other and define a pumping chamber of variable volume, heavily loaded high pressure packing disposed between said plunger and said cylinder effective to seal said pumping chamber, said plunger having a central discharge passageway formed therein in fluid communication with said pumping chamber and discharge valve means located in said discharge passageway, said central discharge passageway being in good thermally conducting relation to said packing so that heat frictionally generated by said high pressure packing is absorbed by the discharge stream of cryogenic liquid and carried away from said pumping chamber.

5. In a positive displacement reciprocating pump for handling cryogenic liquids which pump includes a hollow pump cylinder having a bore therein, a pump plunger partially disposed in the bore of said pump cylinder, said plunger being proportioned so that said plunger and said cylinder are slidable relative to each other and define a pumping chamber of variable volume, means disposed between said plunger and said cylinder effective to seal said pumping chamber, the improvement which comprises said plunger having a discharge passageway formed therein in fluid communication with said pumping chamber and discharge valve means closing said discharge passageway, a portion of said discharge passageway being located in close thermally conducting relation to said sealing means so that heat frictionally generated by said sealing means is absorbed by the discharge stream of cryogenic liquid and carried away from said pumping chamber.

6. A positive displacement reciprocating pump which comprises a stationary pump plunger, a hollow pump cylinder having an opening therein for slidably receiving said stationary plunger and defining therewith a pumping chamber of variable volume, said plunger having a discharge passageway formed therein in fluid communication with said pumping chamber, discharge valve means closing said discharge passageway, intake valve means for selectively controlling the flow of fluid into said pumping chamber, and means connected to said hollow cylinder for effecting reciprocating movement thereof relative to said stationary plunger and for opening and closing said intake valve incident to said reciprocating movement.

7. A positive displacement reciprocating pump which

comprises a stationary pump plunger, a hollow pump cylinder having an opening therein for slidably receiving said stationary plunger and defining therewith a pumping chamber of variable volume, intake valve means for selectively controlling the flow of fluid to be pumped into said pumping chamber, said intake valve means including a valve port in said hollow cylinder and a separable valve stem, means connected to said valve stem for moving said stem in reciprocating motion, and means connecting said valve stem to said hollow cylinder for moving said cylinder in reciprocating motion relative to said stationary plunger incident to the reciprocating motion of said stem.

8. A positive displacement reciprocating pump which comprises a stationary pump plunger, a hollow pump cylinder having an opening therein for slidably receiving stationary plunger in sliding contact therewithin and defining a pumping chamber of variable volume, means disposed between said plunger and said hollow cylinder effective to seal said pumping chamber, said plunger having a discharge passageway formed therein in fluid communication with said pumping chamber, discharge valve means closing said discharge passageway, intake valve means in said hollow cylinder, said intake valve means including a valve port in said hollow cylinder in fluid communication with said pumping chamber and a separable valve stem, means connected to said valve stem for moving said stem in reciprocating motion and a lost-motion connection between said valve stem and said hollow cylinder for moving said cylinder in reciprocating motion relative to said stationary plunger.

9. A positive displacement reciprocating pump that operates on a two-stroke intake and discharge cycle, which pump comprises a stationary pump plunger, a hollow pump cylinder having an opening therein for slidably receiving said stationary plunger and defining therewith a pumping chamber of variable volume, said hollow pump cylinder also having an intake valve port formed therein which opens into said pumping chamber, an intake valve stem for closing said port adapted for movement along an axis co-axial with the axis of said plunger, means connected to said intake valve stem for moving said stem in reciprocating motion to open and close said intake valve on the intake and discharge strokes of the pump, and means connecting said valve stem to said hollow cylinder for moving said cylinder in reciprocating motion relative to said stationary plunger and thereby create pumping action.

10. A positive displacement reciprocating pump that operates on a two-stroke intake and discharge cycle, which pump comprises a stationary pump plunger, a hollow pump cylinder having longitudinal bore therein for slidably receiving said stationary plunger in one end thereof and defining therewith a pumping chamber of variable volume, said hollow pump cylinder having an intake valve port formed therein which opens into the other end of said longitudinal bore and also having an intake valve seat formed around said port, an intake valve stem for closing said port adapted for movement along an axis co-axial with the axis of said plunger, means connected to said valve stem for moving said stem in reciprocating motion to open and close said intake valve on the intake and the discharge stroke of the pump, and means connecting said valve stem to said hollow cylinder for moving said cylinder in reciprocating motion relative to said stationary plunger.

11. A positive displacement reciprocating pump that operates on a two-stroke intake and discharge cycle which comprises a pump casing having a sump formed therein and a passageway opening into said sump, a stationary pump plunger mounted in said passageway, a hollow pump cylinder proportioned to interfit within said passageway and having an opening formed therein for slidably receiving said stationary plunger thereby defining therewith a pumping chamber of variable volume, said hollow pump cylinder having an intake valve port formed therein in fluid communication with said pumping chamber and a funnel-like portion surrounding said port, means for closing said intake valve port, means connected to said hollow cylinder for effecting reciprocating movement thereof relative to said stationary plunger and for opening and closing said intake valve incident to said reciprocating movement, said axis of said funnel-like portion being parallel to the axis along which said reciprocating movement occurs so that movement of funnel-like portion of said cylinder through said sump and away from said plunger causes said pumping chamber to be filled by dynamic induction.

12. A positive displacement reciprocating pump that operates on a two-stroke intake and discharge cycle which pump comprises a pump casing having a sump formed therein and a passageway opening into said sump, a stationary pump plunger mounted in said passageway, a hollow pump cylinder proportioned to interfit within said passageway and having an opening formed therein for slidably receiving said stationary plunger thereby defining therewith a pumping chamber of variable volume, said hollow pump cylinder having formed therein an intake valve port in fluid communication with said pumping chamber and a frustoconical surface surrounding said port and opening outward in a direction away from said pumping chamber, the area of said surface being at least equal to the cross sectional area of said pumping chamber, means for closing said intake valve port, means connected to said hollow cylinder for effecting reciprocating movement thereof relative to said stationary plunger and for opening and closing said intake valve incident to said reciprocating movement, said axis of said frustoconical surface being parallel to the axis along which said reciprocating movement occurs so that movement of said cylinder through said sump away from said plunger causes said pumping chamber to be filled by dynamic induction.

13. In a positive displacement reciprocating pump that operates on a two-stroke intake and discharge cycle which pump includes a pump casing having a sump formed therein and a passageway opening into said sump, the improvement which comprises a stationary cylindrical pump plunger mounted in said passageway, a hollow pump cylinder proportioned to interfit within said passageway and having a bore formed therein for slidably receiving said stationary plunger thereby defining therewith a pumping chamber of variable volume, said hollow pump cylinder having an intake valve port formed therein in fluid communication with said pumping chamber and a funnel-like portion surrounding said port and flaring outward in a direction away from said pumping chamber, means for closing said intake valve port, and means connected to said hollow cylinder for effecting reciprocating movement thereof relative to said stationary plunger and for opening and closing said intake valve incident to said reciprocating movement, the axis of said funnel-like portion being parallel to the axis along which said reciprocating movement occurs so that movement of funnel-like portion of said cylinder through said sump and away from said plunger causes said pumping chamber to be filled by dynamic induction.

14. A positive displacement reciprocating pump that operates on a two-stroke intake and discharge cycle which pump comprises a pump casing having a sump formed therein and a passageway opening into said sump, a stationary pump plunger mounted in said passageway, a hollow pump cylinder proportioned to interfit within said passageway and having an opening formed therein for slidably receiving said stationary plunger thereby defining therewith a pumping chamber of variable volume, said hollow pump cylinder having an intake valve port formed therein in fluid communication with said pumping chamber and a funnel-like portion surrounding said port, a valve stem for closing said valve port adapted for movement along an axis co-axial with the axis of said plunger, means connected to said valve stem for moving said stem in reciprocating motion to open said intake valve port on the intake stroke of the pump and to close said valve port on the discharge stroke of the pump, and means connecting said valve stem to said hollow cylinder for moving said cylinder in reciprocating motion relative to said stationary plunger, the axis of said funnel-like portion being parallel to the axis along which said reciprocating movement occurs so that movement of funnel-like portion of said cylinder through said sump and away from said plunger causes said pumping chamber to be filled by dynamic induction.

15. A positive displacement reciprocating pump the operates on a two-stroke intake and discharge cycle which pump comprises a pump casing having a sump formed therein and a passageway opening into said sump, a stationary pump plunger mounted in said pump passageway, a hollow pump cylinder proportioned to interfit within said passageway and having an opening formed therein for slidably receiving said stationary plunger thereby defining therewith a pumping chamber of variable volume, said hollow pump cylinder having formed therein an in-intake valve port in fluid communication with said pumping chamber and a frustoconical surface surrounding said port and opening outward in a direction away from said pumping chamber, the area of said surface being at least equal to the cross sectional area of said pumping chamber, means disposed between said pump plunger and said hollow cylinder effective to seal said pumping chamber, said pump plunger having a discharge passageway formed therein in fluid communication with said pumping chamber, discharge valve means closing said discharge passageway, a portion of said discharge passageway being located in close thermally conducting relation to said sealing means so that heat frictionally generated by said sealing means is absorbed by the discharge stream and carried away from said pumping chamber, a valve stem for closing said intake valve port adapted for movement along an axis co-axial with the axis of said plunger, means connected to said valve stem for moving said stem in reciprocating motion to open said intake valve port on the intake stroke of the pump and to close said valve port on the discharge stroke of the pump, and lost-motion connection means between said valve stem and said hollow cylinder for moving said cylinder in reciprocating motion relative to said stationary plunger, said axis of said frusto-conical surface being parallel to the axis along which said reciprocating movement occurs so that movement of said cylinder through said sump away from said plunger causes said pumping chamber to be filled by dynamic induction.

16. A positive displacement reciprocating pump for handling cryogenic liquids that operates on a two-stroke intake and discharge cycle, which pump comprises a pump casing having a sump formed therein and a vertical passageway opening upward into said sump, a stationary cylindrical pump plunger mounted in said pump passageway, a hollow pump cylinder proportioned to interfit within said vertical passageway and having a central bore formed therein for slidably receiving said stationary plunger thereby defining therewith a pumping chamber of variable volume, said hollow pump cylinder having formed therein an intake valve port which opens into the top of said pumping chamber and a frusto-conical surface which surrounds said port and opens outward in a direction away from said pumping chamber, the axis of the surface being co-axial with said cylindrical plunger and the area of said surface being at least equal to the cross sectional area of said pumping chamber, a high-pressure seal disposed between said cylindrical pump plunger and the bore of said hollow cylinder effective to seal said pumping chamber, said cylindrical pump plunger having a discharge passageway formed therein in fluid communication with said pumping chamber, discharge valve means closing the junction between said discharge passageway and said pumping chamber, a portion of said discharge passageway being located in close thermally conducting relation to said high-pressure seal so that heat frictionally generated by said seal is absorbed by the discharge stream of cryogenic liquid and carried away from said pumping chamber, a frustum-shaped valve stem for closing said intake valve port and seating against said frusto-conical surface, said stem being adapted for movement along an axis co-axial with the axis of said pump plunger, means connected to said valve stem for moving said stem in reciprocating motion to open said intake valve port on the intake stroke of the pump and to close said intake valve port on the discharge stroke of the pump, and lost-motion connection means between said valve stem and said hollow cylinder for moving said cylinder in reciprocaing motion relative to said stationary plunger so that said motion of said hollow cylinder lags said motion of said valve stem, whereby movement of said cylinder on the intake stroke through said sump away from said plunger causes said pumping chamber to be filled by dynamic induction.

References Cited by the Examiner

UNITED STATES PATENTS

1,683,617	9/1928	Hennessy	103—153
2,598,528	5/1952	French	103—41.1
2,765,625	10/1956	Hart	103—227
2,779,295	1/1957	Manning	103—158
2,855,859	10/1958	Petzold	62—55
3,023,710	3/1962	Tyree	103—153
3,101,057	8/1963	Heiser	103—154
3,137,143	6/1964	Jacobs et al.	62—55

SAMUEL LEVINE, *Primary Examiner.*

H. F. RADUAZO, *Assistant Examiner.*