Jan. 17, 1956 P. M. RIEDE 2,730,957

APPARATUS FOR PUMPING A VOLATILE LIQUID

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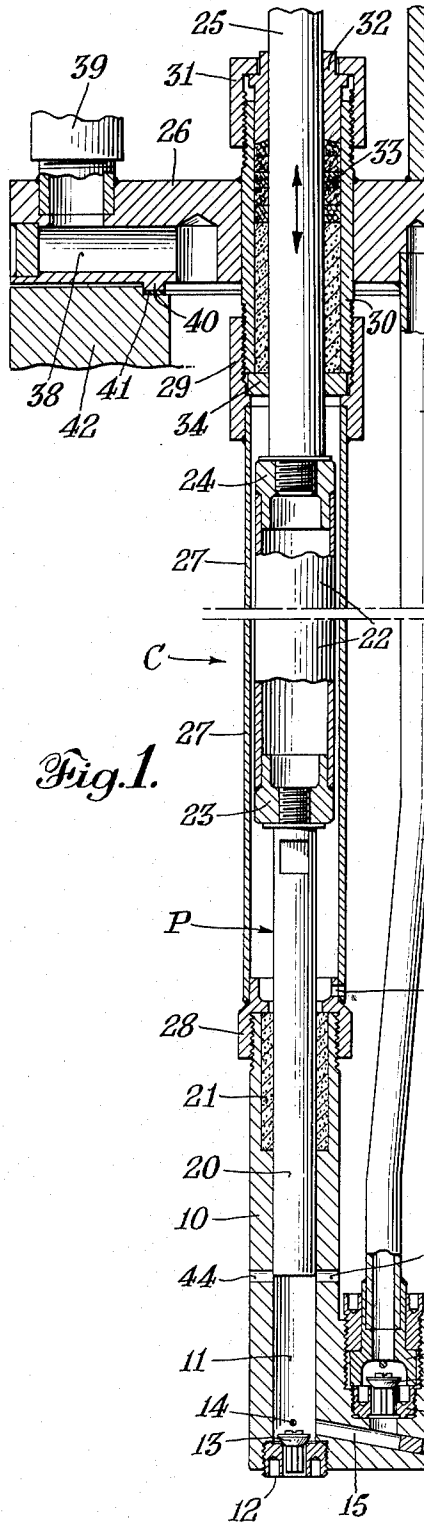
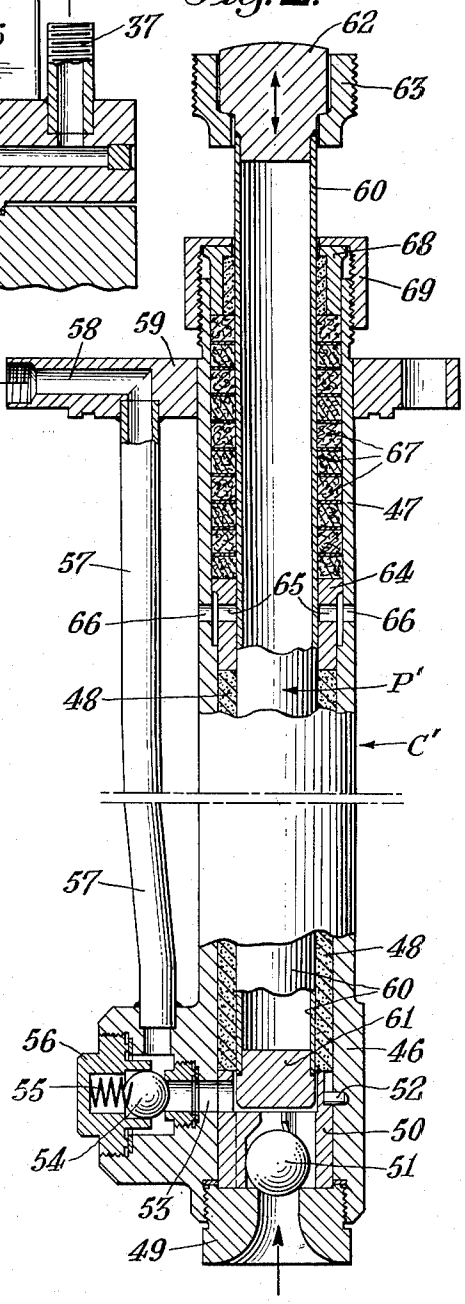


Fig. 1.

Fig. 2.



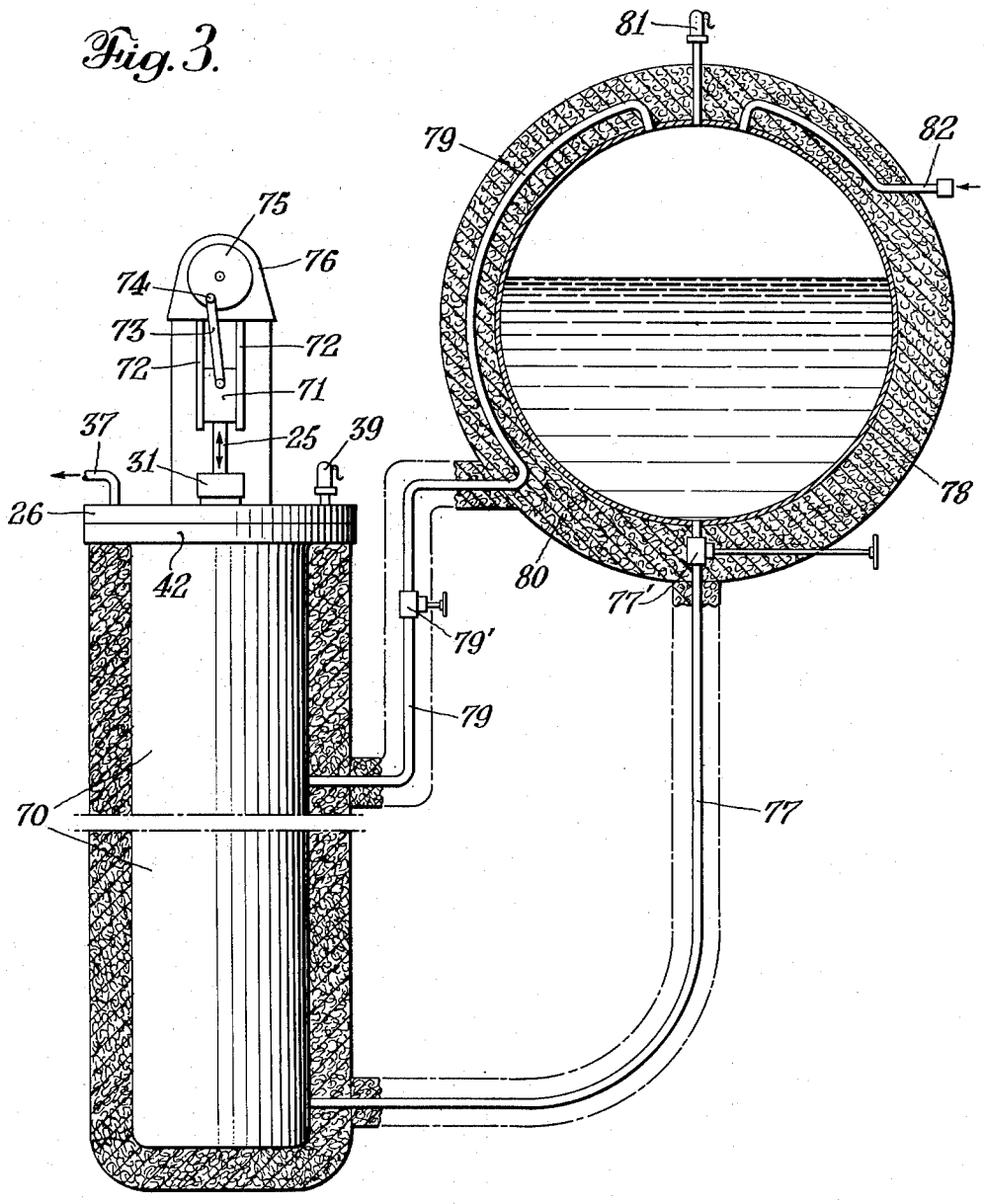
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Fig. 3.



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APPARATUS FOR PUMPING A VOLATILE LIQUID

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11 Claims. (Cl. 103—153)

This invention relates to apparatus for pumping a volatile liquid having a boiling point temperature at atmospheric pressure materially below 273° K., and more particularly to a reciprocating pump for pumping against a high pressure a liquefied gas having a normal boiling point below 233° K., such as liquid oxygen, nitrogen, and the like.

Pumps heretofore proposed for pumping liquefied gases such as oxygen and nitrogen against high pressures involved difficulties due to the properties of the highly volatile liquids. Such difficulties have necessitated that the liquefied gas to be pumped be sub-cooled, or that a forepump be used to provide an initial increase of pressure, or that a refrigerant of lower temperature than the liquefied gas to be pumped be applied to prevent vapor binding of the pump. These difficulties have previously made it impractical to provide a simple apparatus that could be located away from an oxygen producing plant and which could be reliably employed for pumping liquid oxygen from a storage container at desired times and rates to force the liquid through a simple vaporizer and produce high pressure gaseous oxygen for use as required or for charging cylinders at localities removed from an air separation plant without the use of gas compressors.

Among the main objects of the present invention are to provide an improved pumping apparatus which may be employed in, or in combination with, a container of liquefied gas for forcing liquefied gas as and when needed to receiving means under pressure, which apparatus shall avoid the necessity of priming the pumping chamber prior to each period of operation; which provides a pump structure of the reciprocating type that is highly resistant to vapor binding at very low suction heads; that prevents cold liquefied gas from reaching and affecting the efficiency of a warm end operating rod or plunger packing; that keeps a warm end plunger packing subjected only to suction pressure so that packing friction may be much less than if the packing were subject to higher pressures; that substantially prevents the heat which tends to flow along the pumping element or plunger from its warm or operating rod end toward the pumping chamber from adversely affecting the pumping action; which allows the use of a plunger guide sleeve in the part of the pumping chamber through which the plunger enters, to be of a character that provides an easy sliding fit and low friction with resultant low frictional heat production, that allows sufficient leakage along the plunger to carry heat away from the pumping chamber, and which conserves such plunger leakage; and a reciprocating pump structure that is self-venting to effectively avoid vapor binding at low suction heads.

These and other objects of the invention will become more apparent from consideration of the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a view of a longitudinal cross-section through a pump embodying features according to the present invention;

Fig. 2 is a view of a longitudinal cross-section through another embodiment of pump adapted for immersion in a chamber holding the liquefied gas to be pumped; and

Fig. 3 is a more or less diagrammatic view of a pumping apparatus including a supply container and a forechamber in which the pump of either Fig. 1 or 2 is immersed.

According to the present invention, the pumping ends of the pumps are immersed in a body of the liquefied gas to be pumped, so that the pumping chamber is maintained at the working temperature and the pump can be started without a preliminary pump priming operation. The pumps, according to the present invention, can employ simple automatically-operated valves such as a gravity-operated inlet valve and a gravity-operated or spring-closed discharge valve.

A pumping element, preferably in the form of a cylindrical plunger, operates in the pumping chamber of the pumping cylinder to draw in a charge of liquid through the suction valve and force it out through the discharge valve. The point of entry at least of the plunger into the working chamber must be "sealed" sufficiently to prevent flow of most of the charge of liquid along the plunger during the compression stroke. Therefore the plunger may have a diameter which closely fits the cylinder, and there is provided a flow restricting element, between at least a part of the pumping cylinder and the plunger, which is made of a material that provides a low friction coefficient between it and the plunger at the temperature of the liquefied gas. This flow restricting element or sleeve is preferably secured in a manner such that substantially no binding pressure on the plunger is created, and so that a free sliding clearance is provided. Such clearance has the benefit of allowing a small amount of leakage in a direction away from the pumping chamber, so that any gas material heated by the plunger by friction or by heat of compression tends to escape in a direction away from the pumping chamber. Any such liquid which is thus permitted to escape from the pumping chamber along the plunger is immediately by-passed into the chamber in which the pump is immersed, so that such material may be conserved, the liquid portion eventually returning to the inlet valve of the pump. Such by-passing of leakage also insures against allowing cold liquid to flow toward the warm end packing of the plunger or pump-operating rod.

The warm end packing is positioned at a substantial distance from the cold pumping chamber of the pump by providing an elongated extension of the pumping chamber surrounding an extension of the plunger. The aforementioned by-pass serves also to insure that the pressure against which the warm end packing provides a seal, is only that of the chamber in which the pump is immersed. The construction also provides that heat generated at the warm end packing and that received from the surroundings through the operating end of the pumping element, and which tends to be conducted downwardly toward the pumping chamber, can be effectively impeded. The entire pump is mounted on and suspended from a single cover plate for covering an opening of the vessel in which the pump is immersed, and the discharge passage of the pump likewise passes through the same cover plate, so that when repairs are necessary the pump is very quickly removed as a unit from the chamber in which it is mounted. Obviously, all containers and pipes which contain liquid or gas from which heat is to be excluded are protected by suitable heat insulation in the well-known manner.

Referring now to the drawings, and particularly to Fig. 1, the pump comprises a cylinder or pump body indicated generally at C having a lower body portion 10 in which is a cylindrical working or pumping chamber 11

closed at the bottom by a plug 12 having a central passage therethrough controlled by a gravity-closed inlet valve 13. A crosswise pin 14 may be provided to prevent the valve 13 from rising too far off its seat. A lateral discharge passage 15 from the working chamber 11 is also provided which is controlled by a gravity-seated discharge valve 16. The valve 16 cooperates with a valve seat 17 below a valve housing 18 to which is connected a discharge conduit 19.

The pump is provided with a reciprocating pumping element indicated generally at P, the inner working or pumping portion of which is a plunger 20 that enters the end of the working or pumping chamber 11, which is opposite the plug 12. The plunger portion 20 in Fig. 1 preferably fits the bore of the working chamber 11 fairly closely to provide an easy sliding fit. There should, however, be a small clearance at working temperatures. A flow restricting guide sleeve 21 of self-lubricating material, for example a bonded graphite or carbon, is preferably disposed between the upper part of the lower body portion and the plunger 20, the sleeve 21 having an internal cylindrical surface of a diameter similar to that of the working chamber 11. The length of the sleeve 21 and the counterbore in which it fits may be varied as desired; preferably it is as long as or longer than the plunger stroke. It should not fit too tightly, because excess of friction and heat may be developed. Preferably there should be a very slight clearance between the plunger and the sleeve so that a slight amount of liquefied gas can flow along the plunger 20.

The pumping element P is extended upwardly for a substantial distance by suitable means, for example, it could be a continuous rod, but as shown in Fig. 1, the plunger 20 is provided with a tubular extension 22 having an internally threaded closure plug 23 at its lower end threadedly engaged with the end of the plunger portion 20. At the upper end of the tube 22 a similar internally threaded plug 24 threadedly engages an operating rod portion 25 that extends upwardly to a mechanism hereinafter described for effecting reciprocation of the pumping element.

It is preferable to operably position the cylinder or lower body portion 10 with respect to a mounting member such as a cover plate 26 at a substantial distance therefrom by a supporting means of low heat conduction such as a cylinder extension 27 which is constructed as described hereinafter to provide drainage of liquid from a point adjacent the upper end of sleeve 21 to the pumping chamber inlet.

The pump is mounted on cover plate 26 by tubular cylinder extension 27 which is secured at its lower end to the lower body portion 10 by a threaded ring 28 that serves also to retain the sleeve 21. The extension tube 27 surrounds the pumping element and is secured at its upper end to a threaded ring 29 in threaded engagement with a cylindrical stuffing box 30. The stuffing box 30 passes through the plate 26 and is secured thereto by welding. The upper end of the stuffing box 30 has external threads for engagement with a ring-like packing nut 31 that presses a gland 32 against packing rings 33 which provide a gas seal between the pumping element and the mounting member. The packing 33 is retained by a ring 34 supported in the bottom of the packing box. The discharge conduit 19 is secured in an opening 35 in the bottom of plate 26, which opening communicates with a passage 36 connecting to an external outlet conduit 37. The plate 26 may also have another passage 38 therethrough communicating externally with a relief valve 39. The underside of the plate 26 may also be provided with an annular projection 40 to apply pressure on a gasket 41 in the rim 42 of an opening in the upper part of a container of liquefied gas in which the pump is to be immersed.

For venting gas material that may enter the chamber formed between the extension tube 27 and the pumping element, and between the warm end packing 33 and the sleeve 21, a passage means communicating therefrom with the inlet 13 is provided preferably in the form of one or more vent passages or holes 43 through the extension 27. The holes 43 should preferably be at the lower part of the extension 27 and close to the upper end of the sleeve 21 so that liquid that flows upward along the plunger through the sleeve 21 may escape at the holes 43 and be returned to the inlet valve 13. The leakage passing the sleeve 21 in most instances will be sufficient to vent vapors and heated liquefied gas from the working chamber 11 so that such chamber will not become gas-bound. However, sometimes it may be advisable to insure better venting, and for this purpose one or more vent holes 44 in the lower body portion may be provided, preferably at the level of the upper limit reached by the lower end of the plunger 20 during its working stroke. The vents 44 are closed by the plunger during the discharge stroke, but since there must be some clearance for easy operation, a small amount of the liquid will escape from the working chamber 11 through the vents 44, and such liquid that escapes is returned to the inlet valve 13. In order that heat conduction from the operating end of the pumping element and operating rod 25 may be minimized, the extension 27 is made long and as thin as is consistent with adequate strength. Preferably also the material employed is selected to have a lower thermal conductivity. The extension 22, for similar reasons, is of small cross-section and elongated, and may be of a material having low conductivity.

In the embodiment of Fig. 2, the pump body or cylinder C' is made substantially in one piece, comprising a lower body portion 46 and an extension portion 47, the extension portion having a slightly larger bore therein. The lower body portion 46 is lined almost all the way down with a sleeve 48 of solid self-lubricating material which may be of a material similar to sleeve 21, for example, a bonded graphite or carbon. The lower end of the bore of the body portion 46 is closed by a plug 49 that retains a ball valve cage 50, the plug 49 having a central opening therethrough controlled by a ball valve 51. A pin 52 is provided to prevent the valve cage 50 from being turned out of alignment with a lateral discharge passage 53. The upper part of the cage 50 forms a seat for the sleeve 48. The passage 53 is controlled by a ball valve 54 urged to its seat by a spring 55 which is retained by a cap 56. From the side of the valve 54 a discharge conduit 57 conducts the pumped liquid to a passage 58 in a cover plate 59 which is secured tightly to the upper part of the extension 47. The plate 59 constitutes a mounting member for the pump and the cylinder extension 47 forms a supporting means of low heat conduction positioning the portion 46 at a substantial distance from the mounting member.

The pumping element P' of the pump of Fig. 2 is of uniform external diameter throughout and comprises a tube 60 capped at its lower end by a plug 61 and at its upper end by a headed plug 62. A ring nut 63 around the plug 62 may be employed to secure the pumping element to reciprocating mechanism. The tube 60 and plug 61 have an external diameter which is slightly smaller than the internal diameter of the sleeve 48 to provide low friction and to permit passage of a small amount of liquefied gas upward along the operating element to a point near the upper end of the sleeve 48. The sleeve 48 is retained by a lantern ring member 64 having lateral holes 65 which cooperate with holes 66 in the extension 47, so that the leakage fluid may be by-passed around to the inlet valve 51. The gland 64 forms a bottom for the stuffing box portion of the extension 47, which is filled with packing rings 67, the packing rings being retained by a gland follower 68 and a packing nut 69. A suitable type of packing may be composed of asbestos and graphite composition rings which provide a gas seal between the pumping element and the mounting member.

When the liquefied gas to be pumped is liquid oxygen, a suitable type of packing at 67 and 33 may be similar to that described in United States Patent No. 2,292,543 of J. F. Patterson.

Either of the pumps of Figs. 1 and 2 may be mounted so as to be immersed in the liquid to be pumped, for example, they may be mounted directly in, or in a part of, a storage container that forms the source of supply of liquid oxygen, or preferably the pump may be immersed in a special liquid container or forechamber, as illustrated in Fig. 3. In Fig. 3 there is shown a forechamber 70 having an upper rim 42 on which the cover plate 26 is mounted, as indicated in Fig. 1. The operating rod 25 is seen to be secured to a cross head 71 that is laterally restricted for vertical movement between guides 72 by a connecting rod 73 and crank pin 74 mounted on a crank disk 75. The crank disk is rotated by any suitable power device, which is not shown in the interest of clearness of drawing. The crank disk is mounted rotatively in bearings of a supporting frame 76 that is secured to the top of the cover plate 26. The type of bearings employed for the operating members, and the type of lubrication thereof, is selected according to the character of the liquefied gas being pumped, for example, if liquid oxygen is pumped, it is preferable to employ a lubricant that is not dangerous in the event that oxygen should leak from the packing 33.

The forechamber 70 is supplied with liquefied gas by a pipe 77 connecting its lower portion with the lower part of a supply container 78, the conduit 77 being controlled by a valve 77'. It is preferable that the liquid level in the forechamber shall not rise much above the level of the vent hole 43 or 66, respectively, so as to minimize heat conduction from the operating mechanism toward the liquefied gas. To this end there is provided a vent or pressure equalizing connection 79 from an intermediate part of the forechamber 70 connecting to the supply container 78 at an upper portion thereof. This line is also controlled by a stop valve 79'. The container 78 is enclosed within heat insulation 80 and may be provided with a safety valve vent 81 and a filling connection 82. The discharge connection 37 may be connected to any desired liquid oxygen receiving means, such as, for example, a high pressure vaporizer, not shown, that can convert the liquid into a gas of the desired pressure for consumption or for charging into gas cylinders. In some instances the forechamber may not be needed and the supply container may be connected by a liquid line directly to the opening in plug 49 provided a by-pass conduit is connected between vent 66 and the liquid line and a vapor line connects the vent 66 to the supply container.

It will be seen that the venting of the pumping chamber effectively prevents vapor binding and, with a very lightweight inlet valve, the suction heads may be very low. The working end of the plunger is effectively kept at the low temperature of the liquefied gas by a small flow of the liquid along its surface in a direction away from the pumping chamber. The sleeve 21 or 48 does not need to be compressed against the plunger but can allow free sliding as the small clearance usefully aids in venting warmed material away from the pumping chamber without materially reducing the volumetric efficiency of the pump. The warm end packing needs to seal only against inlet pressure so that its friction is low and heat conduction from the warm parts of the pump toward the pumping chamber is reduced to immaterial amounts.

It is contemplated that various modifications of the pumping apparatus may be made without departing from the spirit and scope of the invention herein described and claimed.

What is claimed is:

1. A reciprocating pump for liquefied gases having a boiling point below 273° K. comprising a cylinder having a pumping chamber portion provided with inlet and discharge valve controlled ports, and an outwardly extending tubular extension; a reciprocating plunger in the cylinder, said plunger having an extension portion passing outwardly through the tubular cylinder extension; a guide sleeve secured in the cylinder around the plunger, said guide sleeve having a close sliding fit around the plunger permitting slight flow of liquid during a discharge stroke and being made of a solid material providing low friction against the plunger surface; a warm end packing near the outer end of the tubular cylinder extension for sealing the plunger extension that passes therethrough; a chamber supplied with the liquefied gas to be pumped into which the pump cylinder is immersed, the inlet valve opening into said chamber and the discharge valve communicating with a discharge conduit passing out of said chamber; and means defining a vent passage opening to the surface of the plunger, passing through the wall of the cylinder, and venting into the chamber in which the cylinder is immersed, said vent passage opening to the plunger surface at a point between said guide sleeve and said warm end packing for releasing pumped liquid and vapor thereof that pass between the plunger and said guide sleeve into said chamber and for maintaining the gas pressure against the warm end packing substantially equal to the pressure in said chamber.

2. A reciprocating pump for liquefied gases according to claim 1 which includes a cover for said chamber in which the pump cylinder is immersed from which cover said pump cylinder depends; said discharge conduit passing out through said cover to receiving means.

3. A reciprocating pump apparatus for liquefied gases according to claim 1 which includes a source of liquefied gas at low temperature; a supply connection from said source to said chamber in which the cylinder is immersed; and means for passing vapor from the upper portion of said chamber in which the cylinder is immersed to said source.

4. Apparatus for pumping a liquefied gas having a boiling point below 233° K. comprising an elongated pump body having a pumping chamber therein adjacent one end and an opening at the other end; a reciprocable pumping element extending through said opening in the pump body and having an inner pumping end portion operable in said pumping chamber; a valve-controlled inlet near the end of the pumping chamber opposite said opening; a valve-controlled outlet passage from the pumping chamber for liquid discharge; warm end packing means for the portion of the pumping element passing through said opening, said packing means being spaced a substantial distance from said pumping chamber; a flow restricting sleeve in said pump body closely fitting said pumping element, said sleeve being at least as long as the working stroke of the plunger, the contacting surfaces of said sleeve and pumping element being of different material, one being a hard smooth metal surface and the other being of a solid self-lubricating material compatible with the liquefied gas being pumped; and means having walls defining a passage opening to the pumping element at a point between said sleeve and said warm end packing and constructed and arranged for returning to the inlet valve the portions of pumped liquid which flow between the pumping element and the sleeve from the pumping chamber.

5. Apparatus for pumping a liquefied gas according to claim 4 in which said means having walls defining a passage includes a chamber containing liquefied gas in which said pumping cylinder is immersed, said inlet communicating with the liquid in said chamber, and said passage means communicating with said last-named chamber.

6. Apparatus for pumping a liquefied gas having a boiling point below 233° K. comprising a pump with a cylinder portion having a pumping chamber therein and having an end opening, a reciprocable pumping element having a pumping end portion operable in said pumping chamber and a portion extending through said end opening to a warmer region; a valve-controlled inlet near the

end of the pumping chamber opposite said end opening; a valve-controlled passage from the pumping chamber for liquid discharge; a flow restricting sleeve in said pump body closely fitting said pumping element, the contacting surfaces of said sleeve and pumping element being of different material, one being a hard smooth metal surface and the other being of a solid self-lubricating material compatible with the liquefied gas being pumped; a mounting member in the warmer region having an opening through which the pumping element extends; a gas seal for the opening between the pumping element and the mounting member; supporting means of low heat conduction operatively positioning said cylinder portion with respect to said mounting member and at a substantial distance therefrom, said supporting means being constructed to provide drainage of liquid from a point near the upper end of said sleeve to the pumping chamber inlet and walls defining a passage communicating with said point and the pumping chamber inlet.

7. Apparatus for pumping a liquefied gas according to claim 6 in which said walls defining a passage includes a forechamber containing liquefied gas to be pumped, said forechamber being in communication with the pumping chamber inlet and with said point adjacent the upper end of said sleeve.

8. Apparatus for pumping a liquefied gas having a boiling point below 233° K. comprising an elongated hollow pump body having a mounting member near one end and a pumping chamber adjacent the other end; a reciprocable pumping element having an operating portion extending through an opening at said one end of the pump body and having an inner pumping portion operable in said pumping chamber; a valve controlled inlet to the pumping chamber adjacent said other end of the pump body; a valve controlled discharge passage from the pumping chamber; warm end packing for the operating portion of the pumping element passing through said opening; a guide sleeve about said pumping element and secured in said pump body, said sleeve having a length greater than the stroke of the pumping element, the contacting surfaces of said sleeve and pumping element being of different material, one being a hard smooth metal surface and the other being of a solid self-lubricating material compatible with the liquefied gas being pumped; said sleeve having a predetermined free sliding fit about the pumping element to permit flow during a discharge stroke of a small portion of the pumped material along the pumping element away from the pumping chamber; and means defining a passage opening to the surface of the pumping element adjacent the end of said sleeve furthest from said other end of the pump body and communicating with said inlet, said passage means being constructed and arranged for diverting said small portion of gas material away from said pumping element and conducting said small portion to join with the liquefied gas supplied to said inlet.

9. Apparatus for pumping liquefied gas according to claim 8 which includes means at each end of said sleeve for retaining it against endwise displacement in said pump body; and in which said means defining a passage includes walls forming at least one opening through the retaining means for the outer end of said sleeve and walls forming a liquid holding chamber in which the pump body may be suspended, said mounting member being adapted to close an opening of said liquid holding chamber and said opening being in communication with the pump inlet.

10. Apparatus for pumping liquefied gas according to claim 8 in which said mounting member is adapted to close an opening of a liquid holding chamber in which the pump body may be suspended; and which includes a discharge conduit connected to said discharge passage and passing through said mounting member.

11. Apparatus for pumping liquefied gas according to claim 8 in which said pump body has an axial opening through said other end with a valve device secured therein, said device being provided with an inlet valve port and being formed to provide a retainer and guide for an inwardly opening valve that controls said port, and the inner portion of said device being formed to provide at least the end wall of said pumping chamber and a retaining means for the end of said sleeve.

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