

April 20, 1948.

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2,439,958

PUMP FOR LIQUEFIED GASES

Original Filed Oct. 21 1943

3 Sheets-Sheet 1

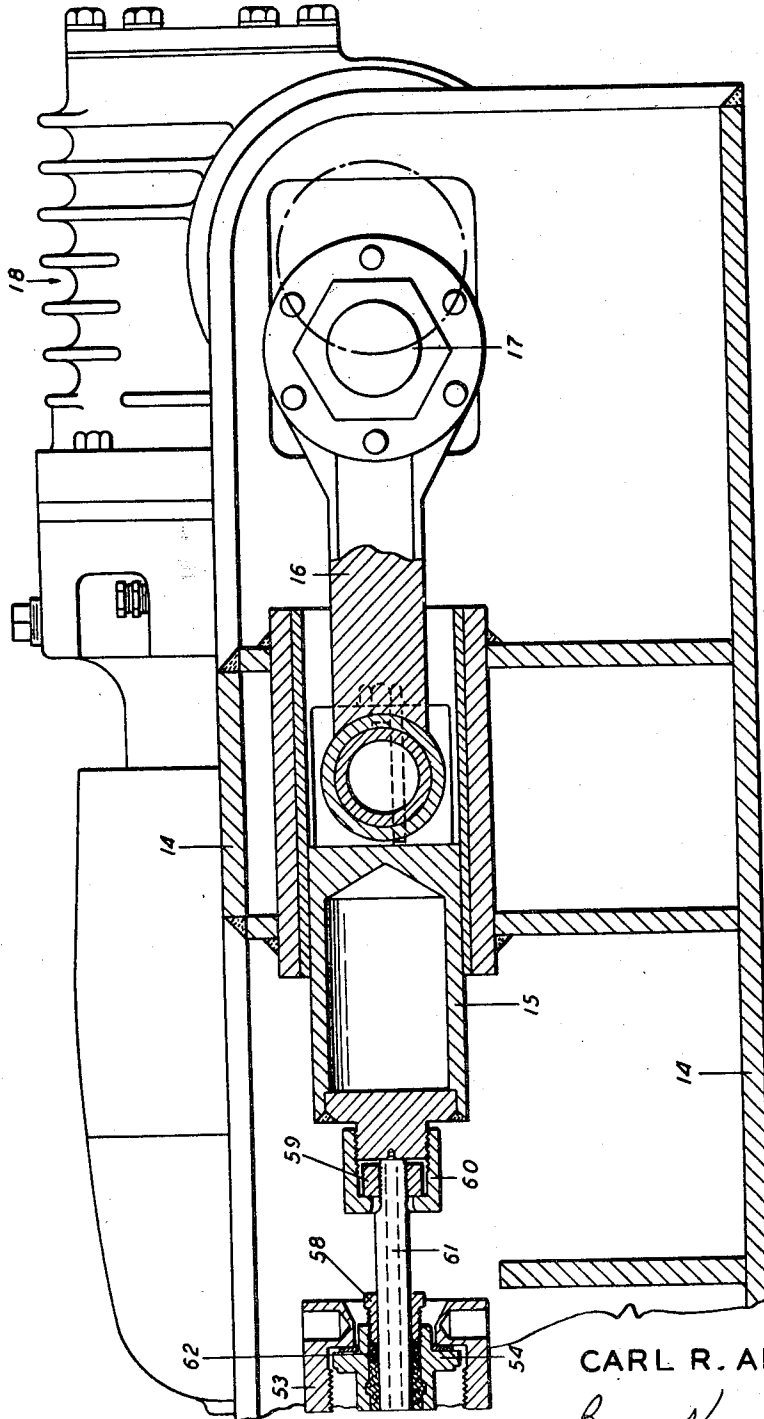


FIG. 1-A

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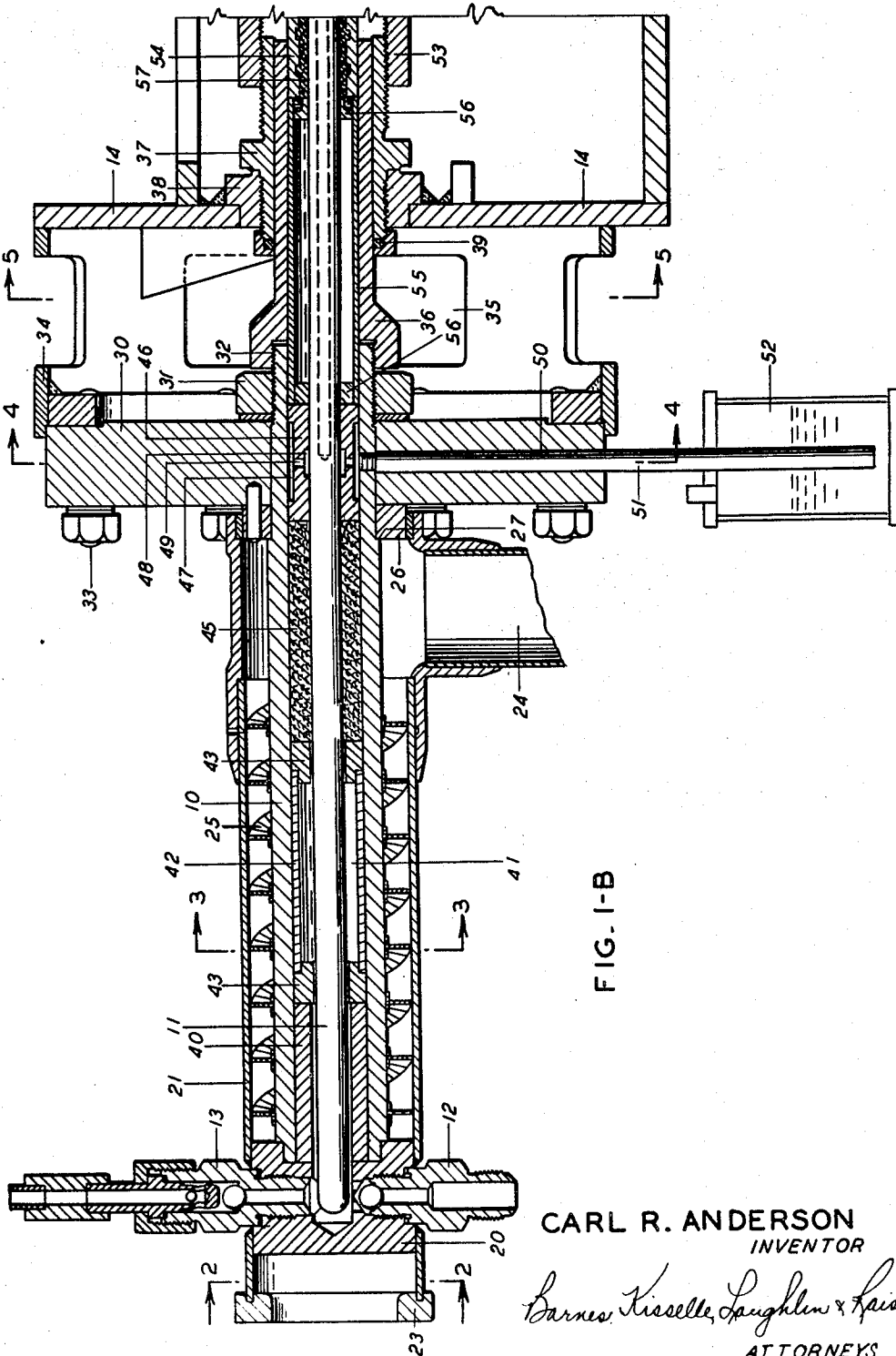
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Original Filed Oct. 21, 1943. 3 Sheets-Sheet 3

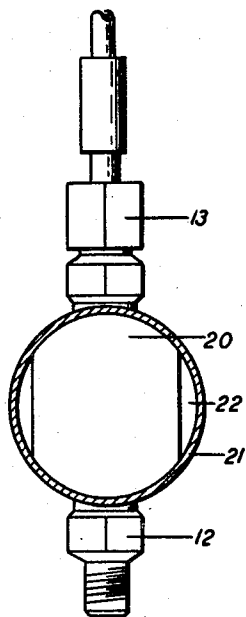


FIG. 2

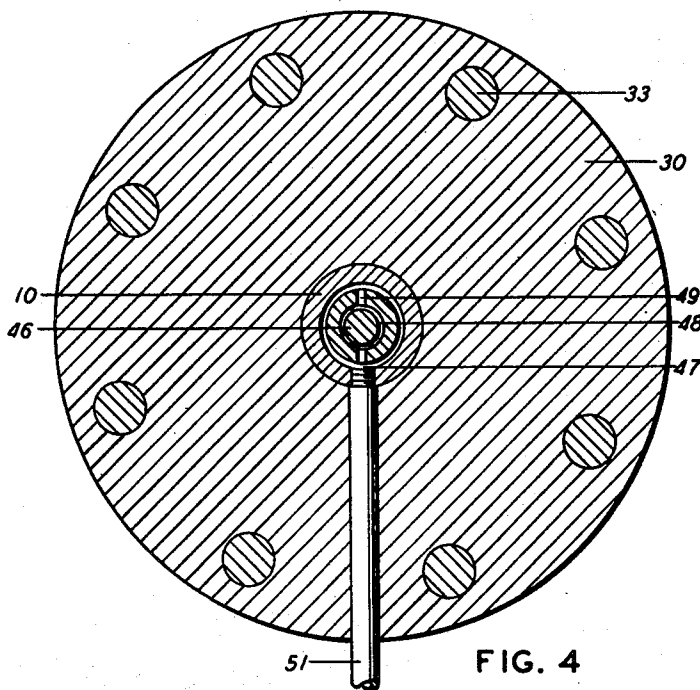


FIG. 4

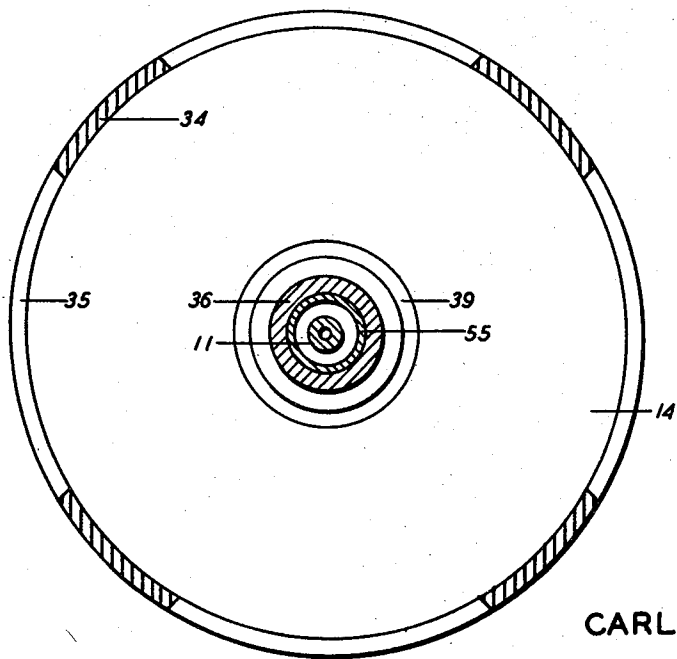


FIG. 5

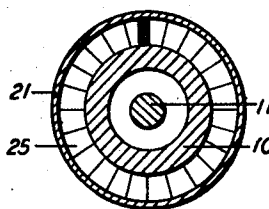


FIG. 3

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PUMP FOR LIQUEFIED GASES

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Original application October 21, 1943, Serial No.
507,091. Divided and this application August
10, 1944, Serial No. 548,846

11 Claims. (Cl. 103-1)

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This invention relates to a pump for liquefied gases.

This invention relates to apparatus for pumping liquefied gases, as for example liquid air or liquid oxygen, in the liquid condition.

In the preparation and use of certain liquids having extremely low boiling points at atmospheric pressure it is often highly economical and desirable to transfer them from one point to another in the liquid rather than in the gaseous condition.

For example, it is now common practice to store liquefied natural gas in large quantities, at or near atmospheric pressure, in heavily insulated tanks. Such liquefied gases have, on occasion, to be transferred at a controlled rate to a vaporizer wherein they are vaporized and super-heated, under pressure, to a temperature suitable for delivery into a distribution system. The use of a suitable liquid pump, as herein described, is a simple and convenient means for effecting such transfer.

It is also common practice to store oxygen and other so-called permanent gases, in the liquefied form, to transport the liquid through pipe lines, and to bring it back to the gaseous condition at the point at which it is to be used or placed in pressure cylinders for final distribution. In such cases the stored liquefied gas is usually at or near atmospheric pressure while the conditions of use or distribution may require that the gasefied liquid be at a very high pressure, often up to or over 2500 pounds per square inch. In such service it is extremely desirable to apply the finally required pressure to the liquid rather than to a gaseous stream, as both the cost of power and the weight of apparatus required in the former case are small fractions of the corresponding figures in the latter.

In pumping liquids which, at normal atmospheric pressure, boil at temperatures ranging from 50° to 190° below centigrade zero, great difficulty is experienced in keeping a pump in operation. At these extremely low temperatures the heat head between the atmosphere and the liquid stream is so great that even the best of insulation becomes relatively ineffective. In consequence, some atmospheric heat leaks into the liquid on the suction side of the pump and, as the liquid is usually just at its boiling point, any input of heat causes the evolution of gas, which has its usual effect of reducing the effective stroke length and finally of locking the pump.

Again, when pumping against considerable back pressure, the liquid is heated somewhat by

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the very act of increasing its pressure and any such liquid leaking back past the discharge valve, into the pump cylinder, may partially vaporize under intake stroke conditions, contributing to vapor lock.

Further, the actuating end of the pump, the end to which power is applied, is almost necessarily in contact with the atmosphere and at a temperature much higher than that of the liquefied gas, the metallic structure of the pump thus transmitting atmospheric heat to the stream being pumped.

Finally, because of the impossibility of lubricating the plunger packing adequately, more or less heat is produced by rod friction and added to the atmospheric heat tending to raise the temperature of the stream at the suction end of the pump.

One remedy for these difficulties is found in cooling the liquid stream below its boiling point at the pressure existing in the pump cylinder during the suction stroke, as described and claimed in my copending application Serial No. 488,650, filed May 27, 1943. Another step to the same end is to provide a pumping means in which the transfer of either atmospheric or frictional heat, by or through the pumping apparatus to the liquid, is reduced to the lowest possible amount. The present invention is directed to the provision of such a pumping means.

The invention in its preferred form is illustrated in the attached drawings and the following description thereof, in which:

Figs. 1—A and 1—B, taken together, show a longitudinal section through the complete assembly: in these figures the left end of Fig. 1—A mates with the right end of Fig. 1—B to show the complete pump.

Fig. 2 is a section taken on the line 2—2 of Fig. 1, showing the cooling gas inlet in section and the pumping cylinder head in elevation.

Fig. 3 is a section through the pumping cylinder as on the line 3—3 of Fig. 1.

Fig. 4 is a section through a thermal break, lantern ring and leak tester, as shown on the line 4—4 of Fig. 1, and

Fig. 5 is a section through a frame extension and a thermal break, as on the line 5—5 of Fig. 1.

Referring to the drawings, the pump illustrated is of the single acting plunger type, the main working parts being a pump cylinder 10, a plunger 11 reciprocating therein, inlet and discharge valves 12 and 13, a frame 14, a crosshead 15, a connecting rod 16, a crank 17 and any suitable type of prime mover indicated at 18.

As the types of prime mover and reducing gear by which power is applied are immaterial to the invention they are not shown in detail. The valve arrangements illustrated are such as would be suitable in a pump horizontally disposed and would be somewhat modified if a vertical arrangement were preferred.

A head block 20 is fitted to the end of cylinder 10 and non-leakably attached to the cylinder wall. A sleeve 21 is passed over the head block (which is relieved as at 22, Fig. 2) to provide passage for a cooling gas and carries a flange 23 at its outer end. The sleeve has a side outlet 24 for the cooling gas. Between the cylinder and the sleeve is placed a spiral baffle 25 to cause the gas to take a circuitous course around the cylinder and, by increasing its velocity, to increase the rate of heat transfer. This baffle is heat-conductively attached to the exterior of the cylinder wall, thus providing an extended heat absorbing and transfer surface. At its inner end the sleeve is made fast to a metallic ring 26 seated against a shoulder 27 on the outer face of the cylinder.

The assembly above described, consisting of elements 21 to 27 inclusive, forms a jacket for effectively insulating the cylinder against inflow of atmospheric heat. It is optional and may be omitted if no supply of cooling gas is available, some other form of insulation being substituted in that case.

Against sleeve ring 26 and fitting the smaller external diameter of the cylinder is placed a thick and relatively rigid disc 30 of a material having a low order of heat conductivity, for example, about 1 B. t. u. per hour per cubic foot per degree F. or less. Material having the lowest heat conductivity coupled with sufficient strength is, of course, preferable. Suitable materials are hard rubber, Bakelite or other synthetic resins or very hard woods such as lignum vitae. Some of these materials have heat conductivities as low as $\frac{1}{16}$ B. t. u. per hour per cubic foot per degree F.

This disc is forced against the sleeve ring, which in turn bears against shoulder 27, by a nut 31, the threads engaged by this nut extending beyond it as at 32. At its outer edge the disc is fastened by bolts 33 to a metallic extension piece 34 which in turn is rigidly attached to frame 14. This extension piece is relieved as at 35 to permit access to nut 31 without dismounting the cylinder assembly.

A cylinder extension 36 of material of low heat conductivity, as above described, is screwed onto projecting threads 32 and passes through frame 14, in which it is free to move longitudinally within a sleeve 37 screwed into a collar 38 fixed in the frame 14. This sleeve serves to support and align the cylinder extension 36 while permitting the travel required by expansion and contraction of the cylinder and extension piece and which follows from temperature changes and stretch under load. It is desirable to place a packing ring 39 at the inner end of the sleeve to prevent the escape of gas through the slip joint between the cylinder extension and the sleeve.

Returning now to the end of the cylinder adjacent the valves, a working barrel 40 is permanently fixed in the end of the cylinder, the bore of this barrel being accurately centered and aligned with, and affording sufficient clearance over, plunger 11 to avoid rubbing contact. The plunger is held in alignment and centered in the bore by a guide 42 which also acts as a spacer to remove the plunger packing to a considerable dis-

tance from the working barrel and thus provide a zone of quiescence 41.

This spacer may be of any desired material capable of holding the rod in alignment and of taking the end thrust of the packing. A preferred form is that shown in Fig. 1—B, in which 42 is a tube of stainless steel or other metal or alloy of low heat conductivity and 43—43 are bushings of leaded bronze or other metal having a low coefficient of friction with the metal of the plunger. Externally the tube should have a close sliding fit within the cylinder while the bore of each bushing should have a free sliding fit on the plunger. At the end of the guide, against one of the bushings 43, is placed the main plunger packing 45, which may be of any type adapted to the liquid to be pumped. This packing should bear on the plunger as lightly as is consistent with tightness against leakage.

On top of the packing and in lieu of the usual follower is placed a lantern ring 46 having an internal circumferential channel 48, an external circumferential channel 47 and a port or ports 49 connecting these channels. A radial bore 50 through the material of the disc and a tube 51 inserted in this bore permit any liquid or gas which may pass the main packing 45 to escape to the atmosphere. The tube being externally in communication with the atmosphere, any liquid passing the packing is vaporized and, if the end of the tube be immersed in a body of liquid, as illustrated at 52, the appearance of a train of bubbles gives an instant indication of leakage which might not otherwise be observed.

If preferred, a frictionless spinner may be placed in a transparent extension of tube 51 to indicate visually the rate of gas flow, or a small gas meter may be substituted for bubbling pot 52 and the packing tightened when the leakage exceeds a permissible rate. It is not essential that the leak tester discharge to the atmosphere; on the contrary it may communicate with any vessel or conduit in which the pressure is materially below the pressure existing in the pump cylinder during the discharge stroke.

The plunger packing is tightened by means of a nut 53 threaded onto sleeve 37 and engaging a gland 54 which transmits the pressure to the lantern ring and through it to the packing, by the agency of a spacer 55. This element consists of a tube, preferably of stainless steel or other metal or alloy of low heat conductivity, provided at its ends with thrust collars 56—56.

In order to ensure that all leakage through the main packing escapes through tube 51, it is desirable that gland 54 be provided with a box for secondary packing 62, which bears against a bushing 57 locked within gland 54. Packing 62 is adjusted by a threaded gland 58. This secondary packing is further desirable as preventing the chilling of the protruding portion of plunger 11 by leakage gas and the consequent deposition of atmospheric moisture or frost at this point.

The plunger 11 is preferably formed of 18/8 stainless steel or other metal or alloy of low heat conductivity. It may also and desirably be drilled out for a portion of its length, as at 61, to reduce its cross section and its ability to transfer heat from the warm end to the cold end of the pump.

A convenient means for attaching the plunger to the crosshead 15 is shown in Fig. 1—A, in which 59 is a nut threaded onto the end of the plunger and 60 a hollow cap nut engaging the threaded end of the crosshead. This construction permits the assembly and packing of the pump with the

attaching means disconnected, so that the alignment and position of the plunger are not affected by the position of the crosshead. The connection may thus be effected subsequently to the assembling and packing operations.

The pump structure above described has material advantages over conventional plunger pumps in handling liquids of extreme volatility, which boil at very low temperatures. The more important of these advantages are found in the following elements of structure:

(1) In the provision of a cold gas jacket surrounding the working barrel of the pump, by which the direct flow of heat into the cylinder from the surrounding atmosphere is prevented.

No matter how effective a static insulation, such as that afforded by cork or wool, may be, some heat will pass through it. Where the heat head is so great as in the pumping of liquefied gases, this direct heat flow may be a highly material amount.

The cooling jacket with provision for passing a refrigerating gas through it provides dynamic insulation which may be so regulated as to absorb and carry away a part or all of the heat passing through the mass of static insulation surrounding it, according to the temperature and the flow rate of the gas stream passed through the jacket.

(2) In the insulation of the cylinder from the metal of the frame by the provision of a substantially non-conductive connecting element such as disc 20, which reduces to an insignificant value the flow of the cylinder of atmospheric heat taken up by the frame, and of heat generated by friction in the actuating mechanism, while affording a sufficiently rigid support for the cylinder.

(3) In the insulation of the cylinder from the metal of the crosshead and frame by the provision of the substantially non-conductive cylinder extension 36, which prevents heat drawn from the atmosphere or generated in the actuating mechanism from entering the cylinder by way of the packing nut and gland.

(4) In reducing the cross-sectional area of the plunger by drilling out as at 61 and by the use of a metal or alloy of low heat conductivity for the plunger.

Because of the substantial insulation of the cylinder from the warm end of the pump, the only road by which any material amount of heat may enter the cold end is along the plunger itself, therefore, this last provision reduces the heat input to the cylinder from the warm end to a very minute quantity.

The effective insulation of the warm end from the cold end of the pump not only minimizes the possibility of gasification of the liquid being pumped but also maintains the warm or actuating end at the relatively elevated temperature at which it may be lubricated properly and at which the condensation of moisture and the formation of frost on the frame and actuating elements are avoided.

(5) In the provision of a quiescent body of liquid at 41, within the cylinder and between the working barrel and the packing, together with the provision of the cooling jacket surrounding this liquid body.

Packing friction may be minimized but cannot wholly be avoided. This friction results in heat, generated within the cylinder and which may be removed only through the cylinder wall.

The provision of this relatively long and narrow jacketed space not only increases the cylinder

wall area available for the transfer of heat to the cooling gas in the jacket but also removes the point at which gas may be evolved during the suction stroke to a long distance from the working barrel and the valves.

Heat produced by packing friction is transmitted to the annular column of liquid surrounding the plunger from that portion of the length of the plunger which reciprocates into and out of the packing. The plunger is made from a metal having low heat conductivity, such, e. g., as stainless steel, so as to reduce heat flow along its length to a very small factor. During the suction stroke the pressure within the working barrel and on the suction valve falls to or even below atmospheric and, lacking any means of restraint, a similar reduction would occur in space 41 and the heat available in that portion of the plunger adjacent the packing would tend to cause evolution of gas within this space and correspondingly to reduce the amount of liquid drawn into the working barrel.

In the structure shown, as the guide bushings 43 are closely fitted to the plunger, only a minute quantity of liquid may be displaced out of zone 41 during the limited duration of the suction stroke and the liquid in this zone is maintained constantly at a pressure materially above that reached in the working barrel during the suction stroke and at a pressure at which the evolution of gas and the consequent short-stroking of the pump are substantially or, in most cases, wholly avoided.

The concomitant use of the cooling jacket is essential to the above function as the heat produced by packing friction must be withdrawn at the same rate as that at which it is generated. The provision of the quiescent liquid body, restrained from rapid flow into the working barrel, permits this heat to be withdrawn at a higher temperature level and therefore at a more rapid rate.

(6) In the interposition of the spacer 55, of low heat conductivity, between the main packing 45 and the gland 54, by which the portion of the plunger in contact with the liquid being pumped is removed to a considerable distance from the portion of the plunger which comes into contact with the atmosphere.

(7) In the provision of lantern ring 46 and an outlet 50 for the escape of packing leakage, together with the use of secondary packing 62. This is not merely a convenient means for momentarily ascertaining the condition of the plunger packing but, and of much greater import, it is a means for reducing packing friction by permitting a relatively light adjustment of the main packing.

In a pump of this type, having a rod-like plunger, packing leakage may be reduced to very low terms by a relatively light compression of a suitable soft packing, but to eliminate leakage entirely requires much greater compression and involves correspondingly increased friction and heat evolution.

Packing leakage of these extremely volatile liquids comes to a very low temperature on reduction to atmospheric pressure and, if permitted to follow the plunger through the main packing nut, will cool the plunger to such extent that it becomes coated with ice. This may readily accumulate to the point at which the operation of the pump is interrupted, but even in milder cases the ice glaze becomes roughened and is extremely destructive to packing.

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It therefore becomes necessary, in the use of the conventional packing arrangements, to operate with the packing tight enough to avoid leakage completely, not to save an immaterial loss of gas but rather to prevent the icing of the plunger. Cooling of the plunger even to the point at which atmospheric moisture is deposited but not frozen is objectionable, as such deposited moisture is carried back into the gland and later, during periods of pump shut-down, when packing friction is absent, the part of the plunger within the gland may become cold enough to freeze this moisture, thus effectively uniting the plunger and the gland.

In detouring the leakage out of the structure through the lantern ring and vent, and in separating the lantern ring from the secondary packing by spacer 55, that portion of the plunger which works within the main packing and which is cold is kept entirely away from contact with the atmosphere and consequently free from any possibility of ice accumulation, while that portion of the plunger reciprocating within the secondary packing is maintained at or close to atmospheric temperature and consequently free from any tendency to condense moisture from the air.

(8) In the provision of a slip joint between cylinder extension 36 and alignment sleeve 37. The use of materials of very low heat conductivity in the cylinder extension and in disc 30 is one of the most important features of the invention. These materials, however, are deficient in rigidity and the disc in particular will deflect appreciably unless made so massive that a material part of its insulating value is lost. The provision of the slip joint absorbs all longitudinal movements due to deflection of the disc and to endwise expansion of the cylinder extension under high-pressure pumping stresses and thus permits the use of the minimum mass of Bakelite or its equivalent consistent with maintenance of alignment of cylinder extension, cylinder and plunger.

Pumps constructed according to the principles above set forth have proven in practice to be completely dependable and have operated over extended periods without icing, short-stroking or gas-locking and without mechanical trouble of any character.

From the above it will be seen that the pump herein shown and described is admirably suited for the pumping of liquid oxygen in accordance with the method described in my copending application Serial No. 488,650, filed May 27, 1943. In using my pump in the apparatus shown in my copending application, the pump would preferably be refrigerated by the gaseous product nitrogen from the fractionating tower or column.

This application is a division of application Serial No. 507,091, filed October 21, 1943.

I claim:

1. In combination with a pump having a cylinder, a plunger reciprocating therein and packing surrounding said plunger within said cylinder: means for supplying said cylinder with a liquefied gas having an atmospheric pressure boiling point materially below atmospheric temperature; a lantern ring within said cylinder on the low pressure side of said packing; means communicating with said packing for converting liquid leaking through said packing to the form of an invisible gas, and means communicating with last said means for rendering a flow of said invisible gas visually evident.

2. In a pump for highly volatile liquids com-

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prising a cylinder, a plunger reciprocating therein, plunger actuating means and a block of solid, heat-insulating material mounted on said cylinder and positioning said actuating means; a high pressure packing surrounding said plunger; a low pressure packing surrounding said plunger on the low pressure side of said high pressure packing; a lantern ring located between said high pressure and low pressure packings and within said block, and a vent through said block communicating with the void space of said lantern ring.

3. In a pump for liquefied gases comprising a cylinder located in a cold zone, a plunger reciprocating therein and extending outwardly from said cylinder into a relatively warm zone, and packing surrounding said plunger: means for preventing the chilling of the outer extremity of said plunger by fluid leaking past said packing including an enclosure around a portion of the length of said plunger exceeding the plunger stroke, and a conduit arranged to direct said fluid away from said enclosure at a point closely adjacent said packing.

4. In a pump for pumping liquefied gases at low subatmospheric temperatures, said pump comprising a cylinder, a packing nut and a plunger reciprocating within said cylinder and extending outwardly through said packing nut into a zone of substantially atmospheric temperature: packing surrounding said plunger and adapted to be compressed by said packing nut, means for confining fluid leaking past said packing, and means for directing said leakage fluid away from said plunger at a point closely adjacent said packing, whereby chilling of the outwardly extending portion of said plunger is materially reduced.

5. In a pump for pumping liquefied gases at low subatmospheric temperatures, said pump comprising a cylinder and a plunger reciprocating therein and extending outwardly from said cylinder into a zone warmer than said liquid, primary packing surrounding said plunger: means defining an elongated confined space surrounding said plunger and extending outwardly from the low pressure side of said packing to a distance exceeding the stroke of said plunger, said defining means including secondary packing closing said space at the end opposite said primary packing, a vent for leakage fluid communicating with said space at a point adjacent said primary packing and means for maintaining a static body of gas in said confined space between said vent and said secondary packing.

6. In a pump having a cylinder of uniform diameter supplied with a liquefied gas and operating at a low sub-atmospheric temperature and a plunger reciprocating in said cylinder and extending into a warm zone and into contact with the ambient atmosphere; means for minimizing the deposition of atmospheric moisture on the outer end of said plunger comprising: primary plunger packing located at a medial point in the length of said cylinder; secondary plunger packing located at the end of said cylinder and spaced from said primary packing by a distance exceeding the maximum stroke of said plunger; a leakage vent from said cylinder to the atmosphere at a point closely adjacent said primary packing and on the low pressure side thereof; independently operable elements mounted in concentric relation on the warm end of said cylinder for adjusting the pressures applied to said primary and said secondary packings.

7. In a pump adapted to the pumping of liquefied gases: a cylinder having suction and discharge valves; a plunger reciprocating in said cylinder and packing surrounding said plunger, said plunger being hollow in its outwardly extending portion; a cylinder extension shielding said outwardly extending portion from contact with the atmosphere, and a vent for fluids leaking past said packing, said vent being located adjacent said packing and on the low pressure side thereof.

8. In a pump for liquefied gases having a cold end including a pumping cylinder and plunger packing, a warm end including plunger-actuating means, and a metallic plunger extending from said cold end through said packing to said warm end: means for substantially preventing the deposition of atmospheric moisture on the warm end of said plunger including a tube of thermally insulating material projected from said cylinder beyond said packing and toward said warm end, said tube being radially spaced from said plunger and shielding said plunger from contact with the atmosphere.

9. In a pump for liquefied gases having a cold end including a pumping cylinder and plunger packing, a warm end including plunger-actuating means, and a metallic plunger extending through said packing from said cold end to said warm end: means for substantially preventing the deposition of atmospheric moisture on the warm end of said plunger including an extension of said cylinder projected for a material distance beyond said packing toward said actuating means and in radially spaced relation to said plunger; a stationary closure at the warm end of said extension through which said plunger passes, said extension and closure shielding said plunger from contact with the atmosphere, and means for directing packing leakage away from said plunger at the cold end of said cylinder extension.

10. In a pump for liquefied gases having a cold end including a pumping cylinder and a high pressure plunger packing, a warm end including plunger actuating means, and a reciprocating plunger extending from said cold end through said packing to said warm end: means for substantially preventing the deposition of atmospheric moisture on the warm end of said plunger including a tube of thermally insulating material projected from said cylinder beyond said packing and toward said warm end, said tube being radially spaced from said plunger and shielding

said plunger from contact with the atmosphere, a low pressure packing surrounding said plunger adjacent the warm end of the above said tube, a lantern ring surrounding said plunger and located between said high pressure and low pressure packings and vented to atmosphere, said lantern ring having one end in contact with said high pressure packing, a spacer tube telescoped within the above said tube radially spaced from said plunger and having one end in contact with the other end of said lantern ring, and means for applying pressure to the end of said spacer tube whereby the spacer tube transmits the pressure to the lantern ring which in turn transmits the pressure to the high pressure packing to tighten the same.

11. In a pump for liquefied gases having a cold end including a pumping cylinder and a warm end including plunger-actuating means: a plunger extending from said cylinder to said actuating means, said plunger being formed of metal of low heat conductivity and of reduced cross-sectional area in at least its outwardly projecting portion, whereby the flow of heat from the warm end to the cold end of said plunger and the deposition of atmospheric moisture on said warm end are materially reduced.

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