

April 20, 1948.

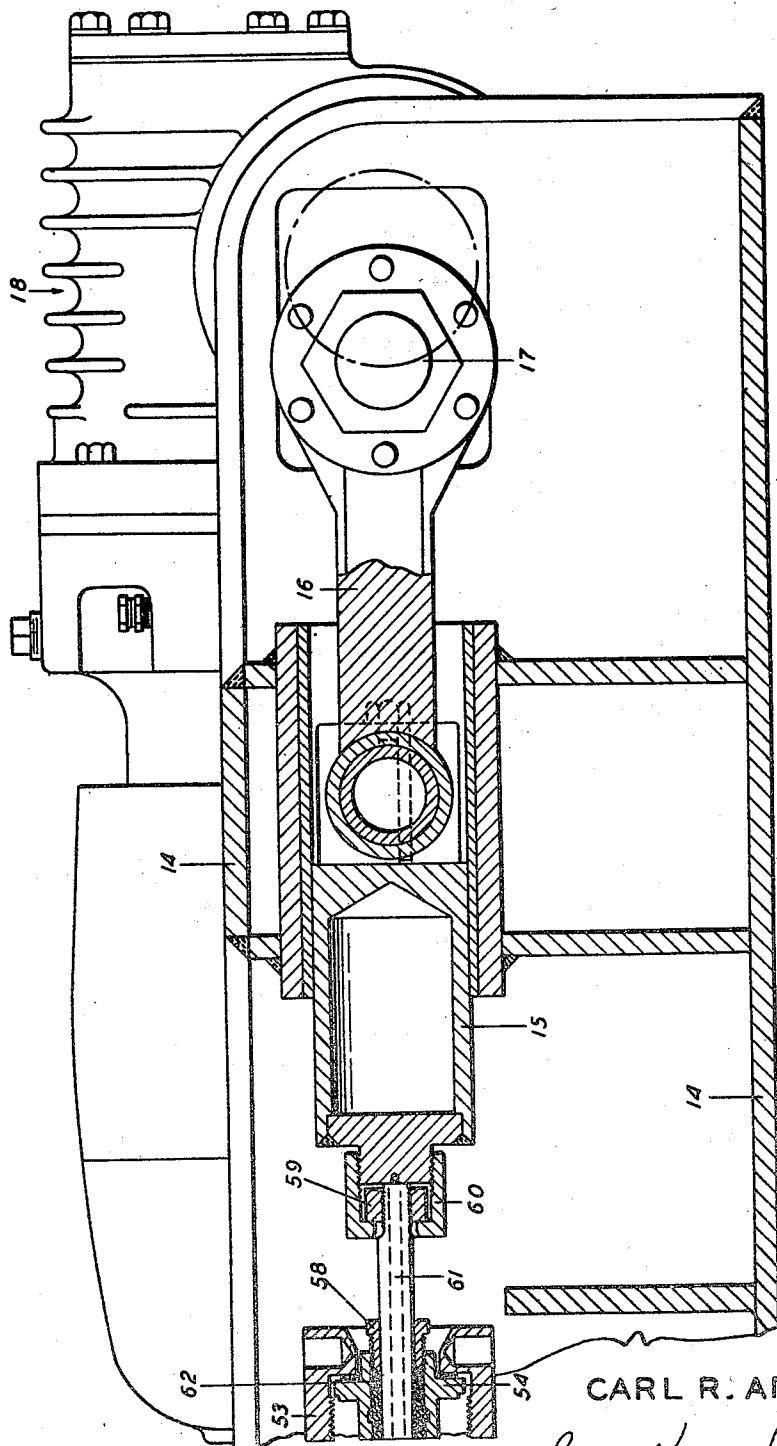
C. R. ANDERSON

2,439,957

PUMP FOR LIQUEFIED GASES

Filed Oct. 21, 1943

3 Sheets-Sheet 1



CARL R. ANDERSON
INVENTOR

Barnes, Kisselle, Laughlin & Faisel
ATTORNEYS.

April 20, 1948.

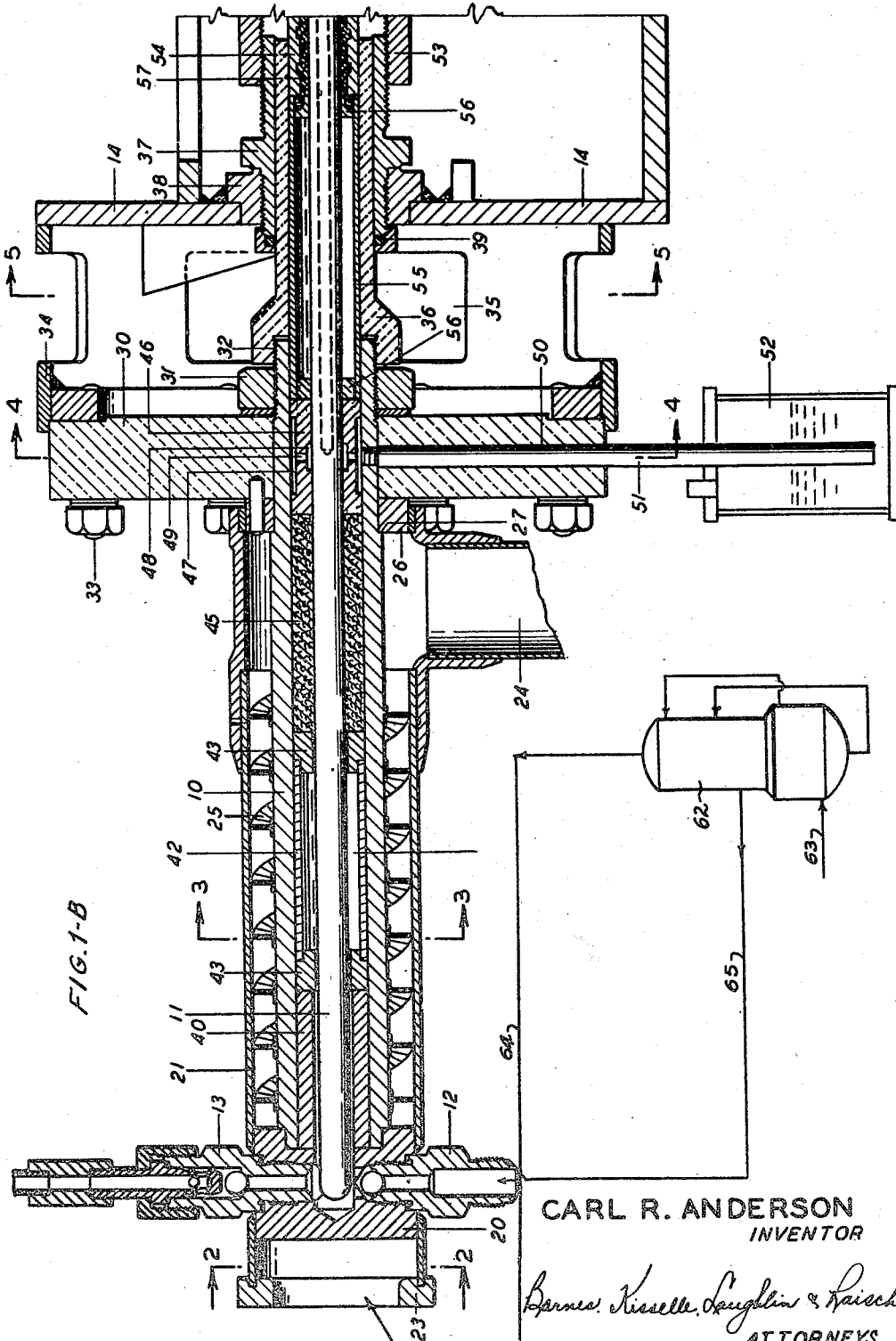
C. R. ANDERSON

2,439,957

PUMP FOR LIQUEFIED GASES

Filed Oct. 21, 1943

3 Sheets-Sheet 2



April 20, 1948.

C. R. ANDERSON

2,439,957

PUMP FOR LIQUEFIED GASES

Filed Oct. 21, 1943

3 Sheets-Sheet 3

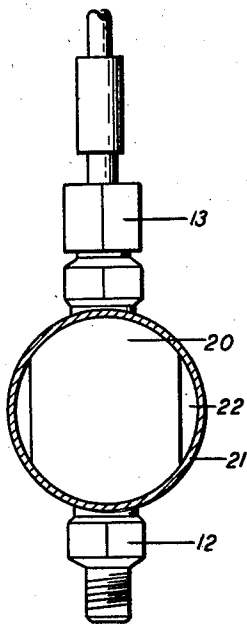


FIG. 2

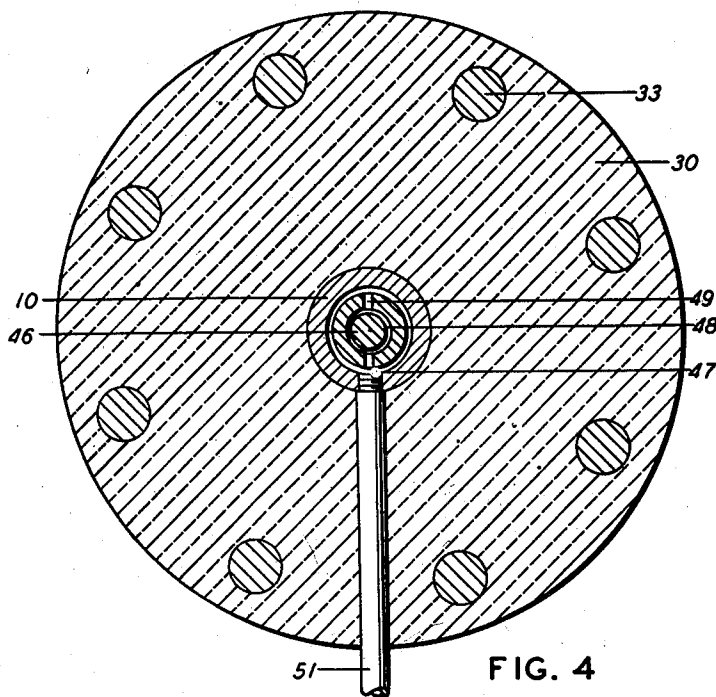


FIG. 4

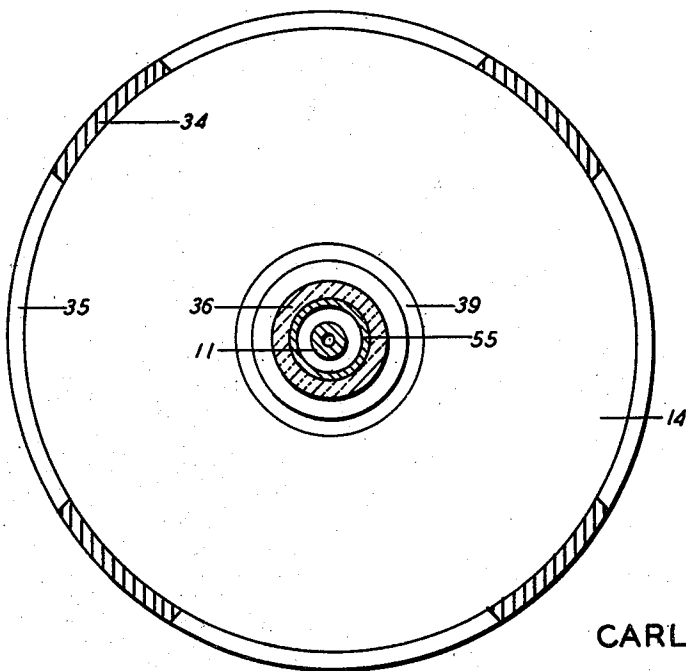


FIG. 5

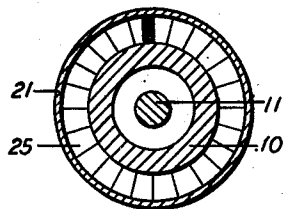


FIG. 3

CARL R. ANDERSON
INVENTOR

Barnes, Kusselle, Laughlin & Kirsch
ATTORNEYS

UNITED STATES PATENT OFFICE

2,439,957

PUMP FOR LIQUEFIED GASES

Carl R. Anderson, Detroit, Mich., assignor to Air Products Incorporated, Detroit, Mich., a corporation of Michigan

Application October 21, 1943, Serial No. 507,091

50 Claims. (Cl. 103—1)

1

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 superheated, 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 gasified 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

2

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

3

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-

4

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

5

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 30, which reduces to an insignificant value the flow to 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

6

der 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.

7

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.

A suitable source of supply of refrigerating fluid is illustrated in Fig. 1—B in which 62 may be any air fractionating column, supplied at 63 with compressed refrigerated air and delivering at least a part of its final product of gaseous nitrogen through conduit 64 to the cooling gas passage terminating at flange 23. The liquid oxygen produced by the column may flow through conduit 65 to the intake valve 12 of the pump.

I claim:

1. In a pump for highly volatile liquids comprising intake and discharge valves, a cylinder and a plunger reciprocating therein, the diameter of said plunger being materially less than the internal diameter of said cylinder, and packing surrounding said plunger within said cylinder: a working barrel fixed in said cylinder adjacent said valves; means for widely spacing said pack-

8

ing from said working barrel to provide a longitudinally extended annular open space between said plunger and said cylinder; means for restricting the flow of liquid between said working barrel and said annular space, and means for refrigerating at least the portion of said cylinder surrounding said annular space.

2. Apparatus substantially as in claim 1, in which said refrigerating means consists of a source of supply of gas at low subatmospheric temperature, a jacket surrounding said cylinder and means for passing said cold gas through said jacket.

3. In a reciprocating plunger pump for highly volatile liquids: means for removing heat generated by friction between said plunger and its packing, comprising, a body of liquid; means for maintaining said liquid body in substantial immobility within the cylinder of said pump in such position as to contact the surface of the plunger as it emerges from the packing during the pumping stroke; a jacket surrounding the pump cylinder adjacent the part of said cylinder enclosing said liquid body, and means for passing a stream of refrigerant through said jacket.

4. In a pump for pumping liquids at low sub-atmospheric temperatures, said pump comprising a cylinder, a plunger reciprocating therein and extending outwardly into a zone of substantially atmospheric temperature, packing between said cylinder and said plunger: a confined, substantially quiescent, insulating body of gas evolved from the liquid being pumped, said body surrounding said plunger outwardly of said packing, and means for maintaining said gas body at a pressure below the maximum pressure existing in said cylinder.

5. In a pump for highly volatile liquids, comprising intake and discharge valves, a cylinder and a plunger reciprocating therein, the diameter of said plunger being uniform throughout its working length and being materially less than the internal diameter of said cylinder, and packing surrounding said plunger within said cylinder: a working barrel fixed in said cylinder adjacent said valves, and means for widely spacing said packing from said working barrel to provide a relatively long and narrow, substantially sealed annular space of unvarying length between said plunger and said cylinder and between said packing and said working barrel.

6. In a pump for highly volatile liquids, comprising intake and discharge valves, a cylinder and a plunger reciprocating therein, the diameter of said plunger being materially less than the internal diameter of said cylinder, and packing surrounding said plunger within said cylinder: a working barrel fixed in said cylinder adjacent said valves, the bore of said barrel slightly exceeding the diameter of said plunger; and means for widely spacing said packing from said working barrel to provide a longitudinally extended annular space, said means including a tube within said cylinder and a guide ring affixed to each end of said tube, the guide ring adjacent said working barrel being so formed as to leave only a minute opening for the passage of pumped liquid out of and into said space.

7. In a pump for highly volatile liquids comprising a cylinder and a plunger reciprocating therein, a working barrel and valves fixed in said cylinder adjacent one end thereof and plunger packing located in said cylinder toward the other end thereof: means for restricting the flow of heat from said packing to said barrel, comprising,

a body of the liquid being pumped, and means for maintaining said liquid body in relative immobility intermediate said packing and said barrel.

8. In a reciprocating plunger pump for highly volatile liquids: means for isolating the plunger packing from thermal contact with the stream of liquid being pumped comprising a constant-volume body of liquid identical in composition with the liquid being pumped, and means for maintaining said liquid in substantial immobility within the cylinder of said pump and intermediate said packing and said stream of liquid.

9. A pump for highly volatile liquids comprising a working barrel, a plunger reciprocating therein, a plunger packing surrounding said plunger and spaced from said working barrel, a chamber surrounding said plunger and positioned between the working barrel and said packing, a body of the liquid being pumped in said chamber, and a restricted communication between the said chamber and the working barrel whereby the body of liquid in said chamber is maintained relatively immobile, said body of liquid serving to restrict the flow of heat from said packing to said barrel.

10. A pump for highly volatile liquids comprising a cylinder, a working barrel located in said cylinder adjacent one end thereof and plunger packing located in said cylinder toward the other end thereof and spaced from said working barrel, a plunger reciprocating in said working barrel and packing, said plunger having a smaller outside diameter than the inside diameter of said cylinder, a chamber within said cylinder and located between the working barrel and the packing, spacing means in said chamber for maintaining said packing in spaced relation with said working barrel, a restricted communication between the inside of said working barrel and said chamber whereby a body of the liquid being pumped is maintained relatively immobile in said chamber and said body of liquid acts to restrict the flow of heat from said packing to said barrel.

11. A pump for highly volatile liquids comprising a cylinder, a working barrel located in said cylinder adjacent one end thereof and plunger packing located in said cylinder toward the other end thereof and spaced from said working barrel, a plunger reciprocating in said working barrel and packing, said plunger having a smaller outside diameter than the inside diameter of said cylinder, a chamber within said cylinder and located between the working barrel and the packing, guide bushings having a close sliding fit with said plunger and positioned at opposite ends of said chamber whereby a body of the liquid being pumped is established in said chamber and maintained relatively immobile, said body of liquid serving to restrict the flow of heat from said packing to said barrel.

12. In combination with a reciprocating pump having a plunger and handling a liquid at a temperature near its boiling point at the minimum pressure occurring within the pump chamber during the pumping cycle, means for avoiding vapor-lock, comprising: means for maintaining a body of the pumped liquid surrounding and in contact with a portion of the length of said plunger exterior to said pump chamber, and means for cooling said liquid body by heat interchange against a stream of fluid colder than the liquid in said body.

13. In combination with a pump having a packed reciprocating plunger, means for reducing

the amount of frictional packing heat imparted to the stream of pumped liquid, comprising: means for maintaining a substantially static body of the pumped liquid surrounding and in contact with that portion of the plunger which reciprocates into and out of the packing, and means for continuously withdrawing from said liquid body heat transmitted thereto from said plunger, whereby said transmitted heat is substantially excluded from said pumped stream.

14. In combination with a reciprocating plunger pump handling liquid oxygen, means for preventing vapor-lock, comprising: means for maintaining a substantially static body of liquid oxygen surrounding and in contact with a portion of the length of said plunger, and means for cooling said liquid body by heat interchange against a colder stream of a vapor rich in nitrogen.

15. In combination with a reciprocating plunger pump handling liquid oxygen at a temperature near its boiling point at the minimum pressure occurring within the pump chamber during the pumping cycle, means for preventing vapor-lock, comprising: means for maintaining a substantially static body of liquid oxygen surrounding and in contact with a portion of the length of said plunger, and means for cooling said liquid body by heat interchange against a colder stream of a vapor rich in nitrogen.

16. In combination with a pump adapted to the pumping of a stream of volatile liquid at a relatively low temperature and having a reciprocating plunger of which one end is immersed in said stream and the other end extends into a zone of relatively high temperature: means for cooling said plunger and thereby retarding heat flow into said pumped stream, said cooling means comprising a substantially static body of the pumped liquid interposed between said pumped stream and said zone of high temperature, and a cooling medium in heat exchange relation with said substantially static body.

17. In a pump for volatile liquids having a pumping chamber, plunger packing and a plunger reciprocating within said chamber and said packing: a substantially static body of liquid bathing said plunger between said chamber and said packing, and means for withdrawing heat from said body of liquid.

18. In combination with a reciprocating pump having a plunger and plunger packing and adapted to handle liquefied gases, means for cooling said plunger, comprising: a jacket surrounding the cylinder of said pump; means for passing a relatively cold fluid through said jacket, and a spacing element interposed between the plunger packing and the working barrel of said pump to provide a liquid-retaining space around said plunger, said space being in sufficient communication with the working barrel of said pump to cause said space to remain constantly filled with the liquid being pumped, said liquid transmitting heat from said plunger to the wall of said cylinder and thence to said cold fluid.

19. A pump for liquefied gases comprising a working barrel; a plunger of less diameter than said barrel reciprocating therein; a packing element surrounding said plunger, and means for removing heat from said plunger, said means comprising: a jacket surrounding the pumping end of said pump; means for passing a relatively cold gas continuously through said jacket, and means interposed between said working barrel and said packing to form an enclosure of space around said plunger, said space being in sufficient

communication with said working barrel to permit passage of the pumped liquid therinto.

20. In a pump for highly volatile liquids having a pumping cylinder: means for supplying said cylinder with a liquid boiling at low subatmospheric temperature; a source of supply of a refrigerating medium at a temperature below the boiling point of said liquid; a substantially tubular jacket surrounding and spaced from said cylinder; means for passing said refrigerating medium through said jacket, and a helical baffle within said jacket for directing said medium circuitously and at enhanced velocity around the exterior of said cylinder.

21. In a pump for highly volatile liquids having a pumping cylinder: means for supplying said cylinder with a liquid boiling at low subatmospheric temperature; a source of supply of a refrigerating medium at a temperature below the boiling point of said liquid; a jacket surrounding and spaced from said cylinder; means for passing said refrigerating medium through said jacket, and a fin-like baffle heat-conductively attached to the wall of said cylinder and projected into said jacket.

22. In a pump for highly volatile liquids having a cylinder and a plunger separated by an annular space and means for maintaining a substantially static body of the pumped liquid within said space; means for excluding atmospheric heat from said liquid body comprising a jacket surrounding and spaced from said cylinder; a source of supply of a gaseous refrigerant at a temperature below the boiling point of the pumped liquid, and means for passing said refrigerant through said jacket.

23. In a pump for highly volatile liquids having a cylinder and a plunger separated by an annular space and means for maintaining a body of the pumped liquid within said space: means for excluding atmospheric heat from said liquid body comprising a jacket surrounding and spaced from said cylinder; a source of supply of a gaseous refrigerant at a temperature below the boiling point of the pumped liquid; means for passing said refrigerant through said jacket at high velocity, and baffling means within said jacket for enhancing the withdrawal of heat from said jacket by said refrigerant.

24. In a reciprocating pump having a plunger and handling a liquefied gas, means for avoiding vapor-lock, comprising: means for maintaining a body of the pumped liquid surrounding and in contact with a portion of the length of said plunger, and means for cooling said liquid body by heat interchange against a stream of fluid colder than the liquid in said body.

25. In combination with a pump having a packed reciprocating plunger, means for reducing the amount of frictional packing heat imparted to the stream of pumped liquid, comprising: means for maintaining a body of liquid oxygen surrounding and in contact with that portion of the plunger which reciprocates into and out of said packing, said body of liquid oxygen being substantially segregated from the stream of pumped liquid, and means for continuously withdrawing from said body of liquid heat transmitted thereto by said plunger, by heat interchange against a stream of a colder vapor rich in nitrogen.

26. In combination with a pump adapted to the pumping of a stream of liquid oxygen at a relatively low temperature and having a reciprocating plunger of which one end is immersed in said stream and the other end extends into a zone of relatively high temperature; means for

cooling said plunger and for thereby retarding heat flow into said pumped stream comprising a substantially static body of liquid oxygen interposed between said pumped stream and said zone of high temperature, and a cooler stream of vapor rich in nitrogen in heat interchange relation with said substantially static liquid body.

27. In a pump for liquefied gases having a cold end including a pumping cylinder, a warm end including plunger-actuating means and a metallic plunger extending from said cold end to said warm end: means for substantially preventing the deposition of atmospheric moisture on the warm end of said plunger, comprising: thermal insulating means interposed between said actuating means and said cylinder; an extension from said cylinder toward said warm end, said extension shielding said plunger from the atmosphere and being formed of thermally insulating material; means for directing packing leakage away from said plunger including primary packing around said plunger on the cold side of said cylinder extension, secondary packing around said plunger at the warm end of said cylinder extension, a spacer of material of low heat conductivity interposed between said packings, a vent to the atmosphere between said primary packing and said spacer, and means for restricting the flow of heat along said plunger consisting in forming said plunger of metal of low heat conductivity and in reduced cross section in at least its outwardly projecting portion.

28. In a pump for liquefied gases having a cold end including a pumping cylinder, a warm end including plunger-actuating means, and a metallic plunger extending 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 a stationary body of heat-flow retarding material interposed between said actuating means and said cylinder.

29. In a pump for liquefied gases having a cold end including a pumping cylinder, a warm end including plunger-actuating means and a metallic plunger extending from said cold end to said warm end: means for substantially preventing the deposition of atmospheric moisture on the warm end of said plunger, comprising: thermal insulating means interposed between said actuating means and said cylinder; an extension from said cylinder toward said warm end, said extension shielding said plunger from the atmosphere and being formed of thermally insulating material; means for directing packing leakage away from said plunger including primary packing around said plunger on the cold side of said cylinder extension, secondary packing around said plunger at the warm end of said cylinder extension and spaced from said primary packing, a vent to the atmosphere between said primary packing and said secondary packing, and means for restricting the flow of heat along said plunger consisting in forming said plunger of metal of low heat conductivity and in reduced cross section in at least its outwardly projecting portion.

30. In a pump for highly volatile liquids comprising a pumping cylinder located in a cold zone, a plunger reciprocating therein and extending into a relatively warm zone, and a projection of said cylinder located in said warm zone: connecting means interposed between said cylinder and said projection, said connecting means being formed of material of low thermal conductivity.

31. In a liquid pump having a pumping cylinder

located in a cold zone and actuating means located in a relatively warm zone: an extension of said cylinder projected toward said actuating means and into said warm zone, said extension being formed of material of low thermal conductivity.

32. In a pump for highly volatile liquids comprising a pumping cylinder, a plunger reciprocating therein and means for actuating said plunger: means for rigidly positioning said cylinder with respect to said actuating means, said positioning means including elements having a thermal conductivity materially less than that of the metal of which the pump is composed, interposed between said cylinder and said actuating means.

33. In a pump for highly volatile liquids having a cold end comprising a pumping cylinder and a plunger reciprocating therein and a warm end comprising actuating means for said plunger and means for positioning said cylinder with respect to said actuating means: heat insulating elements having a thermal conductivity materially less than that of the material of which said positioning means is composed, interposed between said cylinder and said positioning means.

34. In a liquid pump having a pumping cylinder located in a cold zone, a plunger reciprocating therein and extending into a relatively warm zone, plunger packing, and a stuffing box and plunger packing nut located in said warm zone: a thermal insulating section operatively connecting said cylinder with said stuffing box.

35. In a pump for highly volatile liquids having a cold end comprising a pumping cylinder and a plunger reciprocating therein and a warm end comprising actuating means for said plunger: heat insulating elements so arranged between said warm end and said cold end as substantially to restrict the flow of heat from said warm end to said cold end, said insulating elements being of material substantially less heat conductive than the materials of which said actuating means are composed.

36. In a pump for highly volatile liquids comprising a pumping cylinder, a plunger reciprocating therein, actuating means for said plunger and a frame supporting said actuating means: a cylindrical metallic element projected from said frame, a disc of solid material of low heat conductivity secured to the end of said element, said disc being perforated to receive an end of said cylinder, and means on said cylinder for clamping said cylinder within said perforation.

37. In a pump for highly volatile liquids comprising a pumping cylinder, a plunger reciprocating therein, means for actuating said plunger and means for positioning said cylinder with respect to said actuating means: an extension of said cylinder toward said actuating means, said extension being formed of material of low heat conductivity and being co-axial with said cylinder.

38. In a pump for highly volatile liquids comprising a pumping cylinder, a plunger reciprocating therein, means for actuating said plunger, a frame supporting said actuating means and means for positioning said cylinder with respect to said frame: a sleeve mounted in said frame and co-axial with said cylinder, and an extension from said cylinder passing slidably through said sleeve, said extension being formed of material of low heat conductivity.

39. In a pump for highly volatile liquids comprising a pumping cylinder, a plunger reciprocating therein, packing surrounding said plunger

within said cylinder, means for actuating said plunger, a frame supporting said actuating means and means for positioning said cylinder with respect to said frame: an extension of said cylinder formed of material of low heat conductivity and passing through an opening in said frame, a sleeve mounted in said opening surrounding and aligning said extension, and means mounted on the end of said sleeve for applying pressure to said packing.

40. In a pump for highly volatile liquids having a cold end comprising a pumping cylinder and a plunger reciprocating therein and a warm end comprising actuating means for said plunger: heat insulating elements interposed between the warm end and the cold end of said pump, said elements being composed of materials having a heat conductivity not exceeding 1 B. t. u. per hour per square foot per degree F. per lineal foot.

41. In a pump for highly volatile liquids having a cold end comprising a pumping cylinder and a plunger reciprocating therein and a warm end comprising actuating means for said plunger: heat insulating means interposed between said warm end and said cold end for minimizing the flow of heat into said cold end, together with means for refrigerating said cold end.

42. In a pump for highly volatile liquids having a cold end comprising a pumping cylinder and a warm end comprising plunger-actuating means: means for restricting the flow of heat from said warm end to said cold end comprising a plunger reciprocating in said cylinder, said plunger having its cross-sectional area reduced for at least a part of its length, and thermal insulating elements interposed between said cylinder and said actuating means, said elements forming part of the means by which said actuating means is positioned with respect to said cylinder.

43. In a pump for highly volatile liquids having a cold end comprising a pumping cylinder and a warm end comprising plunger-actuating means: means for restricting the flow of heat from said warm end to said cold end comprising a plunger reciprocating in said cylinder, said plunger having its cross-sectional area reduced for a part of its length by hollowing out the outwardly extending portion thereof, and thermal insulating elements interposed between said cylinder and said actuating means, said elements forming part of the means by which said actuating means is positioned with respect to said cylinder.

44. In a pump for highly volatile liquids having a cold end comprising a pumping cylinder and a warm end comprising plunger-actuating means: means for restricting the flow of heat from said warm end to said cold end comprising a partially hollow plunger reciprocating in said cylinder and thermal insulating elements forming part of the connection between said cylinder and said actuating means.

45. In a pump for highly volatile liquids comprising a pumping cylinder, a plunger reciprocating therein, actuating means for said plunger and a frame supporting said actuating means: a projection from said frame rigidly positioning said cylinder with respect to said actuating means, and a thermally insulating element interposed in said positioning means, said element having a thermal conductivity materially less than that of the material of which the remainder of said positioning means is composed.

46. In a pump for highly volatile liquids comprising a pumping cylinder located in a cold zone, a plunger reciprocating therein and extending

15

into a relatively warm zone, packing between said cylinder and said plunger, and packing adjusting means located in said warm zone: an element operatively connecting said cylinder with said packing adjusting means, said element being formed for at least part of its length of material of low thermal conductivity.

47. In a pump for highly volatile liquids having pumping elements and actuating elements: means for restricting the flow of heat into said liquids comprising thermal insulation surrounding said pumping elements and structural elements thermally insulating said pumping elements from said actuating elements, said structural elements being of material substantially less heat conductive than the materials of which said actuating elements are composed.

48. In a liquid pump having a pumping cylinder and a plunger, packing between said cylinder and said plunger, a packing adjusting assembly spaced from said cylinder and supporting means positioning said assembly with respect to said cylinder: a longitudinally slidable connection between said cylinder and said assembly whereby relative movement may occur without placing a stress on said supporting means.

49. In a liquid pump having a pumping cylinder, a plunger, plunger packing within said cylinder, a packing adjusting assembly spaced from said cylinder and supporting means positioning said assembly with respect to said cylinder: a

16

longitudinally slidable, gas-tight, thermally insulating connection between said cylinder and said assembly, whereby relative movement may occur without placing a stress on said supporting means.

50. In combination with a pump adapted to the pumping of a stream of volatile liquid at a relatively low temperature and having a reciprocating plunger of which one end is immersed in said stream and the other end extends into a zone of relatively high temperature: means for cooling said plunger and for thereby reducing the flow of heat into said pumped stream, said cooling means being interposed between said pumped stream and said zone of high temperature and being at a temperature below that of said stream.

CARL R. ANDERSON.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
144,390	Day	Nov. 11, 1873
1,552,281	Weinman	Jan. 6, 1925
1,879,370	McAllister	Sept. 27, 1932
2,292,375	Hansen	Aug. 11, 1942
2,292,617	Dana	Aug. 11, 1942
2,330,781	Langmyhr et al.	Sept. 28, 1943

Disclaimer

2,439,957.—*Carl R. Anderson*, Detroit, Mich. PUMP FOR LIQUEFIED GASES.
Patent dated Apr. 20, 1948. Disclaimer filed Nov. 6, 1950, by the
assignee, *Air Products Incorporated*.

Hereby enters this disclaimer to claims 30, 31, 32, 33, 35, 37, and 45, inclusive.

[*Official Gazette December 5, 1950.*]