Aug. 24, 1948. W. L. DE BAUFRE 2,447,741

LIQUID OXYGEN PUMP

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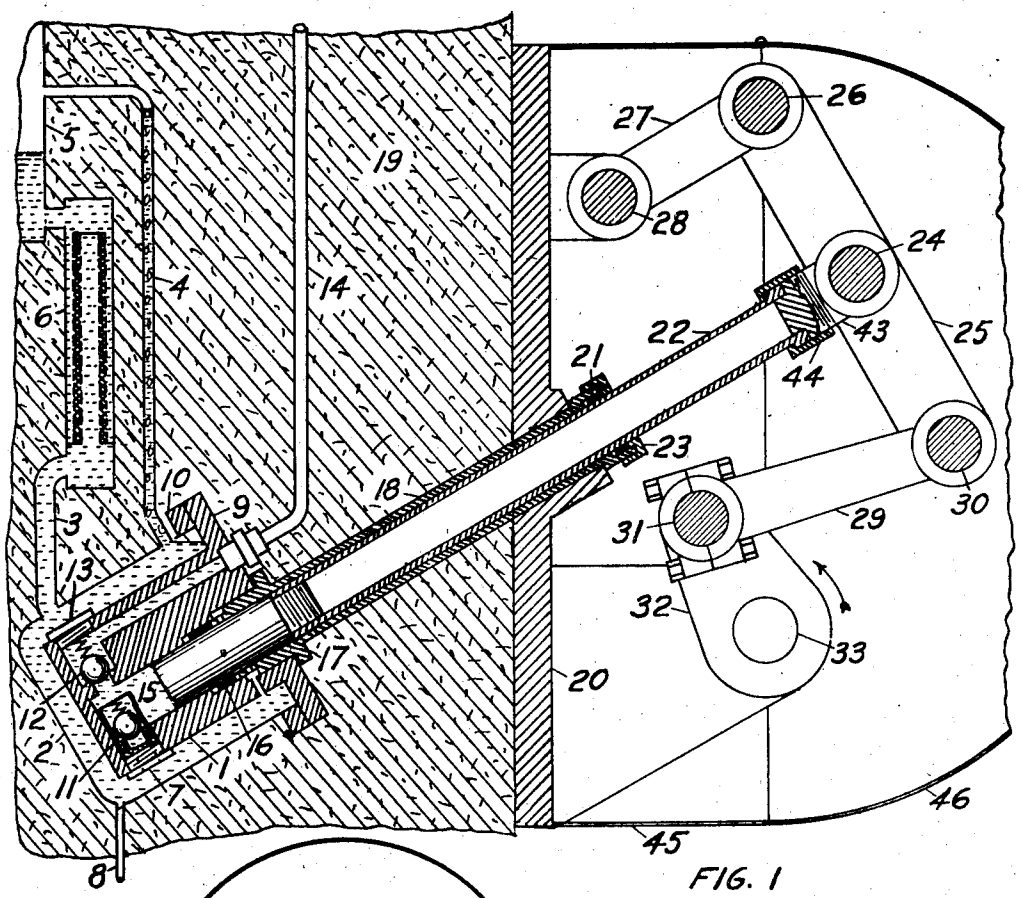


FIG. 1

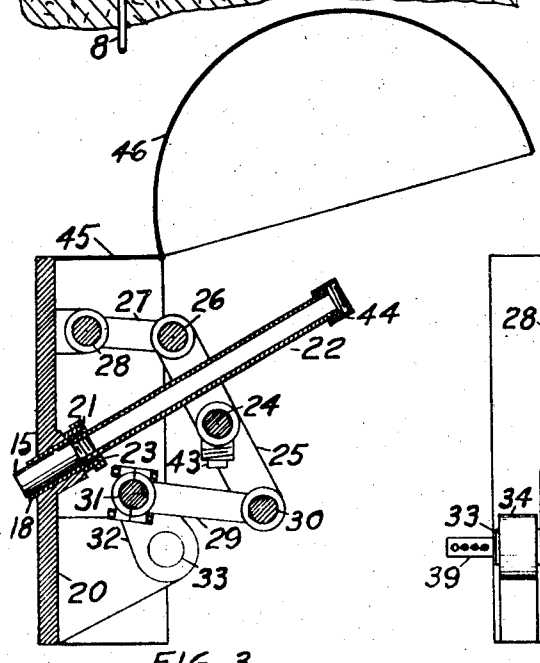
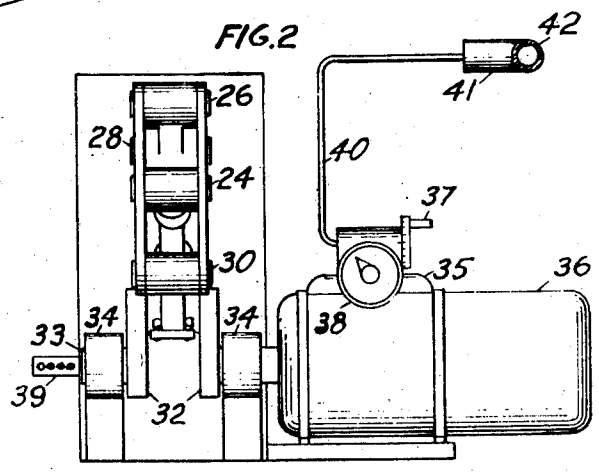


FIG. 3

FIG. 2



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LIQUID OXYGEN PUMP

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16 Claims. (Cl. 103—1)

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This invention relates to improvements in pumps for withdrawing oxygen in liquid form from rectifying columns of plants extracting oxygen from atmospheric air by liquefaction and rectification. The liquid oxygen may be discharged against high pressure such as is customary for storage of gaseous oxygen in cylinders at room temperature. For storage as gaseous oxygen, the liquid oxygen may be vaporized under the discharge pressure and warmed to room temperature "to effect cooling of warm air to be subsequently liquefied" as proposed by M. von Recklinghausen in U. S. Patent No. 1,394,955, issued in 1921.

The improved liquid oxygen pump described in this specification may also be used to increase the pressure of other liquefied gases before their vaporization by "transfer of latent heat from the gaseous fluid to the liquid whose pressure has been raised" as explained in various patents to E. A. W. Jefferies and F. E. Norton, see their U. S. Patents No. 1,264,807 and 1,264,845 issued in 1918.

Thus, the idea is not new to use a liquid oxygen pump to withdraw oxygen in liquid form from a rectifying column and return the liquid under increased pressure in heat transfer with atmospheric air to liquefy it, the liquid oxygen being vaporized and warmed to room temperature. The advantages of so doing were pointed out by von Recklinghausen. Thus, compression of the gaseous oxygen in order to store it in cylinders or tanks is eliminated, whereby great economy is affected because the work to pump liquid oxygen against a pressure difference is much less than the work to compress the same mass of gaseous oxygen between the same two pressures. Furthermore, the possibility of introducing impurities such as water into the oxygen is greatly reduced if not eliminated.

The present invention comprises improvements in the construction and operation of liquid oxygen pumps to meet satisfactorily the conditions to which such pumps are subjected. Thus, the very low temperature of liquid oxygen, below minus 119 centigrade, necessitates imbedding the cylinder of a liquid oxygen pump within thick insulation to reduce heat leak from the surroundings at room temperature into the liquid oxygen. As the pump plunger is operated by mechanism at room temperature outside the insulation, an operating rod must extend from the mechanism at room temperature through the insulation to the plunger within the cylinder at very low temperature. One object of the present invention is

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to reduce heat leak from the surroundings along the operating rod into the liquid oxygen pumped.

The operating rod extends to the plunger in the cylinder where the liquid oxygen is under high pressure and some form of packing must be used around the plunger to hold the liquid oxygen while permitting movement of the plunger. Another object of the invention is to recover any liquid oxygen leaking past the packing and to prevent loss of liquid oxygen along the operating rod.

The liquid oxygen to be pumped may contain impurities such as solidified carbon dioxide which would adversely affect operation of the pump. A further object of the invention is to reduce or eliminate such impurities.

A liquid oxygen pump might fail to operate by becoming vapor bound due to vaporization of liquid by heat produced by friction or leaking into the pump cylinder from the surroundings. A further object of the invention is to reduce the danger of vapor binding.

The rate of pumping of liquid oxygen should be adjustable in accordance with demands for oxygen and the purity of oxygen desired. The pressure pumped against should be limited to a safe value. Another object of the invention is to provide means for manually adjusting the rate of pumping liquid oxygen, for automatically reducing the rate of pumping to prevent excess pressure, and for automatically restoring the higher rate of pumping when the pressure drops to a normal value.

Other objects of the invention are to indicate the rate of oxygen production at any time and to sum up the total oxygen production during any period.

The foregoing objects together with such additional and subsidiary advantages as may hereinafter appear or are incident to the invention, are realized by the novel apparatus described herein and shown in preferred form on the drawings as follows:

Figure 1 is a cross-section of the new and improved liquid oxygen pump with the pump cylinder deeply imbedded in insulation and with a plunger reciprocated by an operating rod projecting through the insulation to a mechanism external thereto.

Figure 2 is a front view to reduced scale of the mechanism with variable speed drive.

Figure 3 is a cross-section of the mechanism disconnected for removal of the reciprocating plunger and operating rod.

Referring to Figure 1, pump cylinder 1 is

mounted within vessel 2 connected by pipes 3 and 4 to container 5 which is the source of liquid oxygen. Pipe 3 is connected through filter 6 to container 5 at a point below the liquid level therein and preferably near the bottom of container 5. Pipe 4 is connected to container 5 at a point above the point of connection of pipe 3 and preferably above the liquid level within container 5. Pipe 4 is connected to vessel 2 near its highest part so as to discharge all vapor formed by heat leaking into vessel 2.

Liquid oxygen to be pumped flows from container 5 through filter 6 and pipe 3 to vessel 2. Any impurities such as solid carbon dioxide in the liquid oxygen in container 5 are removed by filter 6 before the liquid oxygen reaches vessel 2. If these impurities were not strained out of the liquid oxygen before it reached the pump, these impurities might adversely affect operation of the pump by sticking to valves to prevent their functioning or to plunger and cylinder walls to augment frictional resistances.

Vessel 2 is located at some distance below container 5 in order that liquid oxygen within vessel 2 will be under greater hydrostatic pressure than in container 5 where the pressure will usually correspond to the boiling temperature of the liquid oxygen. In container 5, any absorption of heat would therefore produce vaporization of the liquid oxygen. In vessel 2, some heat can be absorbed without vaporization of the liquid oxygen because it is first necessary to raise the liquid to a higher temperature before it will boil under the greater hydrostatic pressure therein.

Suction opening 7 to pump cylinder 1 is located near the lowest part of vessel 2 so that the coldest liquid oxygen will be sucked into the pump. The coldest liquid oxygen will tend to flow to the lowest part of vessel 2 by reason of its greater density relative to surrounding liquid. This tendency is facilitated by connecting pipe 3 to vessel 2 as shown so as to favor flow of entering cold liquid to the bottom of vessel 2 along its protected side. Pipe 3 might be connected to the lowest point of vessel 2; but the connection shown will usually be about as effective and is preferable to a longer pipe with more bends. Drain pipe 8 is connected to the lowest point of vessel 2 for draining all liquid therefrom.

Cylinder 1 is part of or is attached to cover 9 which is bolted to flange 10 on vessel 2. This construction enables pump cylinder 1 to be withdrawn from vessel 2 for maintenance purposes without disturbing pipes 3 and 4.

Suction opening 7 is through a plug screwed into the wall of cylinder 1 and having attached thereto a cage for spring-loaded suction valve 11, which is a ball valve. By unscrewing this plug, suction valve 11 can be replaced. Discharge valve 12 is also a spring-loaded ball valve which can be replaced by removing plug 13. The passageway shown from valve 12 through the wall of cylinder 1 enables pipe 14 for discharge of liquid oxygen under high pressure, to be connected to cover 9.

Plunger 15 has reciprocating motion back and forth within cylinder 1. Packing 16 around plunger 15 within cylinder 1 is provided to reduce if not prevent leakage of high pressure liquid oxygen along plunger 15 during its inward forcing stroke. This packing is V-type leather which has been treated to remain flexible at very low temperature. It is arranged with the trough of the V towards the end of the plunger so that the leather will be pressed against cylinder wall and

plunger by the high pressure of the liquid oxygen during the forcing stroke. Leather packing 16 is held in place by gland 17 which is part of tube 18 extending through insulation 19 and base plate 20. At the outer end of tube 18 is a second leather packing 21 around operating rod 22 attached to plunger 15. Packing 21 is held in place by gland nut 23.

Operating rod 22 does not fit tightly within tube 18 in order to avoid frictional resistance to its reciprocating motion. There is, therefore, an annular clearance space between rod 22, tube 18 and the two leather packings 16 and 21. This clearance space is connected at its lower end to the liquid oxygen space within vessel 2 by holes through gland 17 and through the wall of cylinder 1. An annular space is formed between the bottom of a counterbore in cylinder 1 and the lower end of gland 17 where its diameter is reduced to hold packing 16 in place. Holes through gland 17 connect this annular space to the clearance space between rod 22 and tube 18. A hole through the cylinder wall connects the annular space to the space within vessel 2. Liquid oxygen at suction pressure within vessel 2 can enter the clearance space between rod 22, tube 18 and packings 16 and 21 through the holes to the annular space at the lower end of gland 17.

More important, any liquid oxygen leaking along plunger 15 past packing 16 cannot build up pressure in the clearance space between rod 22, tube 18 and packings 16 and 21, because this liquid oxygen will flow through the holes described into vessel 2 at suction pressure and be returned to cylinder 1 through suction opening 7. Consequently, packing 21 at the outer end of tube 18 is always subjected to the low suction pressure within vessel 2.

Tube 18 of this liquid oxygen pump is inclined upwards from cylinder 1 to the operating mechanism outside insulation 19. This is done in order that liquid oxygen will not flow from cylinder 1 along the clearance space until it reaches packing 21 under normal conditions of leakage at packing 21. If tube 18 were horizontal or inclined downwards, liquid oxygen could flow along the clearance space between operating rod 22 and tube 18 until it reached the outer end of the tube where it would be vaporized in cooling this outer end to very low temperatures. Large loss of refrigeration would result and the operating mechanism would become covered with frost from moisture in surrounding atmospheric air. This frost would interfere with lubrication and operation of the mechanism. By inclining tube 18 with an upward slant as shown in Figure 1, liquid oxygen never reaches the outer end of tube 18 under normal conditions.

There will always be some heat leak along tube 18 and rod 22 from their outer ends exposed to room temperature to their inner ends subjected to liquid oxygen temperature. This heat will slowly vaporize any liquid oxygen within the clearance space between rod 22 and tube 18. With only slight leakage past packing 21, the clearance space will remain filled with gas and liquid oxygen will remain at the lower end of the clearance space. Oxygen gas in the clearance space will assume substantially the same temperature gradient as rod 22 and tube 18 and will conduct very little heat along the clearance space.

In order to reduce conduction of heat along rod 22 and tube 18, these are made of material having low heat conductivity, preferably Monel metal which also has strength and resistance to

abrasion suitable for this purpose. Operating rod 22 is made hollow to reduce the cross-sectional area for conduction of heat along the rod and to secure ample stiffness for the forcing stroke against high liquid oxygen pressure. At its inner end, operating rod 22 is screw-connected to solid plunger 15.

At its outer end, operating rod 22 is coupled to pin 24 in lever 25. The fulcrum of lever 25 is at pin 26 which is connected by link 27 to pin 28 attached to base plate 20. This construction permits fulcrum pin 26 to move sidewise so that rod 22 can have reciprocating motion in a straight line. Lever 25 is oscillated by connecting rod 29 connecting lever pin 30 to crank pin 31. Crank pin 31 is in crank arm 32 which is attached to and rotates with shaft 33 mounted in bearings 34, see Figure 2, supported by brackets on base plate 20. Tube 18 is supported in base plate 20 so as to withstand the thrust of plunger 15 during the forcing stroke. Base plate 20 is mounted on the casing for insulation 19.

Shaft 33 rotates in the direction of the arrow in Figure 1. The center of shaft 33 is offset from a line through the center of pin 30 and parallel to operating rod 22. This is done to reduce sidewise pressure on operating rod 22 during the inward forcing stroke of plunger 15. During the outward suction stroke, larger angularity of connecting rod 29 is permissible because the forces involved are low. With crank arm 32 in the position shown in Figure 1 at right angles to and pointing towards operating rod 22, a line passing through the center of pin 30 and parallel to rod 22 lies about halfway between the centers of crank pin 31 and shaft 33.

Shaft 33 is driven by variable speed drive 35 direct connected to electric motor 36 as shown in Figure 2. Variable speed drive 35 can revolve at any rotative speed from zero to say 40 revolutions per minute with electric motor 36 running at constant rotative speed. The rotative speed of variable speed drive 35 is adjusted manually by control handle 37 and is indicated on dial 38 with micrometer drum attached to control handle 37 for accurate speed setting. Revolution counter 39 is attached to the end of shaft 33 to sum up the total number of revolutions during ony given period.

Since the stroke of plunger 15 is fixed by the dimensions of the operating mechanism, the plunger displacement remains the same during each revolution of shaft 33. That is, the same volume of liquid oxygen is sucked into and discharged from cylinder 1 during each revolution of shaft 33 except as affected by slip which varies somewhat with operating pressure and rotative speed. Approximately, dial 38 indicates the rate of pumping liquid oxygen at any instant and counter 39 sums up the amount of liquid oxygen pumped during any period of time.

The purity of oxygen produced by a plant for extracting oxygen from atmospheric air by liquefaction and rectification varies with the rate at which oxygen is withdrawn therefrom. With the above described means for accurately reproducing the rate at which liquid oxygen is withdrawn from such a plant, it becomes possible to reproduce any desired purity of oxygen without loss of time in making chemical analyses of the product. The plant can be set to operate at any rate of oxygen production from a maximum rate corresponding to the lowest permissible purity to zero rate. Any desired rate of production can be quickly obtained and then maintained.

It is generally desirable to operate a plant at the maximum rate of oxygen production until total requirements are met. If cylinders or tanks are being charged with gaseous oxygen, the pressure pumped against will continue to rise if the rate of pumping of liquid oxygen is not checked. Automatic means of so doing are shown in Figure 2. The control mechanism of variable speed drive 35 is connected by extended shaft 40 to pressure device 41 on oxygen discharge pipe 42. When the oxygen discharge pressure rises above any set value, the excess pressure acts through device 41 and extended shaft 40 to cause variable speed drive 35 to rotate shaft 33 at a lower rotative speed, which decreases with increasing pressure until shaft 33 comes to rest with no further rise in oxygen pressure. Device 41 may be of any well-known type in which pressure change produces mechanical movement. It may be located at any point along the discharge conduit for the liquid oxygen pumped, preferably after the liquid has been vaporized and warmed to room temperature.

When gaseous oxygen is supplied to a system from which the oxygen is withdrawn at a variable rate, device 41 will operate to reduce the rate of oxygen production when the pressure exceeds a set value and to increase the rate again when the pressure drops.

Operating rod 22 is coupled to pin 24 in lever 25 through detachable end piece 43 to which rod 22 is firmly attached by hand nut 44. End piece 43 fits into hollow rod 22 so as to take the thrust on the inward forcing stroke of plunger 15. This construction is employed in order that plunger 15 and operating rod 22 can be entirely removed from tube 18. Hand nut 44 is first loosened. The lever mechanism is dropped slightly as indicated in Figure 3. Plunger 15 and operating rod 22 can then be withdrawn between pins 24 and 26 and the two bars of lever 25. These two bars are spaced far enough apart to permit this to be done.

The whole lever mechanism on base plate 20 is protected by cover 45 with hinged lid 46. This cover protects the mechanism from dust and grit and keeps atmospheric moisture away from the outer ends of operating rod 22 and tube 18. Any slight leakage of dry oxygen gas past packing 21 will fill the space within cover 43 with dry gas. Hinged lid 44 can be raised as indicated in Figure 3 to lubricate the mechanism and to withdraw plunger 15 and rod 22.

Plants for extracting oxygen from atmospheric air must be warmed above room temperature occasionally to defrost them. Warm dry air is used for this purpose. By blowing this warm dry air through filter 6, pipe 3, vessel 2 and drain pipe 8, any solid carbon dioxide in filter 6 will be vaporized and discharged from the system. Plunger 15 and rod 22 can then be withdrawn for blowing the warm dry air through cylinder 1 and tube 18 past packings 16 and 21 to defrost these packings.

I claim:

1. Liquid oxygen pump including a vessel, a source of liquid oxygen, an inlet pipe connected to the source below the liquid level therein for admitting liquid oxygen to the vessel, a cover for the vessel, a cylinder attached to the cover and projecting into the vessel so as to be surrounded by liquid oxygen, a suction opening with non-return valve for flow of liquid oxygen from the vessel into the cylinder, a reciprocating plunger within the cylinder, a discharge opening with non-return valve for flow of liquid oxygen from the cylinder, insulation surrounding the vessel to

reduce heat leak into the vessel from the surroundings, and an outlet pipe near the highest part of the vessel connected to the source of liquid oxygen above the liquid level therein for continuously discharging oxygen vapor formed by heat leak into the vessel.

2. Liquid oxygen pump as in claim 1 wherein the suction opening into the cylinder is located near the lowest part of the vessel.

3. Liquid oxygen pump as in claim 1 including a discharge pipe for liquid oxygen attached to the cover of the vessel.

4. Liquid oxygen pump as in claim 1 wherein said vessel is located below said source.

5. Liquid oxygen pump as in claim 1 including packing around the plunger, and a passage-way from the clearance space beyond the packing into the vessel, whereby liquid oxygen leaking past the packing is returned into the vessel.

6. Liquid oxygen pump as in claim 1 wherein said vessel is located below said source and a filter is provided in said inlet pipe, for removing impurities such as solid carbon dioxide from the liquid oxygen before it reaches said cylinder.

7. Liquid oxygen pump including a cylinder imbedded in insulation to reduce heat leak from the surroundings into the liquid oxygen, a tube extending from the cylinder through the insulation, a reciprocating plunger within the cylinder attached to an operating rod extending through the tube, the reciprocating plunger having substantially the same diameter as the operating rod which is smaller than the inside diameter of the tube, an oscillating lever composed of two bars spaced farther apart than the diameter of the operating rod, means for connecting the operating rod to the oscillating lever whereby the plunger is given reciprocating motion within the cylinder, and means for disconnecting the operating rod from the oscillating lever whereby the operating rod and plunger can be withdrawn from the cylinder and tube between the bars of the oscillating lever.

8. Liquid oxygen pump including a vessel imbedded in insulation to reduce heat leak into said vessel, a pump cylinder mounted within said vessel, a source of liquid oxygen, a pipe connecting said source below the liquid level to said vessel, a second pipe connecting said source above the liquid level to said vessel near its highest point, a tube extending from the pump cylinder through the insulation, a reciprocating plunger within the pump cylinder attached to an operating rod extending through the tube, a packing around the operating rod within the tube near its outer end, and a passageway from the clearance space between the operating rod and the tube to the space within said vessel around said pump cylinder, whereby liquid oxygen leaking past the reciprocating plunger is returned to said vessel around said pump cylinder, vaporized oxygen is returned to said source, and the packing is subjected to substantially the same pressure as in said source.

9. Liquid oxygen pump including a cylinder imbedded in insulation to reduce heat leak from the surroundings into the liquid oxygen, a tube extending from the cylinder through the insulation, a reciprocating plunger within the cylinder attached to an operating rod extending through the tube, a packing around the plunger within the cylinder held in place by a gland which forms part of said tube and projects into a counterbore in said cylinder whereby an annular space is formed between the gland and the bottom of the counterbore, a suction valve for flow of liquid oxygen into said cylinder, and a passageway from the clearance space between the operating rod and the tube to the suction valve formed by holes through the gland and through the cylinder wall to said annular space, whereby liquid oxygen leaking past said packing is returned to said suction valve.

10. Liquid oxygen pump including a cylinder imbedded in insulation to reduce heat leak from the surroundings into the liquid oxygen, a Monel metal tube extending from the cylinder through the insulation, and a reciprocating plunger within the cylinder attached to a Monel metal operating rod extending through the tube to a mechanism outside the insulation.

11. Liquid oxygen pump as in claim 10 wherein the operating rod is hollow to reduce heat leak along the rod.

12. Liquid oxygen pump including a cylinder imbedded in insulation to reduce heat leak from the surroundings into the liquid oxygen, a tube extending from the cylinder through the insulation, a reciprocating plunger within the cylinder attached to an operating rod extending through the tube, a packing around the plunger within the cylinder, a second packing around the operating rod within the tube near its outer end, the tube being inclined upward from the cylinder whereby the second packing is subjected to gaseous oxygen and any liquid oxygen within the clearance space between operating rod and tube remains near the cylinder.

13. Liquid oxygen pump as in claim 12 including a suction valve for admitting liquid oxygen into said cylinder and means for returning to said suction valve liquid oxygen leaking past the reciprocating plunger.

14. Liquid oxygen pump as in claim 12 including a source from which liquid oxygen is supplied to said cylinder and means for returning to said source vapor formed by heat leak into oxygen liquid leaking past the reciprocating plunger.

15. Liquid oxygen pump including a cylinder imbedded in insulation to reduce heat leak from the surroundings into the liquid oxygen, a tube extending from the cylinder through the insulation, a reciprocating plunger within the cylinder attached to an operating rod extending through the tube, a packing around the plunger within the cylinder, a second packing around the operating rod within the tube and near its outer end, a suction valve for admitting liquid oxygen into the cylinder, a source of liquid oxygen, a space connected near its lowest point to said suction valve and near its highest point to said source, and a passageway from said space to the clearance space between the operating rod and the tube whereby liquid oxygen leaking past the first packing is returned to said suction valve, vapor formed therefrom is returned to said source, and the second packing is subjected to the suction pressure.

16. Liquid oxygen pump including a cylinder imbedded in insulation to reduce heat leak from the surroundings into the liquid oxygen, a tube extending from the cylinder through the insulation, a reciprocating plunger within the cylinder attached to an operating rod extending through the tube, a source of liquid oxygen, a suction valve for admitting liquid oxygen into said cylinder, means for separating vapor formed by heat leak into liquid oxygen leaking past the plunger from the remaining liquid oxygen, means for returning the vapor formed to the said source, and means

for returning the remaining liquid oxygen to the said suction valve.

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