LIQUID OXYGEN PUMPING SYSTEM

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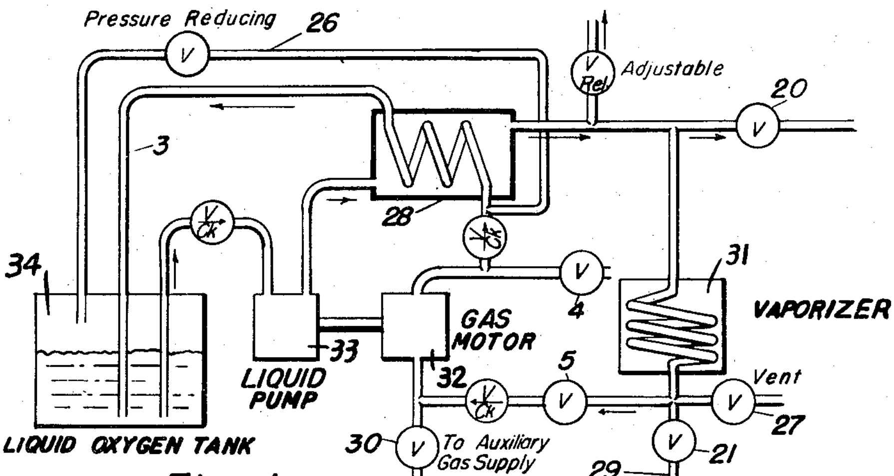

Fig. 1

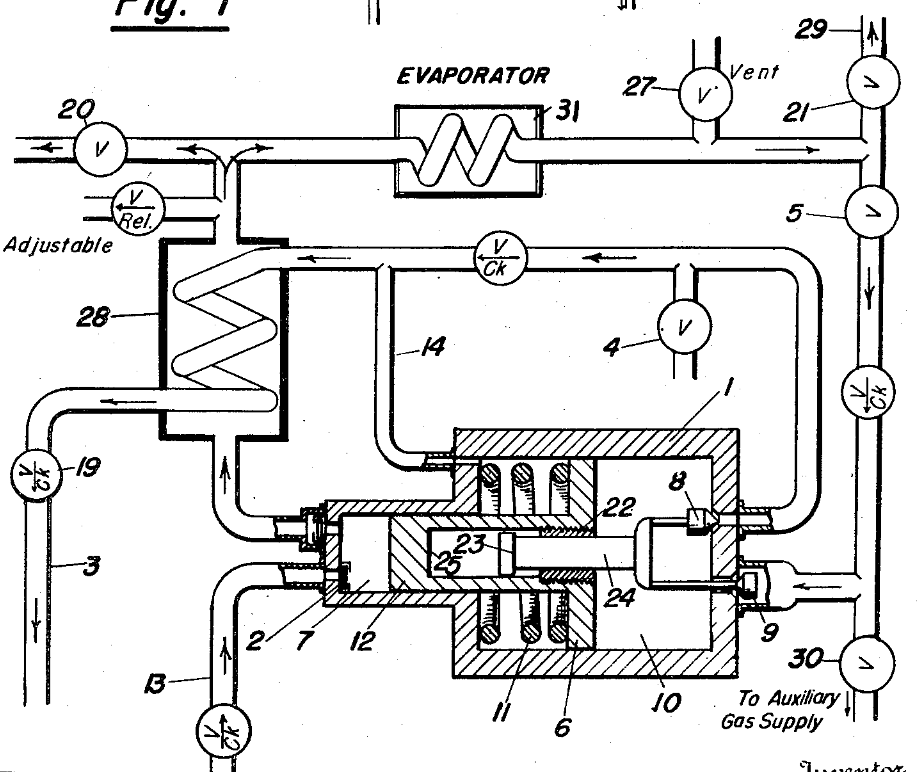

Fig. 2

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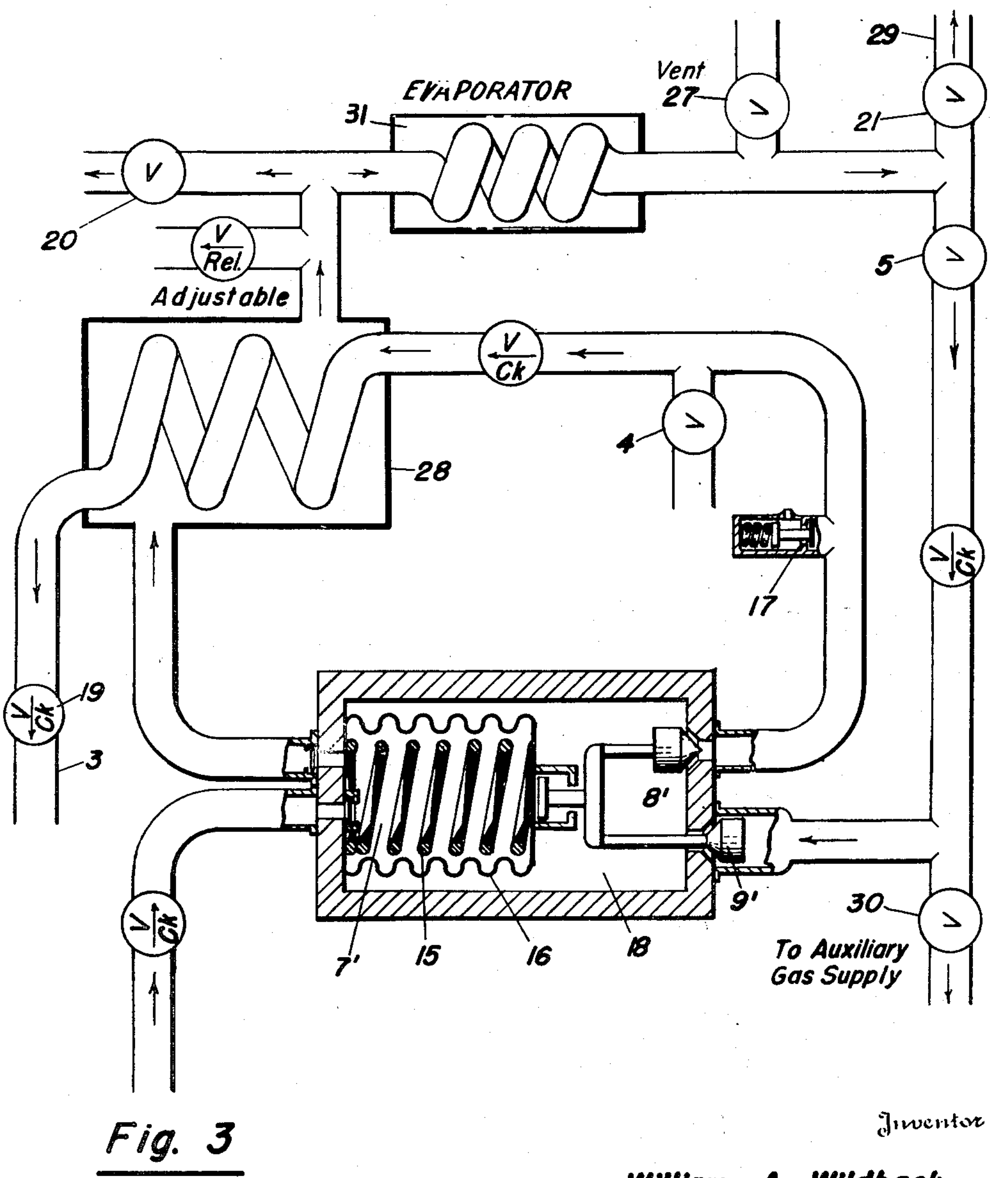

Fig. 3

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Patented Apr. 19, 1949

2,467,413

UNITED STATES PATENT OFFICE

2,467,413

LIQUID OXYGEN PUMPING SYSTEM

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Application February 15, 1946, Serial No. 647,984

11 Claims. (Cl. 62—1)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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This invention relates to means for pumping of liquid oxygen, and more particularly to pumping systems utilizing heat energy absorbed by the liquid oxygen itself, to operate the pumps in a most efficient manner.

Pumping of liquid oxygen may be desired in transferring the liquid from one container to another, in pumping liquid from a container to an evaporator or vaporizer for filling of cylinders with gas, or in supplying gaseous or liquid oxygen to engines, jets, or rockets.

The object of the present invention is to provide oxygen pumping means suitable for use in aircraft, projectiles and the like, and driven by oxygen gas obtained by evaporation of part of the liquid oxygen supply, wherein the exhaust oxygen from the driving means may be condensed and returned to the liquid oxygen supply.

Another object is to provide a simple pumping system for liquid oxygen for delivery either directly in liquid form or through an evaporator or vaporizer in gaseous form as may be desired, using some of the gaseous oxygen as a source of sufficient motive fluid for operating the pump or pumps, and utilizing this portion of the gaseous oxygen, after it has served its purpose as a motive fluid by condensing and returning it to the liquid source, or by delivering it to the gaseous delivery line.

Other and more specific objects will appear in the course of the following description of the illustrative forms of this invention, having reference to the accompanying drawings, wherein:

Fig. 1 is a schematic diagram of a pumping system based on the present invention; and

Figs. 2 and 3 are partially schematic views of similar pumping systems showing two different forms of reciprocating pumps which may be used therein particularly for small capacity installations.

The operation can be understood by reference to Fig. 1, in which the flow directions are shown by arrows. Liquid pumped under pressure into a vaporizer 31 is evaporated by absorption of heat. Part of this gas is delivered to a gas motor 32 through a control valve 5. The gas is utilized in the gas motor 32 to drive the liquid pump 33, which takes liquid from the reservoir or tank 34 and delivers it under pressure. Liquid may be delivered through the manual or automatic control valve 20, or gas through the manual or automatic control valve 21. At least part of the liquid pumped passes through the evaporator or vaporizer 31, thence through the control valve 5 and the motor. The exhaust gas from the motor is shown as flowing through a heat interchanger 28, warming the delivered liquid and being itself cooled, or perhaps partially condensed, and thence to condense in the liquid supply.

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If delivery of liquid at low vapor pressure is desired, the heat interchanger 28 can be omitted, or placed in the evaporator circuit, or be made a part of the evaporator. The evaporator or vaporizer 31 may be either a coil of tubing absorbing heat from the atmosphere, or any other type of heat interchanger heated by any other means.

If delivery of gas is desired, the exhaust gas from the motor may be led directly, or through a pressure reducer, to the gas delivery line 29. For this use, the pump delivery pressure must be maintained high enough so that the exhaust pressure from the gas motor is equal to or greater than the line pressure desired. Obviously, the exhaust gas may be used separately at a sufficient pressure, or allowed to escape if economy is not essential.

The pressure reducing valve circuit 26 shown in Fig. 1 is not essential in all embodiments of this invention, but is desirable when the liquid is to be raised above its original level before entering the pump. Its purpose is to maintain the liquid pumped under a pressure greater than its equilibrium vapor pressure to avoid vapor lock in the pump. The warm gas delivered through the circuit 26 condenses only partially on the surface of the liquid in tank 34. The layer so condensed constitutes a relatively warm liquid layer of high vapor pressure. Because of the great change in density of liquified oxygen with temperature, this surface layer will persist for a long time before the mass of the liquid is warmed to the same temperature. Thus, it is possible in this way to pressurize the main body of liquid without warming it.

It has been found by experience that the condensation of gas introduced into the space above the liquid proceeds slowly, so that excessively high pressures may be generated by adding more and more gas without special provision for condensing, as is provided in my invention.

As shown, the circuit 26 can supply a pressure only equal to the pressure drop across the heat interchanger condenser circuit 3. If this is not sufficient the circuit 26 may be connected on the other side of the motor 32, or even on the other side of valve 5. A separate auxiliary gas supply (as from a tank of compressed gas or another liquid oxygen converter) may be utilized to supply pressure in this circuit through valve 30, particularly for starting.

To stop the operation of the system, the valve 5 is closed. Valves 20 and 21 may then be closed, or check valves may be provided to prevent return flow if the apparatus supplied maintains pressure. To start the operation, the motor may be driven by an auxiliary gas supply, which is turned off at 30 as soon as the delivery pressure has built up sufficiently. Or, if some pressure exists in the storage container, either because of vapor pressure being above atmospheric, or supplied from the pressure reducer circuit 26, the vent 27 may be opened momentarily, allowing liquid to flow through the pump, and into the evaporator. When the vent is closed, pressure builds up in the pump and evaporator circuit as the liquid evaporates. Opening the control valve 5 then starts the motor.

In operation, the pressure delivered by the pump 33 must be greater than that required to drive the motor 32, the exhaust pressure greater than the gas pressure in the storage tank 34 if the exhaust gas is to be condensed, and the pressure in the storage tank 34 greater than the equilibrium vapor pressure by at least the lift from the tank to the pump.

Obviously, it is simpler if the pump 33 can be installed in or below the storage tank with no lift required. However, the embodiment shown was selected to show how satisfactory operation may be achieved under less favorable conditions.

For large capacity pumping, the evaporator or vaporizer 31 might be flame heated, as in jet or rocket motors; a centrifugal pump driven by a turbine motor would probably be suitable. In small capacity applications, a reciprocating motor 1 and pump 2 as shown in Fig. 2 is simpler and may be better suited to these requirements; the condensation may be achieved adequately by merely bubbling the exhaust gas flowing out of conduit 3 through the remaining liquid in the supply tank 34, and an atmospheric evaporator or vaporizer 31 is usually adequate.

Referring to Fig. 2, this system operates as follows: When the starting vent valve 4 and high pressure valve 5 are opened, gas pressure in the evaporator or vaporizer circuit starts the motor 1, and valve 4 may then be closed. The pressure of gas in the evaporator or vaporizer circuit pushes the piston 6 to the left, forcing liquid in the pumping chamber 7 into the evaporator or vaporizing circuit. When the valves 8 and 9 are moved to the other position at the end of the pumping stroke by the lost motion linkage 22, 23, 24, the driving gas is pushed out of the motor chamber 10 through outlet valve 8 as a result of the force of the compressed spring 11 and exhausts through a heat interchanger and through the check valve 19 and the conduit 3 to condense in the storage liquid. As the compression spring 11 moves the piston 6 to the right, the plunger portion 12 on piston 6 draws liquid from the storage supply through conduit 13 into the pumping chamber 7, and the cycle then repeats. The cylinder vent 14 is provided to avoid compression, under the large end of the piston, and to vent blow-by gas. Operation may be started either as mentioned above, by opening the starting vent valve 4, with the storage liquid under some pressure, or by supplying gas under pressure to the motor inlet. To avoid vapor lock, the liquid should be supplied under pressure, either by pressurizing the supply container, or by installing the pump with a direct

connection below the storage level. If the exhaust gas is used to pressurize the storage container, the pressure must not be so high but that the spring 11 can force the piston 6 to the right against the pressure acting on the differential area of the piston 6 and plunger 12.

For most efficient utilization of gas and power, the dead volume in the chamber 10 should be as small as possible.

The areas of the piston and the plunger may be made equal for convenience of construction, but if so, the spring must work oppositely, to pump the liquid, and the return stroke must be powered by the pressure of the liquid from the storage container. Some gas must be vented to permit this operation.

A form of pump embodying these principles is shown in Fig. 3, with a flexible bellows 16 shown as a preferred construction instead of a piston.

The system here is the same as in Fig. 2, except for the action of the pump. Here the liquid is forced into the evaporator or vaporizer 31 circuit by the action of the tension spring 15 compressing the bellows 16, the pressures being essentially equal on the two sides of the bellows when the inlet valve 9' is open. When the valve positions reverse most of the gas in chamber 18 exhausts through the heat interchanger 28 and check valve 19 and conduit 3 to condense in the tank 34, but when the pressure falls below a certain value, the exhaust valve 17, biased inwardly by a predetermined resilient force, opens and the remaining gas is vented to the atmosphere. The bellows 16 is expanded and the spring 15 stretched by liquid forced into the pump chamber 7' by the pressure over the storage liquid in tank 34.

The delivery valves 20 for liquid delivery and 21 for gas delivery may be of any suitable type. The device is called a liquid oxygen pumping system, but may be applied to the pumping of other liquified gases.

Various modifications in the form and arrangement of the parts herein disclosed may be made without departing from the spirit and scope of the present invention, as defined in the appended claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. A liquid oxygen pump apparatus comprising a storage tank for liquid oxygen, a heat interchanger, a liquid oxygen pump for pumping liquid from said storage tank to a delivery line through said interchanger, an evaporator connected to said line for evaporating a portion of the liquid supplied thereby, a gas delivery line connected to said evaporator, a gas motor for driving said pump energized by gas supplied from said gas delivery line through a control valve, a conduit for conducting the exhaust gas from said motor to said heat interchanger for cooling said gas, and another conduit for conducting the cooled gas from said heat interchanger to the liquid in said storage tank for condensation therein.

2. A liquid oxygen pump apparatus comprising a storage tank for liquid oxygen, a heat interchanger, a liquid oxygen pump for pumping liquid from said storage tank to a delivery line through said heat interchanger, an evaporator connected to said line for evaporating a portion of the liquid supplied thereby, a gas delivery line

connected to said evaporator, a gas motor for driving said pump energized by gas supplied from said gas delivery line through a control valve, a conduit for conducting the exhaust gas from said motor to said heat interchanger for cooling said gas, another conduit for conducting the cooled gas from said heat interchanger to the liquid in said storage tank for condensation therein, and a connection between the gas in said heat interchanger and the gas phase in said storage tank having a pressure reducing valve therein for maintaining a pressure differential to provide return flow of said cooled gas to the liquid in said storage tank through said other conduit.

3. A liquid oxygen pump apparatus comprising a storage tank for liquid oxygen, a heat interchanger, a liquid oxygen pump for pumping liquid from said storage tank to a delivery line through said interchanger, an evaporator connected to said line for evaporating a portion of the liquid supplied thereby, a gas delivery line connected to said evaporator, a gas motor for driving said pump energized by gas supplied from said gas delivery line through a control valve, a conduit for conducting the exhaust gas from said motor to said heat interchanger for cooling said gas, another conduit for conducting the gas from said heat interchanger to the liquid in said storage tank for condensation therein, and a starting vent valve connected to the motor exhaust gas conduit.

4. Apparatus as defined in claim 1 wherein the pump and motor is a piston unit of the reciprocating type, spring actuated in one direction and gas pressure actuated in the other.

5. Apparatus as defined in claim 1 wherein the pump and motor is a combined piston unit of the reciprocating type, spring actuated in one direction and gas pressure actuated in the other, having a vent conduit for conducting the blow off gas from the rear of said motor piston to the exhaust gas conduit and to relieve the pressure at the rear of the motor piston.

6. Apparatus as defined in claim 3 wherein the pump and motor are combined into a bellows-type reciprocating unit, spring drawn in one direction, and differential pressure actuated in the other direction by relieving the pressure on the outside of the bellows to atmospheric whenever said pressure is reduced to a predetermined limit, and a spring pressed exhaust valve opening inwardly by spring pressure, connected to the motor exhaust gas conduit for opening the latter to the atmosphere.

7. A pumping system for liquified gas comprising a liquified gas container, a pump driven by a gas motor for pumping said liquified gas from said container, an evaporator connected between said pump discharge and said motor, said motor being powered by gas obtained from the evaporation of some of the liquid being pumped, and means for condensing the spent motive gas from the motor in the storage liquid.

8. A pumping system for liquified gas comprising a liquified gas container, a pump driven by a gas motor for pumping said liquified gas from said container, an evaporator connected between said pump discharge and said motor, said motor being powered by gas obtained from the evaporation of some of the liquid being pumped, means for condensing the spent motive gas from the motor in the storage liquid, and means for maintaining pressure above the storage liquid at a value greater than its equilibrium value.

9. A pump for pumping liquified gas from a container, driven by a motor operating by gas under pressure, atmospheric heat absorbing means for evaporating a sufficient amount of the discharge from said pump to supply the motive gas to said motor, a return conduit for the exhausted gas from said motor to the liquified gas from the container for condensation therein, and a heat exchanger in said return conduit for cooling said exhausted gas by the cooler discharge from the pump.

10. A pump for pumping liquified gas from a container, driven by a motor operating by gas under pressure, atmospheric heat absorbing means for evaporating a sufficient amount of the discharge from said pump to supply the motive gas to said motor, a return conduit for the exhausted gas from said motor to the liquified gas from the container for condensation therein, a heat exchanger in said return conduit for cooling said exhausted gas by the cooler discharge from the pump, and means for maintaining pressure above the liquified gas in the container at a greater value than its equilibrium vapor pressure.

11. A pump for pumping liquified gas from a container, driven by a motor operating by gas under pressure, atmospheric heat absorbing means for evaporating a sufficient amount of the discharge from said pump to supply the motive gas to said motor, a return conduit for the exhaust gas from said motor to the liquified gas from the container for condensation therein, a heat exchanger in said return conduit for cooling said exhausted gas by the cooler discharge from the pump, means for maintaining pressure above liquified gas in the container at a greater value than its equilibrium vapor pressure, and a conduit with a pressure reducing valve between a sufficiently high pressure point in the discharge from said pump and the container to control and maintain said greater value of pressure in the container.

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