Nov. 1, 1955 F. G. KEYES 2,722,105

DELIVERY TUBE FOR LIQUEFIED GASES

Filed Oct. 13, 1952 4 Sheets-Sheet 1

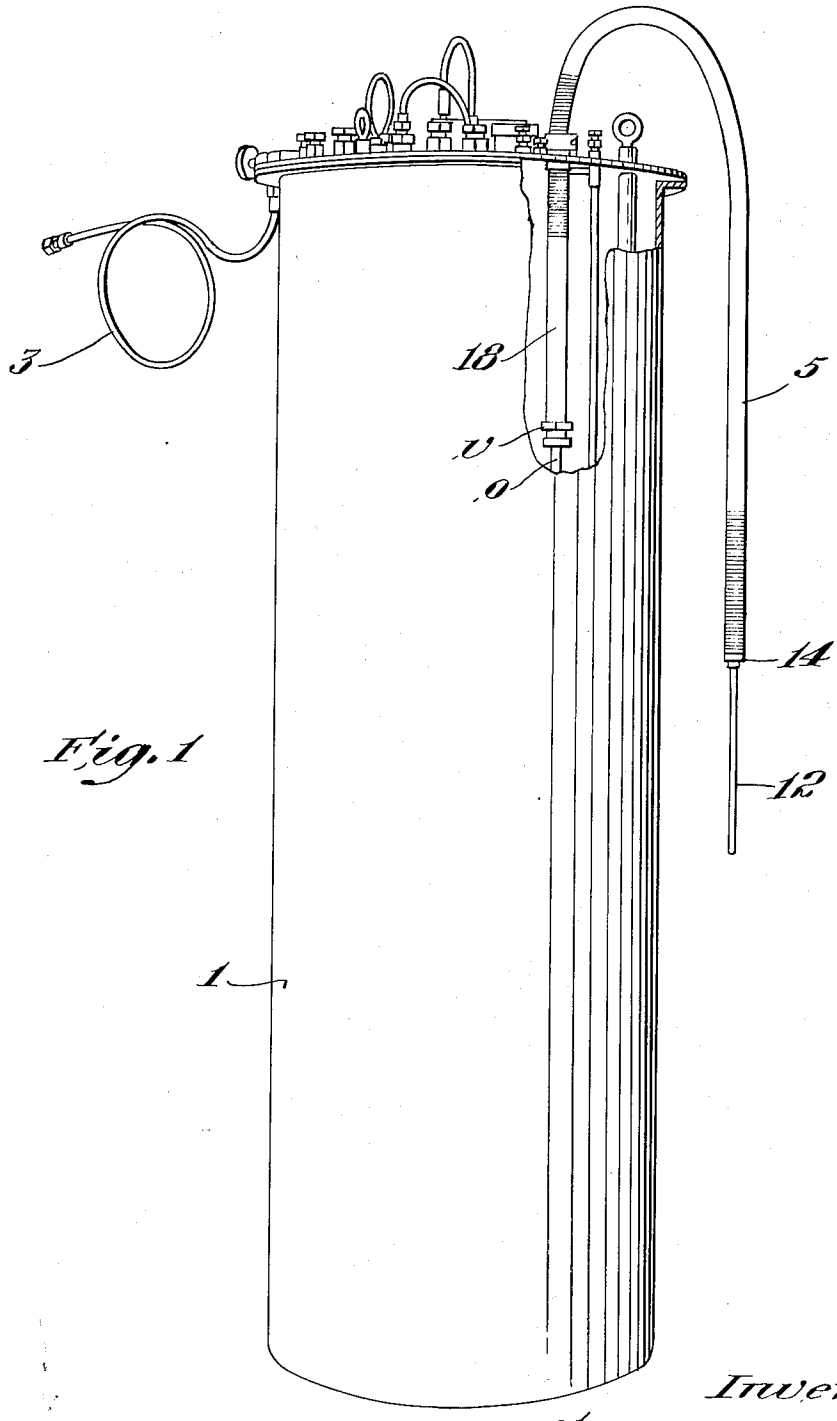


Fig. 1

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Filed Oct. 13, 1952 4 Sheets-Sheet 2

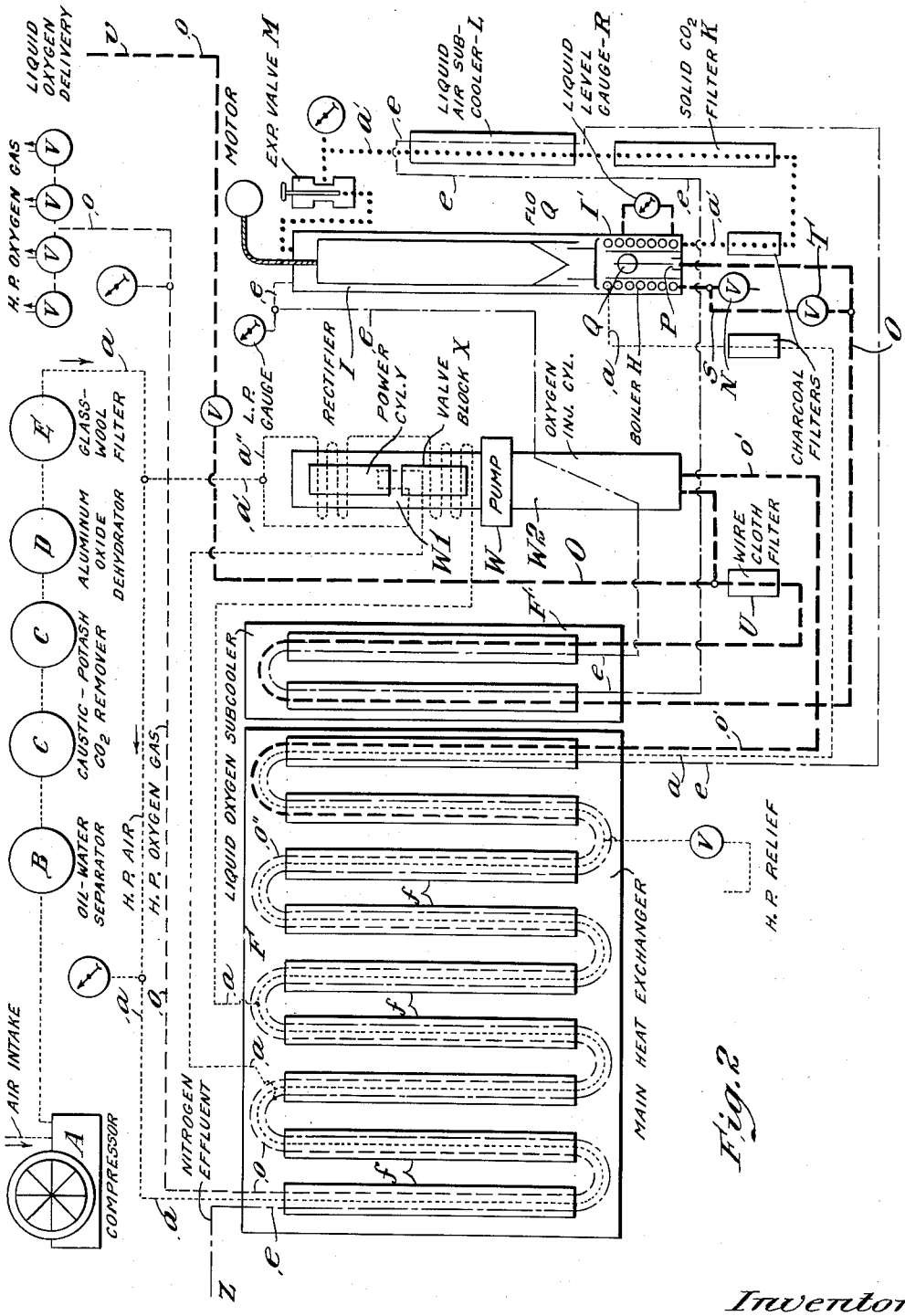


Fig. 2

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DELIVERY TUBE FOR LIQUEFIED GASES

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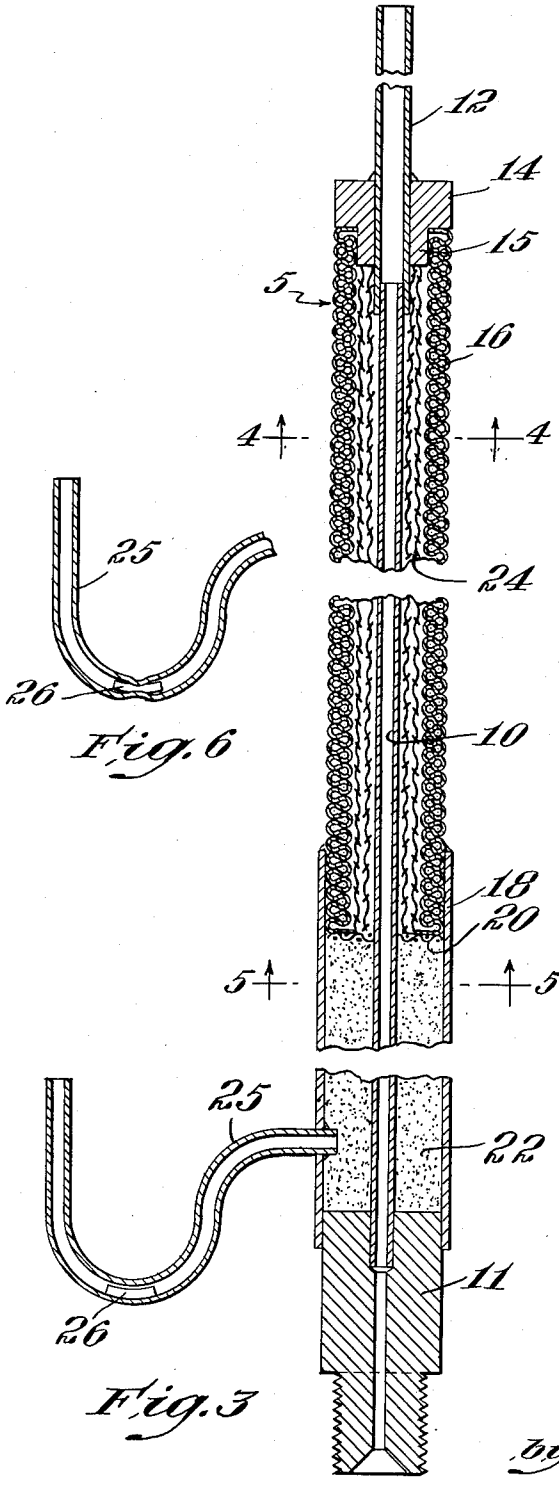


Fig. 3

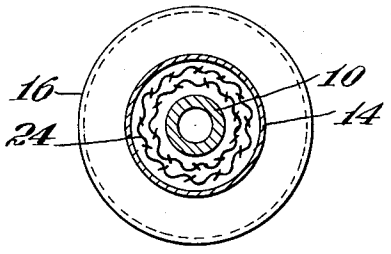


Fig. 4

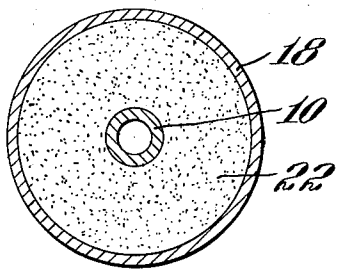


Fig. 5

Fig. 6

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Nov. 1, 1955 F. G. KEYES 2,722,105

DELIVERY TUBE FOR LIQUEFIED GASES

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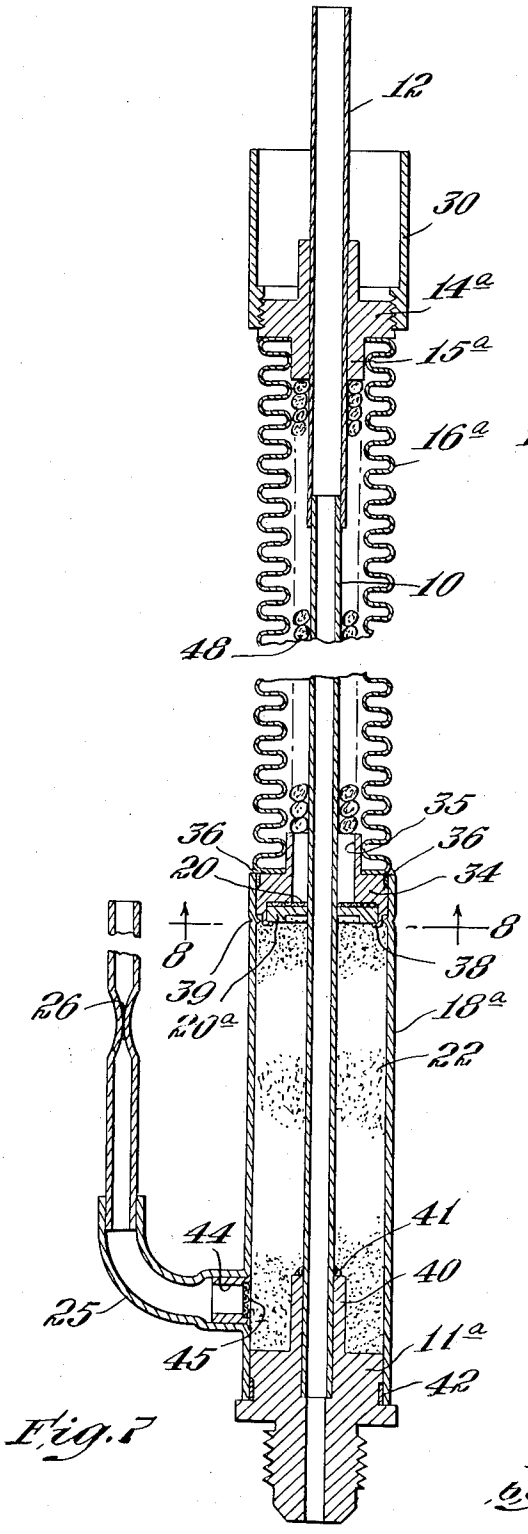


Fig. 7

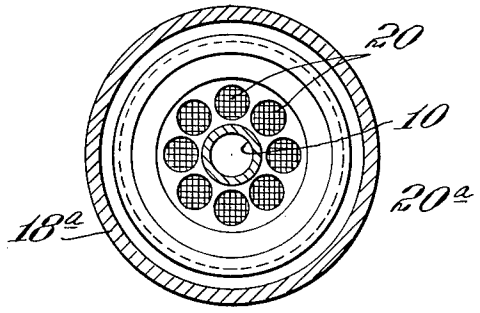


Fig. 8

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2,722,105

DELIVERY TUBE FOR LIQUEFIED GASES

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Application October 13, 1952, Serial No. 314,484

9 Claims. (Cl. 62—1)

In the production of liquid oxygen and the like gases it is the usual practice to store the liquid gas in a Dewar flask or the like jacketed receptacle rather than in cylinders as is the practice with gases under pressure. Since the temperature of liquefied gases commonly employed in industry ranges from a few degrees below 0° F. to approximately 300° below zero in the case of liquefied oxygen, and lower temperatures in the case of nitrogen and other gases, special precautions must be taken in conducting the liquid gas from the producing apparatus or other source of supply to the storage receptacle in order to avoid considerable losses due to evaporation and, in the case of liquid oxygen hazards such as possible combustion or explosition.

It is desirable that such a delivery tube be strong and durable, yet conveniently flexible and, above all, have a high heat insulating capacity; and it is the principal object of the present invention to provide such a delivery tube so that liquid oxygen and the like gases may safely and efficiently be handled.

Further objects will be apparent from a consideration of the following description and the accompanying drawings, wherein:

Fig. 1 is an elevation of an oxygen producing apparatus having a delivery tube constructed in accordance with the present invention;

Fig. 2 is a diagrammatical representation of the oxygen producing apparatus showing the courses of flow therethrough;

Fig. 3 is a medial section through the delivery tube shown in Fig. 1;

Figs. 4 and 5 are enlarged sections on the lines 4—4 and 5—5, respectively, of Fig. 3;

Fig. 6 is a sectional detail illustrating the manner in which the exhaust tube is sealed;

Fig. 7 is a medial section through a delivery tube of modified construction; and

Fig. 8 is an enlarged section on the line 8—8 of Fig. 7.

In accordance with the present invention I provide a delivery tube which comprises an inner flexible tube preferably of a material having a high fatigue point and non-reactive with the liquefied gas with which it is to be used. Where such an inner tube has a relatively large diameter it may be circumferentially corrugated so as to permit flexibility, but where a relatively small size tube is adequate, then a thin wall metal tube is sufficiently flexible to be satisfactory. One end of the inner tube carries a coupling member by means of which it may be connected with the apparatus for producing liquefied gas or other source of supply, and the opposite or delivery end is provided with a nozzle. Between the coupling and nozzle is a flexible outer tube or jacket which is hermetically sealed about the inner tube and is provided with an exhaust pipe. In the annular region adjacent to this exhaust pipe the jacket carries granulated charcoal and in the other parts the jacket may be packed with a heat insulating material. The interior of the jacket is

exhausted and the exhaust pipe sealed in any suitable manner so as to preserve the vacuum.

Although such a delivery tube may be connected with any apparatus for producing liquefied gas, it is herein shown in connection with the particular apparatus disclosed in my copending application, Serial No. 689,768, filed August 10, 1946 and entitled Oxygen Producing Apparatus, now United States Patent No. 2,640,332, granted June 2, 1953, to which reference may be had for a more detailed disclosure of the various parts of the system.

Such an apparatus provides a compact portable unit for use on a vehicle, in industrial plants and laboratories and, as shown in Fig. 1, the apparatus is completely housed within a cylindrical casing **1**, the interior of which is packed with insulating material around the various parts, so that outside heat does not penetrate inwardly to any appreciable extent. The apparatus is designed to deliver either gaseous oxygen under pressure through delivery pipes **3** which may be connected to storage cylinders, or liquefied oxygen through the delivery tube **5**. The system is diagrammatically shown in Fig. 2 and the operation is as follows:

Atmospheric air is compressed to a high pressure by any suitable compressor A and passed through a clean-up train which may comprise an oil and liquid water separator B, one or more caustic potash carbon dioxide removers C, an aluminum oxide dehydrator D, and a glass wool filter E. This train is no part of the apparatus **1**, and other clean-up means may be employed instead of those suggested, provided that the air is made as completely free as possible of hydrocarbon vapor from the oil in the compressor, carbon dioxide, liquid water and water vapor. This highly compressed clean air (indicated by the light dotted line *a*) may all be used for the production of oxygen, but when gaseous oxygen is to be delivered by the apparatus a portion of the compressed air can be utilized to actuate a pump W. This use of the air as a source of power is not essential because other means, if desired, could be relied upon to drive the pump. This pump can be exhausted to the atmosphere, but as herein shown the exhaust is led into the effluent stream. Another portion of the air supply is employed in connection with the pump to retain some of the refrigeration that might otherwise be lost. This portion of the air is returned to the air stream and utilized in the production of the oxygen.

The air, except as above noted, is conducted through a main heat exchanger F made up of a series of unit sections *f* intimately arranged and so connected that the flow from the bottom of one section enters the bottom of the next adjacent section while the flow from the top of one similarly enters the top of the next. As the compressed air travels its course through a passageway of this main heat exchanger F much of its heat is transferred to the cooler effluent and oxygen which simultaneously is passing through other and separated passageways of the exchanger, as will presently appear.

The cooled air from the main exchanger F passes thence through a charcoal absorber or filter G and into a coil of tubing H, the turns of which are suitably spaced to allow for the free circulation of the boiling oxygen-rich liquid which is not permitted to exceed a desired level in the bottom portion I', or so-called boiler, of a rectifier column I. The upper portion of this column is generally referred to as the distributor. During the passage of the air through this tubing H the heat transfer from it to the surrounding bath of oxygen-rich liquid causes the air to be transformed from the gaseous to the liquid state under the pressure of the air feed. The liquid air (indicated by the heavy dotted line *a'*) issuing from the boiler coil H

passes through a charcoal trap or filter J and, preferably, a solid carbon dioxide filter K. The liquid air is then passed through another heat exchanger L, hereinafter called a liquid air sub-cooler, which further reduces its temperature. Up to this point in its course of travel the air has been almost continuously giving up heat and therefore arrives at the discharge end of the sub-cooler at a very low temperature.

The liquid air next goes through an expansion valve M and is immediately led into the top of the rectifier column I, above the distributor. While the expansion greatly reduces the pressure of the liquid air only a small portion of it changes back to the gaseous state because of its exceedingly low temperature. For the most part the liquid air flows downward through the rectifier entering into mass exchange with vapors having their origin in the boiler and rising upward through the column. In this process the liquid air is deprived of its nitrogen and part of the argon along with other rare gases which rise to the top of the column, join with whatever gaseous air may be present, and pass off from the rectifier along a course presently to be described. The remaining liquid continues downward into the bottom of the rectifier to maintain about the coil H a bath of nearly pure liquid oxygen.

This liquid oxygen (indicated by the heavy dash line O), may be drained from the bottom of the rectifier via a drain valve N when desired, but ordinarily the drain is closed and the flow of oxygen from the boiler is by way of valve P under control of a float Q. The latter automatically maintains the liquid oxygen at a predetermined level which can be indicated by a gauge R placed at any desired location. If, for any reason, this valve P should be unable to pass all the liquid oxygen produced, another line S, connected to the bottom of the boiler and thence with the line from the valve P, can be opened by means of the valve T which is normally closed.

The liquid oxygen passing the float valve P, and such as passes through the line S when open, flows through a sub-cooler F' comprising unit sections similar to those making up the main heat exchanger F. From the sub-cooler F' the liquid oxygen goes through a wire cloth filter U, and may then be delivered from the apparatus through an outlet *v* connected to the delivery tube hereinafter described. If only liquid oxygen is to be produced, the described course of the oxygen would be its complete course and the high pressure pump W could be omitted, when gaseous oxygen is to be a product of the apparatus, then the liquid oxygen follows a different course beyond the filter U.

The liquid oxygen after it flows through the sub-cooler F' and the wire cloth filter U is led to a novel pump W which transforms the relative low pressure liquid oxygen into high pressure liquid oxygen. The high pressure oxygen (indicated by the heavy dash line *o'*) delivered by the pump W is caused to traverse the main heat exchanger F hereinbefore mentioned, through which most of the incoming compressed air is flowing. Heat is absorbed by the liquid oxygen, thus raising its temperature and causing it to be transformed into high pressure oxygen gas (indicated by the thin dash line *o''*). When it finally leaves the heat exchanger it is at the proper temperature and pressure to be delivered into the customary storage cylinders for transportation to its ultimate place of use. If the oxygen gas is needed as produced, as for example if the gas is to be used in a sealed cabin of a high flying airplane or within compartments of a submarine, it can be discharged directly from the unit through a suitable pressure reducing valve (not shown) instead of into the customary portable containers.

The oxygen pump has a cylinder and plunger at one end for highly compressing the liquid oxygen and at its other end has another cylinder and piston to which force is applied to actuate the oxygen plunger. This force, as previously noted, may conveniently be supplied by the compressed air, a portion of which is taken from the main line and led as at *a'* to a valve block X and thence to and from the power cylinder Y of the pump. After being used there, the air may be exhausted from the valve block to atmosphere, but in the particular apparatus being described it is led into the effluent passage of the main heat exchanger.

The compressed air is also used as a thermal agent in connection with the driving end of the pump. A tube *a''* leads from the branch *a'* to the upper casing W_1 of the pump and is there coiled a few turns about the outside of the casing. The tube then extends to the lower end of the same upper casing W_1 where it is likewise coiled a few times about the surface of the casing. Thence the tube is connected to the air passage at some intermediate point in the main heat exchanger. As will be more particularly described later herein, this use of the air in the coils about the upper casing of the pump improves the thermal conditions in the power or driving end of the pump, and saves refrigeration that otherwise would be lost from the oxygen end of the pump.

Going back now to where it was noted that the effluent rises in the rectifier column I, it remains to point out how effective use can be made of this effluent for cooling purposes. The effluent (indicated by the dot-and-dash line *e*) is first led from the top of the rectifier to the lower casing W_2 of the pump W and serves to keep the temperature within this casing low so there will be no conversion of the liquid oxygen into gas during the intake stroke of the oxygen plunger. The compressing of the liquid oxygen increases its temperature and the cold effluent within the casing W_2 also removes this heat, a necessary item to prevent "vapor lock."

From the casing the effluent flows next through the sub-cooler F' for the liquid oxygen and thence passes through the sub-cooler L for the liquid air on its way from the boiler H to the expansion valve M. Lastly the effluent passes to and through the main heat exchanger F, absorbing heat from the incoming compressed air, and is finally vented to atmosphere at Z.

The courses of flow of the air, oxygen and effluent are so arranged as to effect a desired and highly efficient exchange of heat to the end that oxygen will be produced by the apparatus as desired. Gaseous oxygen can be delivered at substantially room temperature and at the proper pressure for loading the standard storage cylinders. Also, and alternatively if desired, liquid oxygen may be discharged into containers or receptacles through the delivery tube presently to be described.

Referring to Figs. 3 to 6, the delivery tube **5** shown therein comprises a thin wall inner tube **10** which provides the oxygen duct and is of low brass composition having a high fatigue point and which, when thoroughly annealed, can endure bending many times without fracture. The inner end of this tube is soldered or otherwise connected to the opening in a coupling member **11** which screws into the oxygen delivery outlet *v* in the line O (Figs. 1 and 2), and the opposite or delivery end of the tube **10** is sealed to a suitable piece of stiff tubing **12** which serves as a nozzle for delivery of the oxygen into proper containers therefor. Around this piece of stiff tubing is secured a collar **14** having a reduced stem **15**. Sealed to the outer side of this stem and to the shoulder formed thereby is a flexible corrugated metal outer tube or jacket **16** which extends along the inner tube in spaced relation thereto and terminates in a sealed connection with a metal tubular shell **18**. The latter is secured to the coupling **11** and provides a pocket or annular space about the inner tube beyond the said member in the direction of flow. At the end of this annular space is a screen partition **20** between the inner tube **10** and the shell **18**. This pocket or annular space is filled with a suitable adsorbent such as silica gel or activated charcoal **22**, the latter being preferred. Between the inner tube **10** and the flexible jacket **16** is a packing of glass twine

and glass cloth **24**. This packing not only serves as a heat insulator but also prevents contact of the two metal portions (**10** and **16**) of the hose when the latter is flexed.

From the side of the metal shell **18** around the pocket or annular space filled with the adsorbent, a small bent exhaust pipe or tube **25** extends for connection with an exhauster by means of which a vacuum is pumped in the hose while the latter is maintained at a suitable high temperature of say 250° F. When as complete a vacuum has been effected as possible, the bottom of the bent tube **25** is pinched as shown in Fig. 6, against a piece of soft solder **26** previously inserted in the tube. Then the tube is heated sufficiently to melt the solder and effectively seal the tube to preserve the vacuum in the hose. The maintenance of this vacuum is essential in preserving the insulating properties of the hose at a high degree of effectiveness.

High activity of the adsorbent charcoal **22** and consequent ability thereof to remove any gases between the jacket and shell **18** by adsorption on the charcoal surface, are greatly promoted by very low temperature. Hence, shell **18**, as shown in Fig. 1, is positioned within the apparatus where the temperature is low. When the liquid oxygen enters the inner tube **10** during the operation of the apparatus, the first effect is to cool even further the adsorbent **22**, with consequent enhancement of the activity and adsorbing capacity of the latter. When the oxygen first flows through the inner tube **10**, it is cooled down and once cooled, the oxygen is delivered from the nozzle **12** without loss due to evaporation. The adsorbent action of the glass cloth **24** in the flexible portion of the tube is not great but if any vapor forms on the surface of the glass it is removed from such phase by the charcoal which under the conditions described is highly effective as an adsorbent. Thus the hose as a whole is durable, flexible and maintains the liquid oxygen at a temperature where loss by evaporation is negligible.

The embodiment shown in Figs. 7 and 8 provides an improved construction, but in principle is substantially the same as that shown in Figs. 2 to 6 and the same or similar reference characters are applied to corresponding parts. In this embodiment the collar **14***a* is provided with a threaded exterior to receive an interiorly threaded sleeve **30** which extends outwardly so as to fit about the neck of a Dewar flask or the like container when being filled, thereby preventing the accumulation of frost.

The inner end of the outer tube **16***a* is connected to the tubular shell **18***a* by a coupling member or collar **34** which is circumferentially spaced from the inner tube **10** so as to provide a communication between the annular chambers defined by the outer tube **16***a*, the shell **18***a* and the inner tube **10**. The collar **34** is formed with an outwardly extending reduced stem **35** providing a shoulder against which the end of the tube **16***a* is seated and sealed by a ring of silver braze **36**. The inner end of this collar is formed with an inwardly extending flange **38** spaced from its periphery so as to define inner and outer annular recesses, the outer recess providing a clearance permitting the shell **18***a* to be circumferentially grooved or crimped, as indicated at **39**, so as to clamp the parts together. The inner recess receives the screen partition **20** and perforated metal disk **20***a* which are held in position by the peened-over edge of the flange **38**.

The coupling **11***a* is formed with an inwardly projecting stem **40** to receive the inner end of the tube **10** which is brazed thereto as indicated at **41** and the periphery of this coupling is flanged and grooved to provide a seat for the outer end of the shell and a recess for a band of silver braze **42** which seals the inner end of the shell to the coupling. Adjacent to its inner end the shell **18***a* is provided with an exhaust pipe **25** within which is a small sleeve **44** carrying a disk of fine mesh screen **45**.

The shell **18***a* is packed with activated charcoal **22** or other suitable adsorbent material and this packing is retained within the chamber by the screens **20** and **45**. That portion of the inner tube between the collars **14***a* and **34** is loosely wound with ⅛ inch of fiber glass cord **48** so as substantially to fill the annular chamber and thus provide a heat insulating packing. In all other material particulars the construction is substantially the same as that of the previously-described embodiment.

The present application is a continuation-in-part of my copending application, Serial No. 689,768, filed August 10, 1946, now Patent No. 2,640,332 granted June 2, 1953.

I claim:

1. A delivery hose for liquefied gas comprising an internal metal tube constituting the flow passageway, an outer tube separated from said inner tube by a heat insulating packing, and a packing of adsorbent material near one end of the hose in thermal contact with said internal metal tube; the space between the inner and outer tubes being otherwise substantially a vacuum.

2. A delivery tube for liquefied gas comprising an inner tube through which the liquefied gas passes, an outer tube circumposed about and in spaced relation to said inner tube and defining therewith an elongate annular chamber, means for hermetically sealing the end portions of said outer tube about said inner tube, means communicating with said annular chamber providing a gas-tight enclosure in thermal contact with said inner tube, and adsorbent material within said enclosure, said chamber and enclosure being evacuated.

3. A delivery tube for liquefied gas comprising a flexible inner tube through which the liquefied gas passes, the outer end of said inner tube having an extension providing a nozzle, a collar carried by said nozzle, a coupling carried by the inner end of said tube, a tubular shell circumposed about and in spaced relation to the inner end portion of said inner tube and defining therewith a gas-tight enclosure, said shell being sealed at one end to said coupling, a flexible outer tube circumposed about and in spaced relation to said inner tube and defining therewith an elongate annular chamber, the outer end of said outer tube being sealed to said collar and its inner end adjoining the outer end of said shell so that their respective interiors are in communication with each other, and carbonaceous adsorbent material within said enclosure, said chamber and enclosure being evacuated.

4. A delivery tube for liquefied gas comprising a flexible inner tube through which the liquefied gas passes, the outer end of said inner tube having an extension providing a nozzle, a collar carried by said nozzle, a coupling member carried by the inner end of said tube, a second collar circumposed about and in spaced relation to said inner tube between the first-mentioned collar and coupling member, a tubular shell circumposed about and in spaced relation to said inner tube with one end sealed to said second collar and the other end sealed to said coupling member so as to provide an enclosure, a flexible outer tube circumposed about and in spaced relation to said inner tube and defining therewith an elongate annular chamber communicating with said enclosure, the outer end of said outer tube being sealed to said first-mentioned collar and its inner end being sealed to said second collar, and carbonaceous absorbent material within said enclosure, said chamber and enclosure being evacuated.

5. A delivery tube as set forth in claim 2, wherein said annular chamber contains a heat insulating packing.

6. A delivery tube as set forth in claim 2, wherein a foraminous member is circumposed between said chamber and enclosure.

7. A delivery tube as set forth in claim 3, wherein said shell is provided with an exhaust tube for evacuating said enclosure and chamber.

8. A delivery tube as set forth in claim 3, wherein the collar carried by said nozzle is provided with a sleeve surrounding the nozzle.

9. A delivery tube for liquefied gas comprising spaced inner and outer tubular members defining an elongate annular chamber, the inner tubular member providing a

duct through which the liquefied gas passes, one of said tubular members having a bellows section permitting expansion and contraction relative to the other of said tubular members, means at the ends of said tubular members hermetically sealing said annular chamber, one of said means providing a coupling member for attachment to a supply of liquefied gas, and adsorbent material in thermal contact with said inner tubular member, said annular chamber being evacuated.

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