July 16, 1968 R. C. WOERNER 3,392,537

LIQUID CYLINDER SYSTEM

Filed March 29, 1967 2 Sheets-Sheet 1

FIG. 1.

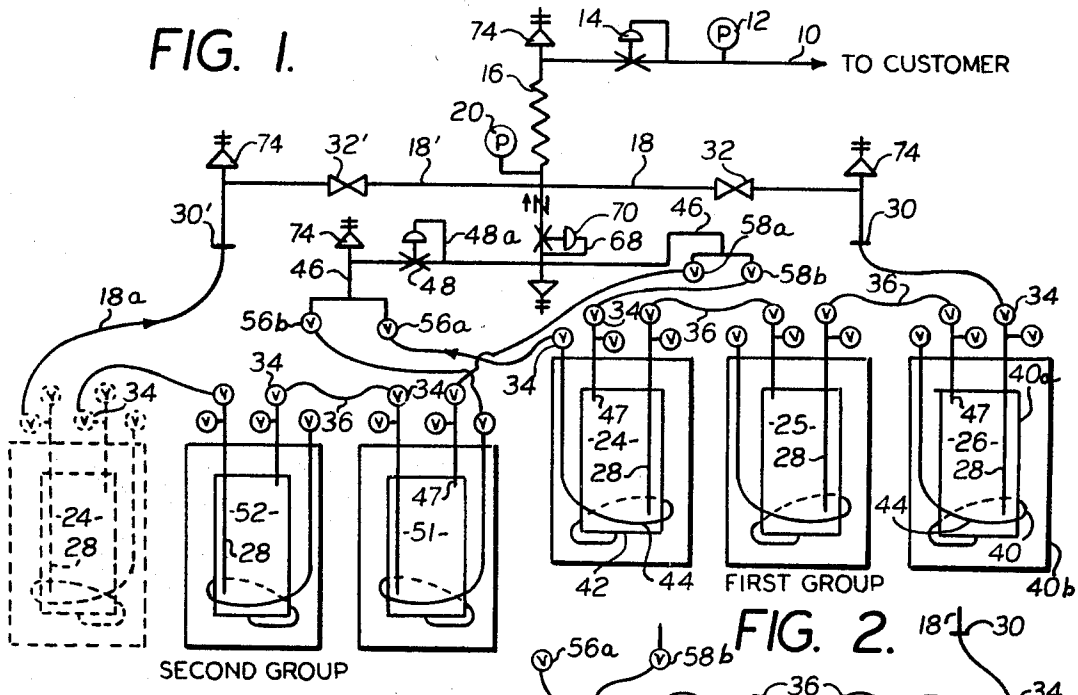


FIG. 2.

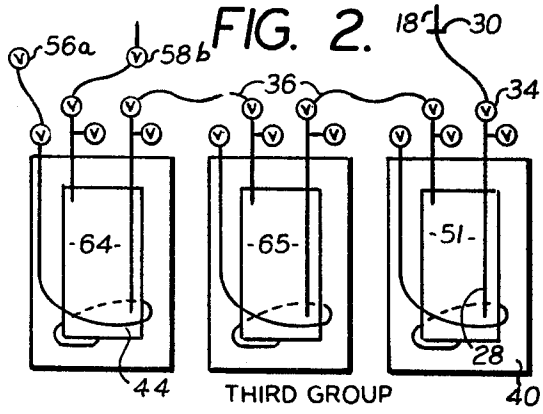
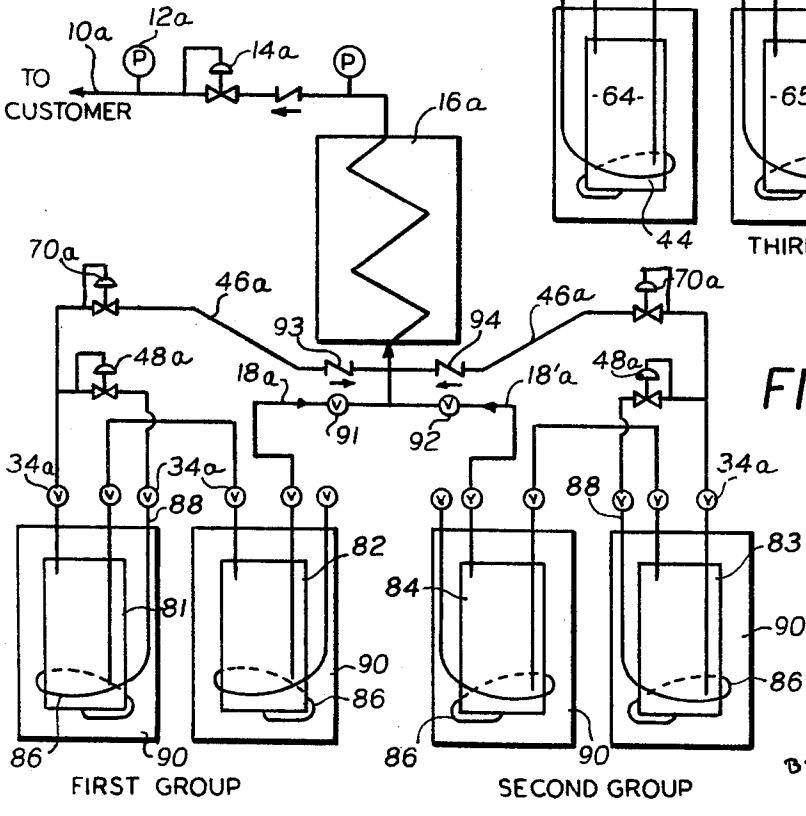


FIG. 4.



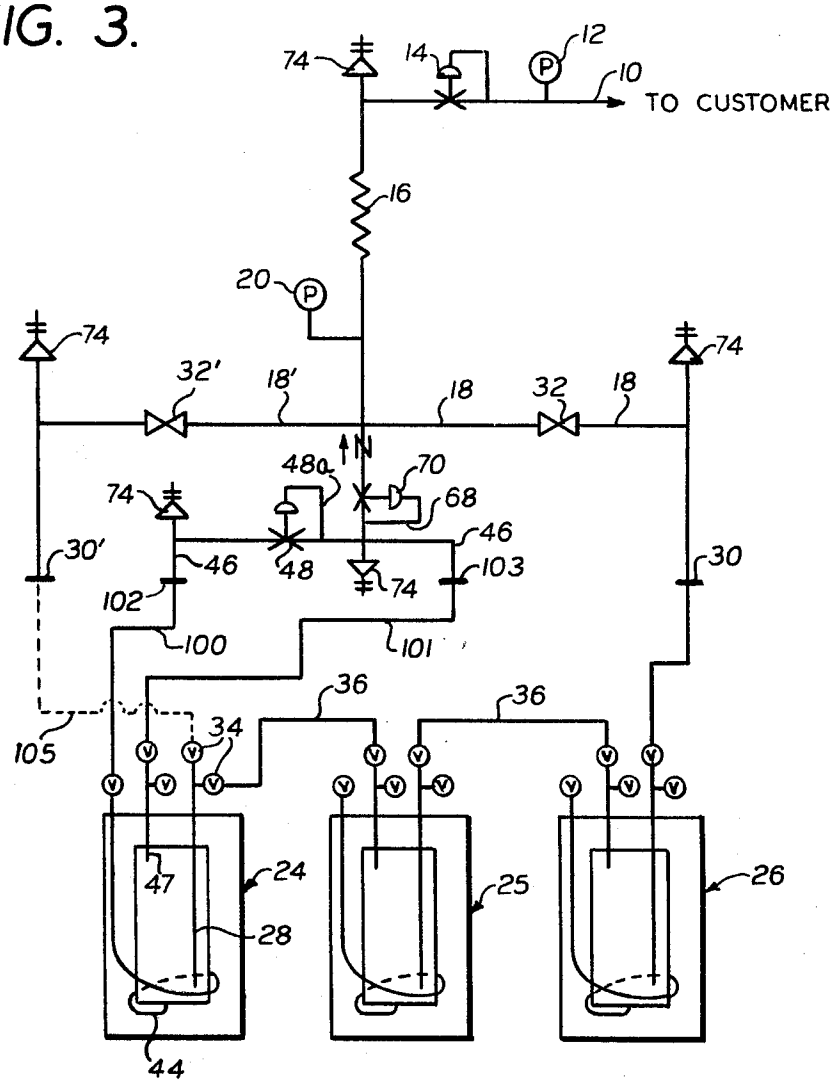
INVENTOR
RICHARD C. WOERNER
BY Francis B. Henry
ATTORNEY

July 16, 1968 R. C. WOERNER 3,392,537

LIQUID CYLINDER SYSTEM

Filed March 29, 1967 2 Sheets-Sheet 2

FIG. 3.



INVENTOR

RICHARD C. WOERNER

BY Francis B. Henry

ATTORNEY

United States Patent Office 3,392,537 Patented July 16, 1968

3,392,537

LIQUID CYLINDER SYSTEM

Richard C. Woerner, Scotch Plains, N.J., assignor to Air Reduction Company, Incorporated, New York, N.Y., a corporation of New York

Filed Mar. 29, 1967, Ser. No. 626,727
16 Claims. (Cl. 62—50)

ABSTRACT OF THE DISCLOSURE

This invention is directed to a distribution system for vaporizable liquid in which the liquid is stored in individual storage containers and is dispensed under pressure. A pressurizing system is associated with at least one of the storage containers to maintain a desired pressure in the system.

This invention relates to distribution systems for cryogenic gases. More particularly the invention relates to the distribution of gas, in vapor phase, in a system having cylinders in which the gas is stored in liquid phase. The invention is intended primarily for bulk distribution of gases, such as oxygen, nitrogen and/or argon, which can be more conveniently stored as liquids in individual containers.

It is an object of this invention to provide an improved gas distribution system, with a plurality of liquid storage cylinders connected in series and pressurized to make the rate of withdrawal of liquefied gas from the cylinders independent of the number of cylinders in the system.

Another object is to provide a gas distribution system with liquid storage cylinders connected in series for sequential delivery of the liquid from successive cylinders and with means for pressurizing the system through pressure applied to the last cylinder in the series. The invention provides for replacement of empty cylinders with full cylinders without interrupting the supply of gas to the customer's distribution line, and for changeover to other independent, series-connected, liquid storage cylinders as those of a first group become exhausted.

Another object relates to an improved method of connecting the liquid storage cylinders in different groups for efficient operation and economy in the use of cylinders.

Other objects, features and advantages of the invention will appear or be pointed out as the description proceeds.

In the drawing, forming a part hereof, in which like reference characters indicate corresponding parts in all the views:

FIGURE 1 is a diagrammatic view of a cryogenic gas distribution system made in accordance with this invention;

FIGURE 2 is a diagrammatic view showing a subsequent arrangement of cylinders for use in the distribution system shown in FIGURE 1; and

FIGURES 3 and 4 are diagrammatic views showing modified forms of the distribution system shown in FIGURE 1.

The gas distribution system shown in FIGURE 1 includes a customer's line **10** having a pressure gauge **12** and a line pressure regulator **14**. This customer's line **10** is connected with the downstream end of a vaporizer **16**; and liquid is supplied to the upstream end of the vaporizer **16** through a liquid supply line **18**. A gauge **20** indicated the pressure in the liquid supply line **18**.

The pressure gauges **12** and **20**, pressure regulator **14** and vaporizer **16** may be mounted in a control panel for the convenience of the operator. The vaporizer **16** preferably may comprise one or more passes of tubing on which are mounted heat absorbing fins. The purpose of the vaporizer is, of course, to warm up the cryogenic liquid so that it changes from a liquid phase to a gaseous phase. In most cases, the customers desire a gaseous product. Of course, this system can also deliver liquid product to a use point. This can be accomplished by taking liquid directly from a cylinder and not sending it into the vaporizer.

The liquefied gas for the liquid supply line **18** comes from a group of storage cylinders **24**, **25** and **26** connected in series with one another. A discharge pipe **28** leading from the lower end of the cylinder **26** is connected with the liquid delivery line **18** by a connector **30**. There is a shut-off valve **34** in pipe **28** at the upper end of the cylinder **26**. The valve **32** may be mounted on the abovementioned control panel.

Each of the cylinders in the First Group is provided with a long discharge pipe **28** which extends through the top of the cylinder and terminates adjacent the bottom of the cylinder and a short pipe **47** which also extends through the top of the cylinder and terminates close to the top of the cylinder.

As shown in FIG. 1 the long pipe **28** in cylinder **25** is connected to the short pipe **47** in cylinder **26** by means of a flexible tubular connector **36**. The long pipe in cylinder **24** and the short pipe in cylinder **25** are similarly connected. Both the long and short pipes may be closed off by means of valves which are illustrated schematically in FIG. 1. Flexible tubular connectors are used due to the fact they are easy to handle and allow for some relative movement between the cylinders.

The cylinders **24**, **25** and **26**, which are in fact representative of all the cylinders in the different embodiments discussed below, are of the vacuum jacketed variety. Many different kinds of vacuum insulated cylinders that are specifically designed for storing cryogenic liquids are commercially available. A specific description of the structure of the cylinders is therefore unnecessary. The reference number **40** is used to denote the vacuum space between the interior cylinder **40*a*** and the outside cylinder **40*b***.

The flexible tubular connectors **36** are not vacuum insulated and therefore ambient temperature comes in relatively close contact with product passing through the connector. The purpose this serves will be described below.

For purposes of explanation, cylinder **26** will be referred to as the first cylinder and cylinder **24** as the last cylinder in the first group. A liquid line **42** is connected with the bottom of the last cylinder **24** and conducts liquid to to a vaporizer **44** which is located in the bottom portion of the vacuum space **40*b*** in the last cylinder. The vaporizer may conveniently be a single turn of tubing wrapped around the lower end of cylinder **40*a*** and is shown schematically in FIG. 1. The vaporizer could be located outside the cylinder **24**, but this is not preferred since it would be more susceptible to damage.

For purposes of standardization, each cylinder, in the preferred construction, is equipped with an internal vaporizer **44** which can be referred to as an internal pressure building coil. This coil would be connected to a valve **34**, on the upper portion of the cylinder so that flow through the coil can be controlled. When the cylinders are connected in series as in FIG. 1, only the vaporizer or pressure building coil in the last cylinder in the series is operated. The pressure building coils in the remaining cylinders are closed off by means of the aforementioned valves.

The downstream end of the vaporizer **44** associated with the last cylinder is connected by a tubular line to a valve **56*a*** in conduit **46**. The valve may be mounted on the aforementioned control panel. Conduit **46** extends into the control panel and then back to the cylinder **24** and is connected to pipe **47**. A shut-off valve **34** is positioned in said connection. A pressure building regulator **48** is

positioned in line 46 and is set to maintain a desired pressure in cylinder 24. This is accomplished in the following manner. When valves 34, 56*a* and 58*b* are opened and valves 46*b* and 58*a* are closed and the pressure in cylinder 24 is less than that desired as determined by the set pressure on regulator 48, the regulator 48 will open. Liquid which is in the coil 44 will vaporize and pass through conduit 46, regulator 48 and back into the upper portion of cylinder 24. Vaporization takes place in coil 44 due to the fact that the temperature in the space 40 is higher than in the cylinder 40*a*. This vaporization and consequent pressure build-up will continue until the pressure in cylinder 24 and in conduit 46 reaches the set pressure buildup regulator. At that time, regulator 48 will close and prevent the removal of further liquid from the bottom of the cylinder 24. The regulator 48 will remain closed until the pressure in the cylinder 24 drops below set pressure at which time it will open and allow flow through conduit 46. The specific structure of the pressure buildup regulator will not be described in view of the fact that many different varieties of pressure regulators are known in the art and could be used. In a typical pressure buildup regulator the pressure downstream of the regulator is continually sensed, as for example through conduit 48*a*. This sensed pressure could, for example, act against a preset spring force to regulate downstream pressure.

The delivery pressure of the regulator 48 is the pressure in the entire group of cylinders 24, 25 and 26, since these cylinders are directly connected in series with one another; and it is also the pressure at which liquid is supplied from this first group of cylinders to the liquid delivery line 18 and to the upstream end of the vaporizer 16. Thus the pressure indicated by the gauge 20 is substantially the same pressure as the delivery pressure of the regulator 48 with some drop for the losses incident to the flow of the liquefied gas through the different passages and fittings.

When liquefied gas is supplied to the vaporizer 16 from the first group of cylinders, the cylinder 26 has its liquid drawn off first. The liquid in the tubing connection 36 between the cylinders 25 and 26 is subject to some evaporation as a result of heat absorbed from the ambient atmosphere and the vapor produced by this evaporation is enough to maintain the gas pressure over the liquid in the cylinder 26 as the level of liquid is drawn down with discharge of liquid through the pipe 28 and the liquid delivery line 18 to the vaporizer 16.

As soon as the liquid in the cylinder 26 has dropped below the lower end of the pipe 28, the vapor pressure in the cylinder 26 begins to drop faster than the rate of evaporation in the tubing connection 36 and liquid from the cylinder 26 is forced out through the pipe 28 of cylinder 25 into the cylinder 26 for further discharge into the liquid delivery line 18. With liquid flowing in the tubing connection 36, it only remains long enough to be partly vaporized by heat leakage.

It has been found that as cylinder 26 empties of liquid, approximately 4 or 5% of the contents of cylinder 25 is removed in order to maintain a constant pressure in cylinder 26. After the cylinder 26 has been emptied to the level of the lower end of tube 28 there is intermittent liquid and gas flow from cylinder 25 to cylinder 26 in order to maintain the liquid level just at the tube 28 entrance opening. Cylinder 25 continues to supply its liquid to cylinder 26 until its liquid level drops to the level of the entrance to tube 28. While this liquid level has been dropping, cylinder 24 has been providing a small amount of liquid to be vaporized in connecting line 36 so as to maintain the pressure in cylinder 25 in much the same manner that cylinder 25 provided a small amount of liquid to maintain pressure in cylinder 26. Similarly when the liquid level in cylinder 25 drops below the tube entrance 28, an intermittent flow of liquid and vapor will flow from cylinder 24 so as to maintain the liquid level at the entrance to the tubes 28 in both cylinders 25 and 26.

In order to further stabilize the system it has been found helpful to place restrictor plugs in the connecting lines 36. These plugs, which contain orifices serve to further control the fluid flow into the next upstream cylinder.

It has been noted that when liquid is being transferred from cylinder 24 to cylinder 25, the tubing connection 36 becomes completely frosted. This would indicate to an alert operator that he is operating on his last cylinder and replacement cylinders should be ordered. The method by which the operator incorporates new full cylinders in the system will be discussed below.

It has been found that under certain conditions pressure builds up in conduit 46 and in the cylinder 24. This pressure buildup can exceed the set pressure of regulator 48 since this valve only operates to open when a pressure lower than the set pressure is sensed. To relieve this pressure build up an economizer regulator 70 is provided in a conduit 68 which connects the conduits 46 and 18. The economizer regulator is set at a pressure higher than the regulator 48 and will lift when this pressure is reached and dump the pressurized vapor into the vaporizer 16.

The excess pressure buildup in the system could be caused by a number of things. For example heat leak due to close proximity to a heat source such as a radiator, engine etc. Heat leak over a prolonged period during which the system is not in operation.

In a typical operational set up regulator 48 will be set at 100 p.s.i. regulator 70 at 150 p.s.i. and regulator 14 at 75 p.s.i. It has been found that a 25 lb./in.^{2} increment between regulators 48 and 14 provides good operating characteristics.

When cylinders 25 and 26 are essentially evacuated and cylinder 24 is furnishing the liquid to be veporized in the vaporizer 16, the operator should replace the evacuated cylinders with full ones. There are a number of ways in which this can be done, one of which is illustrated in FIG. 1. The system is designed so that gas flow to the consumer line is never interrupted.

Each pipe 28 is provided with two connections, controlled by valves through which liquid can be drawn. On seeing that cylinder 24 is supplying liquid, the operator connects a conduit 18*a* between the second connection on tube 28 on cylinder 24 and connector 30' on delivery line 18'. Thus the connection between cylinders 24 and 25 through conduit 36 may be maintained while the connection to line 18' is hooked up. When the last mentioned connection is complete and the associated valve set 34 opened, valve 32 in the line 18 may be closed and valve 32' opened simultaneously. These valves may be conveniently located on the control panel. Thus liquid will be continuously supplied to vaporizer 16. When this is done the valve 34 associated with connection 36 between cylinders 24 and 25 should be closed. The connections between cylinder 26 and line 18, and between cylinders 24, 25 and 26 may then be broken and cylinders 25 and 26 removed. Only cylinder 24 will then be operating to supply liquid product. Replacement cylinders 52 and 51 are then connected in series relationship with cylinder 24 in the manner shown in FIG. 1, second group. The pressure building circuit associated with the last cylinder 51 in the group is then connected to valve connections 56*b*, 58*a* and pressure is built up in cylinders 51 and 52 until they are at the same pressure as cylinder 24. When this has been done the valve 34 in pipe 47 of cylinder 24 is opened and the pressure building circuit associated with cylinder 24 is closed off and disconnected. Thus the last cylinder 51 will pressurize the preceding cylinders in the manner described above in connection with cylinder 24 in the first group. The pipe 47 in cylinder 24 has a dual connection so that a concurrent coupling with both the line 46 and the associated interconnecting conduit 36 to cylinder 52 may be had.

When cylinders 24 and 52 have delivered all their fluid and cylinder 51 is supplying the demand, the operator proceeds to replace the empty cylinders with new ones 64, 65 in the same manner as described above with refer-

ence to cylinders **25** and **26**. The operational set-up in which cylinders **64** and **65** are on the line is shown in FIG. 2.

In another and more simple embodiment of the invention the independent valves **56***a*, **56***b* and **58***a*, **58***b* can be replaced by a pair of three position selector valves so that by merely turning a single valve alternate supplies could be selected. The third position of the valve would interrupt flow entirely.

In the simplest embodiment the valves **56***a*, **56***b*, **58***a*, and **58***b* are entirely eliminated. This embodiment is shown in FIG. 3 in schematic. The vaporizer **44** is connected to line **46** by means of a conduit **100** and a connector **102**. Similarly the tube **47** is connected to the line **46** by conduit **101** and connector **103**. The connectors may be of the conventional screw variety used in cryogenic couplings. When operating on the liquid supply of the last cylinder **24** as indicated by excessive frosting in the line **36** between cylinders **24** and **25**, a connection **105** is made between the discharge tube **28** of cylinder **24** and delivery line **18'** through connection **30'** as shown in dotted lines. As mentioned previously, tube **28** has two outlet connections each controlled by a valve **34**. When this connection is complete the valve **32'** is opened and valve **32** is closed so that liquid from cylinder **24** goes directly to line **18'**. Cylinders **25** and **26** are then disconnected and replaced with full cylinders **52** and **51**. After the series connection between cylinders **24**, **52** and **51** are made, as shown in FIG. 1, second group, the pressure buildup circuit of cylinder **24** is disconnected at the cylinder. The same connecting lines **100** and **101** can then be used to connect up the pressure building circuit in the last cylinder **51** in the series. It has been discovered that the pressure from the cylinder **24** will not drop significantly over the short period of time it takes to hook up the pressure building circuit to the last cylinder in the series. This last mentioned simplified embodiment is much less expensive in that the valves **56***a*, *b* and **58***a*, *b* are eliminated.

The system is provided with valves and connectors wherever needed and is also provided with safety valves **74** at all locations where pressure may build up when the passages beyond these locations are shut off by closed valves or where the system is improperly operated.

FIG. 4 shows a modified form of the invention. The distribution system, except for the cylinders, is essentially the same as in FIG. 1 though the positions of various parts are not the same. However, the corresponding parts are indicated by the same reference characters as in FIG. 1 and with a letter *a* appended. The system is somewhat simplified in that safety valves and connections are omitted, but it will be understood that this is merely to simplify the drawing and that in actual practice these safety valves and connections are provided where needed as in FIG. 1.

The cylinders shown in FIG. 4 are the same as those used in the embodiments shown in FIGS. 1, 2 and 3. The pressure building coils **86** are shown in each cylinder **81**, **82**, **83**, **84** for purposes of illustration. Conduits **88** extend down through the vacuum space to the coils. In FIG. 4 the coil **86** of the cylinder **81** is used to pressurize the cylinders in the first group in the same manner that coil **44** in cylinder **24** pressurizes the cylinders of the first group in FIG. 1. In this arrangement the groups are arranged so that they can supply the vaporizer **16***a* alternately. When the first group is supplying liquid and valve **91** is open and **92** closed, back pressure regulator **48***a* serves to maintain pressure in the cylinders on the left and conduit **18***a* directs liquid from said cylinders to the vaporizer. Economizer regulator **70***a* directs fluid to the vaporizer through a check valve in line **46***a* when its set pressure is exceeded. The regulators **48***a* and **70***a* work in the same manner as regulators **48** and **70**, described above. When the liquid in the first group is almost exhausted, control valve **91** is closed and control valve **92** is opened. By doing this the flow of liquid from the first group of cylinders will be interrupted and the flow from the second group will be connected. Check valves **93** and **94** prevent the back-up fluid in lines **46***a*. By arranging the cylinders as described in FIG. 4, a continuous supply of fluid to the vaporizer **16***a* is assured. With valve **91** closed, empty cylinders in the first group may be replaced.

It will be understood that the groups of cylinders in FIG. 3 can contain more than two cylinders, just as the groups shown in FIG. 1 can contain more than three cylinders, if desired. In practice, the number of cylinders used in each group depends upon the gas requirements of the customer. If a customer requires large amounts of gas, more cylinders are used so as to reduce the frequency of visits which the gas supplier has to make to the customer's plant.

The preferred embodiment of the invention has been illustrated and described, but changes and modifications can be made and some features can be used in different combinations without departing from the invention as defined in the claims.

What is claimed is:

1. A cryogenic liquefied gas distribution system including a plurality of storage cylinders for gas in liquid phase and under pressure, tubing connections from the lower part of one cylinder to the upper part of the next cylinder, said tubing connections connecting the cylinders in series with one another, a vaporizer from which gas is supplied to a customer's line, a liquid-conveying line from the first cylinder in the series to the vaporizer, means for maintaining a pressure on the liquid in the series-connected cylinders including apparatus that vaporizes liquid of the last cylinder in the series, a gas line through which vaporized gas from the last cylinder is delivered back to said last cylinder to increase the pressure of gas above the liquid in the last cylinder and to maintain pressure on all of the series-connected cylinders.

2. The distribution system described in claim **1** characterized by the means for maintaining pressure on the liquid in the last cylinder including a pressure building vaporizer, a liquid supply line leading from the lower part of the last cylinder to one side of the pressure building vaporizer, a gas line leading from the other side of the pressure building vaporizer to the upper part of the last cylinder, and a pressure-maintaining regulator in said gas line for regulating the pressure of the gas.

3. The distribution system described in claim **1** characterized by the storage cylinders being at least partly vacuum-jacketed and the tubing connections from each cylinder to the next cylinder including a portion that extends outside of the jacket and in which some liquid is vaporized by heat leakage from the ambient atmosphere through said tubing connections when the cylinder to which a tubing connection supplies liquid is partially full and there is little or no flow from the next cylinder to the partially full cylinder.

4. The distribution system described in claim **2** characterized by a line pressure regulator beyond the first-mentioned vaporizer and through which gas from said vaporizer is supplied to the customer's line, and the pressure-maintaining regulator has a substantially higher delivery pressure from that of the line regulator.

5. The distribution system described in claim **2** characterized by a connecting gas passage leading from said gas line to the first vaporizer, and an economizer regulator in said connecting gas passage and having a delivery outlet communicating with the first vaporizer, the economizer regulator having a delivery pressure substantially higher than that or the pressure regulator in said gas line from the pressure building vaporizer to the last cylinder.

6. The distribution system described in claim **4** characterized by an economizer pressure regulator communicating at its upstream side with said gas line at a location on the downstream side of the pressure-maintaining regulator, and said economizer pressure regulator, pressure-

maintaining regulator and line regulator having progressively lower delivery pressures differing from one another by substantial amounts.

7. The distribution system described in claim 6 characterized by the delivery pressure of the economizer pressure regulator, pressure-maintaining regulator and line regulator being 150; 100 and 75 pounds per square inch.

8. The distribution system described in claim 1 characterized by two different liquid delivery lines leading to the vaporizer, with connections for connecting each liquid delivery line with a different group of series-connected cylinders, and valve means in the liquid delivery lines for shutting off one line from the vaporizer for change of cylinders in the group that is connected with that line.

9. The distribution system described in claim 2 characterized by the gas line having branches at one end for alternately connecting with another pressure building vaporizer on a different group of liquid storage cylinders, and having branches at the other end for alternately connecting with the last cylinder of different groups of cylinders, and valve means for selectively shutting off either of the branches of said gas line.

10. The distribution system described in claim 2 characterized by each of the cylinders having a liquid storage compartment and a vaporizer coil extending around the liquid storage compartment, valve means at the delivery end of each coil, the vaporizer coil of the last cylinder being the pressure building vaporizer, and the vaporizer coils of the other cylinders being available for use as pressure building vaporizers when and if the cylinder positions are interchanged.

11. The distribution system described in claim 2 characterized by a second group of cylinders including a last cylinder with a pressure building vaporizer, the pressure building vaporizers being located below the level of the liquid in the last cylinders of their respective groups, different branch lines connecting the pressure building vaporizers with the same gas line on the upstream side of the pressure-maintaining regulator, different branch lines connecting the upper portions of the last cylinder of each of the different groups with the gas line on the downstream side of the pressure-maintaining regulator, switch-over means for the different branch lines for selectively putting the last cylinder of either group into communication with the pressure-maintaining regulator, other valve means between the preceding and last cylinders of each group for isolating the last cylinder to permit removal of the last cylinder from each group, connections for putting the last cylinder of one group into the second group as the first cylinder of the second group, a liquid delivery line leading from the first cylinder of the second group to the first vaporizer, valve means in each of the liquid delivery lines for selectively shutting off each of the cylinder groups from the first vaporizer, and a connecting gas passage leading from the gas line on the downstream side of the pressure-maintaining regulator to the upstream side of the first vaporizer, and an economizer pressure regulator in said connecting gas passage, the economizer pressure regulator having a delivery pressure substantially higher than that of the pressure-maintaining regulator.

12. The method of supplying cryogenic gas from series-connected storage cylinders to a customer's supply line, which method includes storing the gas in liquid phase in said cylinders, withdrawing liquid from the bottom of the first cylinder, vaporizing the liquefied gas withdrawn from the first cylinder, regulating the pressure of the vaporized liquid, and supplying the gas in vapor phase to the customer's line at a regulated pressure, supplying liquefied gas from the bottom of one cylinder to the top of the next preceding cylinder, withdrawing liquefied gas from the last cylinder, vaporizing the liquefied gas from the last cylinder, and regulating the pressure of the vaporized gas from the last cylinder and returning that gas to the top of the last cylinder to pressurize the liquefied gas in the series-connected cylinders.

13. The method described in claim 12 characterized by drawing down successive cylinders in sequence, vaporizing liquefied gas in connections between successive cylinders during the time in which the liquid level is being drawn down in the next preceding cylinder beyond the connection to supply gas to the space in said next cylinder above the falling liquid level therein and at a pressure to maintain the pressure in the cylinder in which the liquid level is being drawn down.

14. The method described in claim 12 characterized by supplying gas directly from the last cylinder to the customer's supply line in vapor phase whenever the pressure in the last cylinder exceeds a set pressure.

15. The method described in claim 12 characterized by supplying gas alternately from two different groups of storage cylinders with the cylinders of each group connected in series for successive drawing down of the liquid in the cylinders starting with the first cylinder of one of the groups and before drawing down completely the liquefied gas in the last cylinder of the said one group, shifting from supplying gas from said one group to another group so that the gas supply is uninterrupted.

16. The method described in claim 12 characterized by withdrawing liquid from said series until the liquid is entirely supplied from the last cylinder, removing liquid from the bottom of said last cylinder and vaporizing it, replacing the empty cylinders in the series with full ones, discontinuing the pressurization of the said last cylinder and commencing the pressurization of the last of the series of replacement cylinders.

References Cited

UNITED STATES PATENTS

2,968,162	1/1961	Acomb	62—50
3,066,495	12/1962	Biggins et al.	62—50
3,319,432	5/1967	Nebgen	62—45
3,319,433	5/1967	Pauliukonis et al.	62—45

LLOYD L. KING, *Primary Examiner.*