UNITED STATES PATENT OFFICE

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APPARATUS FOR STORING AND DISPENSING LIQUEFIED GASES

Odd A. Hansen, Kenmore, N. Y., assignor to The Linde Air Products Company, a corporation of Ohio

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13 Claims. (Cl. 62—1)

This invention relates to a method of and apparatus for storing and dispensing liquefied gases which have boiling points at atmospheric pressure below 230° K., particularly to a system for providing oxygen or nitrogen at a substantially constant superatmospheric pressure for industrial use, generated from the respective liquefied gases which are shipped to the place of consumption and supplied to the system in the liquid state.

The supply of large quantities of oxygen to industrial consumers has been effected by systems employing apparatus similar to that of U. S. Patent No. 1,943,047. In such apparatus liquid oxygen is stored in a pressure-resistant vessel that is insulated to reduce absorption of heat from the atmosphere. Since the demands for gas are irregular and usually intermittent with periods of shut-down that may be of considerable duration, it was necessary to provide for the effects of constant heat leak to the stored liquid. Also, in such systems any withdrawal of liquid to be gasified also acts to add heat to the liquid holding vessel, thus it was necessary not only to construct the apparatus for pressures considerably in excess of the desired delivery pressure, but also to provide heavy walled gas storage receivers and one or more pressure-reducing devices in addition to the devices for controlling the gasification of liquid oxygen to supply gaseous oxygen as required for consumption.

A principal object of the present invention is to provide a system for storing and dispensing liquefied gases and a mode of operation and control thereof that avoids the objections of systems heretofore used as indicated in part above.

Other objects of the invention are to provide a system that is fully automatic in operation; that does not require the use of gaseous storage receivers to avoid loss of gas; that permits the use of a storage vessel constructed to withstand only a moderately higher pressure than the gas supply pressure; that supplies substantially all of the gas delivered to the consumer from direct evaporation of liquefied gas without addition of heat to the stored liquid; that supplies gas at such a constant pressure that a gas pressure-reducing device is not needed; that permits recharging of the liquid container without interruption of delivery of gas to consuming devices, thus avoiding the use of duplicate containers or a reserve storage means; and that provides for both a normal demand for gas and for suddenly imposed relatively large demands for gas for short periods with a heat energy source having a maximum heating rate only slightly greater than that required for the normal or average demands for gas.

These and other objects of the invention will be evident from the following description taken with the accompanying drawings, in which:

Fig. 1 is a diagrammatic view illustrating a preferred embodiment of a system for the storage and dispensing of a liquefied gas according to the invention; and

Fig. 2 is a view of a schematic diagram of electrical connections for automatic control of the valves of the apparatus illustrated in Fig. 1.

This application is a continuation-in-part of my copending application, Serial No. 491,746, filed June 19, 1948, and which has become Patent No. 2,479,070 of August 16, 1949.

Referring particularly to Fig. 1, there is depicted a system for storing and dispensing gaseous material such as liquid oxygen, illustrative of the principles of the invention. A supply of liquid oxygen is held within an inner vessel 10, the walls thereof having sufficient thickness and strength to withstand a pressure which need be only moderately higher than the pressure of gaseous oxygen to be delivered to the consuming devices. An outer shell 11 gas-tightly surrounds the inner vessel 10, and provides an insulating space 12 which may preferably have a low apparent density filling of finely divided solid material such as magnesium carbonate and in addition, preferably is evacuated of gases to provide a powder-in-vacuum insulating means resistant to heat transfer to an exceptionally high degree.

When straight powder insulation is used the insulation thickness required must be very great, such that the volume of insulation exceeds the volume of the vessel by more than 50%. With powder-in-vacuum the thickness should be less, but not less than ¼ foot, the space being also evacuated to a combined gas and vapor pressure therein below 10 millimeters of mercury absolute, but not necessarily lower than 10 microns of mercury. The thickness of the insulation space and the pressure therein should be correlated within the ranges indicated and with the character of the filling to restrict heat inflow thereto through to the vessel to less than 5 B. t. u. per hour per square foot of surface of the inner vessel under a temperature differential of 200° C. as will obtain when the vessel is charged with liquid oxygen. Alternatively, straight vacuum with high polished interior surfaces could also be used for insulating the liquid provided an extremely high vacuum is maintained, however,
for vessels over two feet in diameter the powder-in-vacuum insulation is usually preferable.

With a powder-In-vacuum type of insulation the pressure increase in container 10 during idle periods is very slow and according to 31 vessel may be designed for a lower maximum pressure and of lighter weight. When highly effective powder-in-vacuum insulation is employed, the outer shell 11 is made gas-tight and there is preferably provided a means for maintaining the vacuum in the vessel. From the conclusions of heat leak into the liquid from the surrounding atmosphere may be kept very low so that the pressure rise in the vessel 10 is slow during periods of complete shut-down even through no gas receivers are provided in communication with the gas phase of the vessel 10, as was formerly customary. Suitable means for maintaining the vacuum may be provided in the form of a vacuum pump V, the inlet of which is connected to the interior of the shell 11 by the connection 14 controlled by a valve 15. The vacuum pump V may be driven by a directly connected electric motor 16.

The vessel 10 is preferably supported independently of the filling in space 12 by suitable supports extending through the insulating space, as for example by suspending it on thin rods 13 secured at their lower ends to the vessel and at their upper ends to the wall of the shell 11. The container is provided with gas and liquid conduits which pass from the inner vessel through the insulating space 12 to points outside of the shell 11. The places where such conduits pass through the shell are, of course, sealed gas-tight. One such connection 17 extends from the bottom of the inner vessel 10 to the high pressure chamber of a liquid level indicating gauge 18. The low pressure side of the gauge 18 is in pressure communication with the upper part of the inner vessel 10 through a connection 19. The connection 19 also has branches 20 and 21 connected respectively to the pressure responsive elements in pressure switches 22 and 23, the function of which will be hereinafter explained.

One connection normally employable for gas phase withdrawal, is a conduit 24 connected with the top of the inner vessel 10 to which may be connected a safety release valve 25. Preferably, there are two independent connections for withdrawal of liquid from the vessel 10. One of these, in the form of an eduction tube 26, is the main outlet for liquid, and this passes from a point near the bottom of the vessel 10 upwardly through the upper walls of the vessel 10 and shell 11. The eduction tube conduit 26 connects directly to the inlet end of a vaporizer passage or coil 27 disposed within a heater jacket 28. Interposed in the conduit 26 is a flow-controlling valve 29 which is automatically operable by a solenoid 30. From the discharge end of the vaporizing coil 27, the oxygen vapor passes through a conduit 31 to a superheater passage or coil 32 within a heating jacket 33. From the superheater coil 32 the warmed oxygen vapors are conducted directly to the customers' pipeline or consumers' apparatus by a service connection 34. The other liquid outlet is a conduit 35 connected to the bottom of the inner vessel 10 and which forms part of a means for building and maintaining a pressure in the container 10 at a substantially constant value suitable for effecting delivery of the liquefied gas to the vaporizer 27 and superheater 32 for delivery to the service connection 34 at the desired substantially con-

stant pressure. Such means includes an external fluid circuit beginning with the conduit 35, which connects to the inlet end of a vaporizer passage or coil 36 that is preferably surrounded by the in-vacuum insulation. The conduit 35 'preferably controls the conduit 35. The discharge end of the coil 36 is connected with the gas phase conduit 24 by a conduit 37. The conduit 38 is controlled by an automatically operable valve 39 which may be operated by a solenoid 40. The valve 39 also has interconnected between the valve 39 and the conduit 24 a stop-valve 39'. The vaporizer coil 36 is located below the level of the liquid in the vessel 10, and preferably somewhat lower than the lowest point on the bottom of the vessel 10. The specific construction thereof and the manner of applying heat to the gas material within the vaporizer 36 may vary depending upon circumstances. Preferably, however, the heat is supplied by a liquid heating medium passed through the jacket 37 as will hereinafter be described. The pressure building valve 41 may be located either in the gas or liquid line portions of the pressure building circuit but is more conveniently located in the gas line 38. The valve 39 is made responsive to the pressure in the vessel 10 by an electric circuit hereinafter described so that when the pressure within the inner vessel 10 falls below an operating value not much different from the service pressure desired to be maintained in the conduit 34, the pressure switch 22 acts to energize the solenoid 40 to open the valve 39 which allows liquid to flow by gravity into the vaporizer coil 36. The vapor produced passes through conduits 36 and 24 to the gas phase of the vessel 10 for building a non-equilibrium pressure therein. As soon as the pressure exceeds a slightly higher desired operating value, the pressure switch 22 opens to deenergize the solenoid 40 which allows the valve 39 to close.

The supporting means 13 and the conduits 11, 13, 17, 18, and 35 where they pass through the insulating space, are constructed as to material and length to provide substantial resistance to heat conduction therethrough toward the inner ves-

sels. If the pressure in the inner vessel 10 should exceed the operating value, gas is allowed to pass out through conduit 24 which has its outer end connected to the conduit 31, so that such gas may be warmed in the superheater 32 before it is passed to the service connection 34. The portion of conduit 24 nearest the conduit 31 has interposed therein a check valve 43 opening in the direction toward conduit 31. This portion of conduit 24 is also controlled by a control valve 44 which is operateable by a solenoid 45. Also in conduit 24 between control valve 41 and the conduit 38 is a stop valve 46. Control by the action of the pressure switch 23, which, when the pressure in vessel 10 exceeds the operating value to be maintained, closes its circuit and energizes the solenoid 42, which opens the valve 41. The energizing of solenoid 42 by pressure switch 23 is arranged to simultaneously deenergize the solenoid 30 so that the valve 29 will close. Thus when the valve 41 is open, valve 29 is closed and vice versa, so that liquid and gas withdrawal cannot occur simultaneously to the delivery conduit 34, and the pressure within the inner vessel 10 is quickly reduced to the desired operating pressure. In pressure communication with the service connection 34 is a pressure switch 44 responsive to a pressure higher than the desired
service pressure and arranged to be open only when such higher pressure is exceeded. Normally, pressure switch 44 is closed to permit pressure switch 23 to control valves 28 and 41. The service connection 34 also has interposed thereon a temperature-sensitive element of a thermally operable switch 45 which functions to stop operation in the event that the temperature of the outflowing oxygen falls below a predetermined minimum, for example about 40°F.

Means for recharging the liquid vessel 10 is also provided and to avoid the use of additional conduits through the insulation space 12 that might increase the paths of heat leak, use is made of the conduits 24 and 35 for filling into the gas or liquid spaces of the vessel 10. To this end there is provided a filling connection 46 having branches 47 and 48 controlled by normally closed valves 47' and 48', respectively. The branch 47 connects with the liquid phase conduit 35 at a point between valve 35' and the vaporizer coil 36. Branch 48 joins the conduit 24 between the stop valve 24' and the heated vessel 41. Valves 24' and 48' normally remain open. Since liquid oxygen is ordinarily transported at or near atmospheric pressure and the vessel 10 operates at a substantially constant superatmospheric pressure, the charge of liquid must be forced in against the pressure. This is conveniently done by a pumping means and a metering device which are associated with the liquid oxygen transport that would be coupled to the connection 46. The liquid oxygen delivered is of lower temperature than the contents of the vessel 10, therefore by adjusting valves 47' and 48', the delivery is proportioned between the gas and liquid phases of the vessel 10, so that the pressure in the vessel 10 may remain substantially constant. Entry of the colder liquid oxygen through the conduit 24 into the gas space tends to effect condensation of gas in the gas space so that the pressure tends to fall even though the vessel is being filled with liquid. Entry of liquid through the conduit 35 tends merely to compress the gas in the gas space at a rate faster than it can condense at the liquid surface, and thus the pressure would tend to rise unless of course the flow from the storage connection 34 were great enough to prevent such rise.

The heating jackets 37, 28, and 33 are preferably heated by a liquid heating medium which is circulated with sufficient rapidity to avoid any freezing thereof on the vaporizer coil. The heating liquid may be a water or a water solution, and preferably flows in a closed circuit which includes a storage tank 50 of substantial size to provide a reservoir of heat. From the bottom of the tank 50 a conduit 51 controlled by valve 51' conducts liquid to the inlet of a water circulating pump 52 which is driven by an electric motor 53. From the pump 52 the liquid is conducted to a conduit 54 to the vaporizer heating jacket 37. From jacket 37 a connection 55 passes the water to a jacket 28 from whence it flows through a connection 55 to the heating jacket 33. From heating jacket 33 the cooled liquid is passed through conduit 34 to the heater 50 located within the tank 50. The heating chamber 58 is provided with a tube 59. Extending into the heating chamber 58 and immersed in the liquid therein are electric heating elements indicated generally at 60. Preferably there are three sets of elements shown diagrammatically at 60a, 60b, and 60c. The tank 50 is preferably surrounded by insulating jacket 61 to avoid excessive loss of heat to the atmos-
a line L4. The thermo switches 70, 71, and 72 are connected by lines 91, 92, and 93, respectively, in series with three relay coils 100, 101, and 102. The coils 100, 101, and 102 respectively close switches 103, 104, and 105, which, in turn connect the heating elements 60a, 60b, and 60c across the lines 82. The use of three temperature controls provides greater flexibility of control. Thus, if the water temperature is less than, for example, 120° F., the temperature switch 70 will close for energizing coil 100 which closes switches 103 to energize the heating element 60a. A pilot lamp P1 connected across the coil 100 will indicate operation of the heater element. If the temperature of the water falls to a lower value, such as 115° F., the thermo-switch 71 will close, energizing coil 101 which closes switch 104 to put heater element 60b into operation. If the water temperature should fall still lower to, for example, 110° F., thermo-switch 72 will close for energizing coil 103, closing switch 105, and putting heater element 60c into operation. As the temperature of the water rises, the temperature switches will be opened in the reverse order to cut off the heaters which they control and extinguishing the respective pilot lights shunted across the lines.

Operation of oxygen delivery is initiated by momentarily closing a push button switch 107. Normally open switch 107 is connected in series with a normally closed switch 108 usable to stop operation, a relay coil 109, and the contacts of the thermo-switch 45 which is also normally closed, all connected by line L10 between line L and L4. Coll 109 closes switches 111 and 112, 111 being shunted across push-button 107 so that the coil 109 will remain energized. Switch 112 connects line L4 with a line L5. A line 113 connected between lines 1114 and L6 connects the pressure switch 22 in series with the coil of solenoid 40 which operates valve 35. A normally closed manually operated switch 114 is also interposed in the line 113, in order when desired to connect solenoid 40 into or to isolate it from the control circuit. The pressure switch 44 is connected between lines L5 and L6. Pressure switch 44 is normally closed and opens only when the pressure in the vessel 10 exceeds the desired service pressure by a predetermined amount. Pressure switch 23 controls two sets of contacts, an upper set 116 which are normally disengaged and are connected directly with the pressure in the vessel 10 exceeds the desired working value and a lower set 116. Contacts 116 are always closed unless the pressure in the vessel exceeds the operating value by a small amount when the contacts 115 will be closed. Contacts 116 are connected in series with the coil of the superheater valve 41 by a line 117 between line L and L6. Similarly, contacts 116 are connected in series with the coil 30 which controls valve 25 by a line 118 between lines L and L6. In order to manually select withdrawal of liquid alone, or to permit liquid withdrawal through line 40 in an emergency, manual on and off switches 119 and 120 are interposed in lines 117 and 118, respectively, and manually operated on-and-off switches 121 and 122 are shunted across the contacts 115 and 116, respectively. If desired, indicator or pilot lights P4, P6, and P6 may be shunted around the coils, 40, 42, and 30, respectively, to indicate operation of the valves 35, 41, and 25.

As previously indicated, the system is prepared for operation by closing switches 80 and 78 and depressing the push button switch 88. The water pump thus operates continuously. Such operation can be stopped by opening push button switch 89. If the water level in chamber 88 should be too low, the switch 88 will open, which prevents operation of the heating elements 60 and also prevents operation of the oxygen delivery circuit. For normal operation of switches 114, 115, 120, 121, and 122 will be as shown, namely, 114, 115, and 120 are normally closed and switches 121 and 122 remain normally open. A pilot light P7 connected between line L and L4 will indicate whether switch 88 is closed and whether operation of the water pump is allowed. Push button 107 is then momentally closed to initiate oxygen delivery, and operation from then on is automatic unless push button switch 105 is opened, or the thermo-switch 45 should open due to too low a temperature of the oxygen leaving the supply vessel 10. Pressure switch 22 is then in control of the solenoid 40 of automatic valve 35 to keep the pressure within the vessel 10 at a predetermined substantially constant operating pressure which is only slightly higher than the service pressure desired in the service conduit 34. If such pressure tends to exceed the predetermined value, valve 39 remains closed; but if the operating pressure tends to drop below the predetermined value, the switch 22 closes and opens valve 39 allowing liquid to flow into the pressure building vaporizer 36, which then delivers gas through the line 24 into the vessel 10. The valves 35, 39, 41, and 39 are open during normal operation. This pressure building control can be made so sensitive that it is not necessary to provide pressure-reducing regulators in the service conduit 34, as was formerly necessary.

Under normal operating conditions the pressure switch 44 remains closed and when the consumption of gas from service conduit 34 tends to reduce the pressure therein, the small difference in pressure, for example, about 1 psi, between the vessel 10 and service conduit 34 causes flow of liquid through the eductor tube 26 into the vaporizer 27 and superheater coil 32, which path provides the main source of oxygen for the service conduit 34. Normally valve 29 is open due to energization of solenoid 30 by the closed lower contacts 116 of switch 32. When the pressure in the vessel 10 is below the desired service pressure, the differential pressure causing flow is reduced resulting in less liquid vaporization. If, for example, after a shut-down period the pressure in vessel 10 should be at a higher value than the predetermined operating pressure, the pressure switch 22 will open, the contacts 116, and close the contacts 115. In that event, if the service line pressure is reduced by consumption to keep the pressure switch 44 closed, the circuit through the solenoid 30 will be opened and the circuit to the solenoid 42 will be energized so that the valve 41 will be opened, and the essential flow from the upper part of the vessel 10 through the conduit 24, conduit 31, and superheater 32 to the service conduit 34. Gas withdrawal through such gas phase passage will continue until the pressure in vessel 10 has reduced to the operating value when valve 41 will be closed by the opening of contacts 115 and valve 25 will be opened.

In some instances the gas to be supplied to the consuming apparatus will be a mixture rather than a single pure gas. Thus commercial oxygen
2,500,249 is not 100% oxygen but contains 99.6% oxygen, the balance being mainly nitrogen with some argon. Ordinarily a slight change of purity in this range is of no consequence but often it is desired to deliver a mixture of gases such as a mixture of oxygen and nitrogen of constant composition. This may be accomplished with the system described herein because it is possible to operate substantially solely with liquid phase withdrawal. Due to the difference of boiling points of gases in a mixture of gases, the composition of the gas phase or vapor in the gas space when in equilibrium with a liquefied gas mixture in the vessel, will differ substantially from the composition in the liquid phase: thus by complete gasification of liquid drawn from the liquid phase only, the composition of the stored liquid will remain constant and the gas mixture delivered to the service connection 34 will remain of constant composition.

Operation with liquid phase withdrawal alone is obtained by opening switch 119 and closing switch 122, making valve 25 solely responsive to pressure switch 44. Because of the high efficiency insulation of the vessel 10, and because no heat is added to the contents of the vessel 10 by the system employed for vaporizing the withdrawn liquid to produce gas for the service connection, and unless a period of complete shutdown should be of abnormally long duration, there will usually be no excessive pressure rise in the vessel 10. If, due to an abnormally long shut-down, the pressure should increase to a value for which the relief valve 25 is set, some gas will be blown off but the amount will be small because the rate of heat leak is very slow.

During a shut-down the heat leak to the vessel from the atmosphere is absorbed mainly as sensible heat in the liquid and vessel and with a vessel of substantial size a long period would elapse before the pressure in the vessel reaches a predetermined value above the operating service pressure.

The effectiveness of powder-in-vacuum insulation for the liquid holding vessel in the system of the present invention is shown by the following measurements of pressure rise during a complete shut-down. With an installation substantially according to the disclosure of U. S. Patent No. 1,943,047 and in which the insulation was a 1 foot thickness of non-abrasive carbon dioxide powder, at atmospheric pressure the pressure rise when the vessel was full was 3 p.s.i. per hour and 72 p.s.i. per day, and when ¼ full the pressure rise was 10 p.s.i. per hour and 240 p.s.i. per day. With an installation according to the present invention, the pressure rise with vessel 10 filled was 0.9 p.s.i. per hour and only 2.2 p.s.i. per day, and when ¼ full the pressure rise was 0.36 p.s.i. per hour and only 9 p.s.i. per day.

It is seen that even after several days' complete shut-down the pressure rise is moderate. Thus, for example, the container 10 can be constructed for a pressure of say only 50 p.s.i. above the service pressure and when only ¼ full there could be over five days’ complete shut-down before blow-off pressure is reached. If the shut-downs are normally of only two days’ duration, operation may be with only liquid phase withdrawal with very little loss of gas.

If desired the eduction tube 26 could be omitted and the inlet to the valve 25 could be connected to the line 35 or line 47 and thus eliminate a conduit through the insulation space 12. If repairs are to be made to valve 25, it can be isolated by closing suitable stop valves in conduit 26 not shown, and operation continued by sealing charging connection 46, opening valves 47' and 48' and closing valve 24'. Liquid then flows through conduits 35, 47, 48, valves 41, 43, conduit 31, and heater 32 to the service connection 34. Pressure switch 44 is then placed in sole control of valve 41 by closing switch 121 and opening switch 120.

What is claimed is

1. In a system for storing liquefied gas having a boiling point below 233° K. at atmospheric pressure and dispensing gas material therefrom, the combination of a pressure vessel for holding a supply of the liquefied gas and having normal liquid and gas spaces therein; heat insulation surrounding said vessel of a thickness and character such that heat inflow through the insulation to said vessel is restricted to no more than about 5 B. t. u. per hour per square foot of surface of the vessel under a temperature differential of 200° C.; a service connection for consuming apparatus requiring gas material at a desired service pressure; automatic pressurizing means including an external vaporizer having connection to the gas and liquid spaces of said vessel and an automatic fluid control device interposed therein and having an operating element arranged to respond to changes of pressure in said vessel for controlling the vaporization of portions of liquefied gas in response to pressure in said vessel to maintain the pressure therein at a predetermined substantially constant operating value within selected limits; and withdrawal passage means connected between said vessel and said service connection for supplying gas material thereto at a substantially constant service pressure and including means connected to be responsive to demand for stopping such supply of gas material when the demand for gas by the consuming apparatus ceases; the heat leak to said vessel then being absorbed mainly as sensible heat in the liquid and vessel for an abnormally long period of no demand before the pressure in the vessel reaches a predetermined value above said service pressure.

2. In a system for storing liquefied gas and dispensing gas material therefrom according to claim 1, in which said withdrawal means includes a gas phase passage connection between the gas space of said vessel and said service connection, a liquid phase passage connection including a vaporizer between the liquid space of said vessel and said service connection, and automatic valve means interposed in said passages and constructed so as to control flow therein to pass gas from the gas phase of said vessel to the service connection only when the pressure in the vessel exceeds said predetermined substantially constant value.

3. In a system for storing liquefied gas and dispensing gas material therefrom according to claim 1, in which said withdrawal means includes a gas phase passage connection between the gas space of said vessel and said service connection, a liquid phase passage connection including a vaporizer between the liquid space of said vessel and said service connection, a first automatic valve means in said gas phase connection, a second automatic valve means in said liquid phase connection, means responsive to pressure in said service connection and operatively connected to said first and second automatic valve means for allowing either of said automatic valve means...
to open at all times except when the service connection pressure rises above a substantial amount higher than the desired service pressure, and maintaining said pressure by pressure in said vessel and operatively connected to said first and second automatic valve means for opening said first automatic valve means only when the pressure in the vessel exceeds said predetermined substantially constant value and for allowing opening of said automatic valve means when the pressure in said vessel does not exceed said predetermined substantially constant value.

4. Apparatus for supplying gas material in the gas phase converted from liquefied gas having an atmospheric boiling point below 233° K., and comprising a heavy walled pressure-resistant inner vessel for holding a body of such liquefied gas under a substantially superatmospheric pressure; a larger gas-tight shell completely encompassing said inner vessel providing therewith an intervening evacutable insulation space; and a minimum gas-tightness of not less than 1/4 foot, said space containing a low apparent density filling of finely divided solid material and being evacuated to a combined gas and vapor pressure therein below 10 millimeters of mercury absolute, the thickness of said space and the range therein being correlated within the specified ranges and with the character of the filling to restrict heat inflow through the insulation to said vessel to less than 5 B. t. u. per hour per square foot of surface of the inner vessel under a temperature differential of 200°C.; means extending through said insulating space for supporting said inner vessel in spaced relation to said shell independently of said filling; a liquid conduit communicating with the bottom of said inner vessel, and a gas conduit communicating with the upper part of said inner vessel, both said conduits passing by an elongated path through said space to the exterior of said shell, said supporting means and conduits being constructed and arranged to provide substantial resistance to heat conduction therethrough; and means for supplying gas at a desired service pressure to a service connection for consuming apparatus, including passage means connecting both the liquid conduit and the gas conduit to said service connection, liquid vaporizing means interposed between said liquid conduit and said service connection, and automatic valve means interposed in said liquid conduit and said service connection, and automatic valve means having operating means responsive to the service connection pressure and the vessel pressure and constructed and arranged to selectively control the flow through said liquid conduit and said gas conduit toward said service connection and arranged to vaporize liquid at a rate required for supplying gas to the service connection at the service pressure as demanded by the consuming apparatus and preferentially to feed gas phase toward said service connection when the pressure in said vessel exceeds said service pressure, means provided to stop said feeding of gas and vaporization of liquid during periods of no demand for gas by the consuming apparatus, the heat leak to said body of liquefied gas being so low that it is absorbed as sensible heat in the liquid and vessel for an abnormally long period of no demand before the pressure in the vessel reaches a predetermined value above said service pressure.

6. In apparatus for storing liquefied gas having a boiling point below 233° K. at atmospheric pressure and dispensing gas material therefrom, the combination of an insulated pressure containment for the liquefied gas having normal liquid and gas spaces therein, a service connection for consumption apparatus, a liquid withdrawal line connected between said container and said service connection, an external fluid circuit having a connection to the bottom of said container and arranged to receive liquid therefrom under gravity and having an opposite connection to the gas space of said container, heating means in said circuit located at least in part lower than the bottom of said container, automatically controlled valve means in said circuit responsive to the pressure in said container to control circulation of said heated fluid and adapted thereby to maintain the pressure in said container above a predetermined value, a liquid withdrawal line connected to withdraw liquefied gas from said container independently of said fluid circuit and to deliver gas generated from the withdrawn liquid to said service connection, said liquid withdrawal line having interposed therein vaporizing and superheating means, and means responsive to pressure in the service connection and operative to control flow through said liquid withdrawal line for effecting preferential liquid withdrawal when the pressure in the service connection tends to fall below a desired value under that of the container.

7. In a system for storing liquefied gas having a boiling point below 233° K. at atmospheric pressure and dispensing gas material therefrom, the combination of a pressure vessel for holding a supply of the liquefied gas and having normal liquid and gas spaces therein; heat insulation surrounding said vessel of a thickness and character such that heat inflow through the insulation to said vessel is restricted to no more than about 5 B. t. u. per hour per square foot of surface of the vessel under a temperature differential of 200°C.; a service connection for consuming apparatus requiring gas material at a desired service pressure; means including an external vaporizer having connection to the gas and liquid spaces of said vessel and an automatic fluid control device for controlling the vaporization of portions of liquefied gas in response to pressure in said vessel to maintain the pressure therein at a predetermined substantially constant value, such pressure building means being constructed and arranged to maintain the operating pressure within a small range of said predetermined value and to shut off completely at said range; and withdrawal means connected between said vessel and said service connection for supplying gas material thereto at a rate corresponding to the consumption demand, said withdrawal means comprising a liquid phase connection including a vaporizer between the liquid space of said vessel and said service connection, and a flow controlling device interposed therein constructed and arranged to respond to service pressure so that a relatively small differential of pressure between said vessel and said service connection effects flow of liquid to the vaporizer at a rate for producing gas corresponding to the demand, such flow stopping when the demand ceases, the heat leak to said vessel then being absorbed mainly as sensible heat in the liquid and vessel for an abnormally long period of no demand before the pressure in the vessel reaches a predetermined value above said service pressure.
the combination of a pressure vessel for holding a supply of the liquefied gas and having normal liquid and gas spaces therein; heat insulation surrounding said vessel for restricting flow of heat thereto to a low value; a service connection for consuming apparatus requiring gas material at a desired service pressure; means including an external vaporizer having connection to the gas and liquid spaces of said vessel and an automatic fluid control device for controlling the vaporization of portions of liquefied gas in response to pressure in said vessel to maintain the pressure therein at a predetermined substantially constant operating value; a gas phase passage between the gas space of said vessel and said service connection; a liquid phase passage including a vaporizer between the liquid space of said vessel and said service connection; automatically operable valve means in each of said passages; and pressure responsive means connected for operating said valve means to open the valve in the gas phase passage when the pressure in the vessel exceeds said operating value by a desired amount, and to allow only the valve in the liquid phase passage to be open when the pressure in said vessel does not exceed said operating value by said desired amount.

9. In a system for storing liquefied gas and dispensing gas material therefrom according to claim 10, means including an external vaporizer having connection to the gas and liquid spaces of said vessel and an automatic fluid control device for controlling the vaporization of portions of liquefied gas in response to pressure in said vessel to maintain the pressure therein at a predetermined substantially constant value; the combination with a heating chamber for heating said vaporized gas; a heating fluid circuit with a heating fluid therein connected to circulate heating fluid through said chamber; and a tank for holding a substantial quantity of said heating fluid interposed in said circuit and providing sufficient heat ballast to supply sudden large demands for heat at the vaporizer.

11. In a system for storing liquefied gas and dispensing gas material therefrom according to claim 10, heating means for said heating fluid having a heat-producing power not greater than sufficient to provide heat required for an average demand by the vaporizer, the sum of the heating power of the heating means and the available stored heat of the heating fluid being sufficient to supply the maximum demand for heat for a substantial period.

12. In a system for storing liquefied gas and dispensing gas material therefrom according to claim 10, in which said means for controlling said service pressure includes a liquid phase passage from the liquid space of said container with a vaporizer interposed therein, and a second heating chamber for the last mentioned vaporizer, said second heating chamber being interposed in said heating fluid circuit.

13. In a system for storing liquefied gas having a boiling point below 233° K. at atmospheric pressure and dispensing gas material therefrom, the combination of a pressure vessel for holding a supply of the liquefied gas and having normal liquid and gas spaces therein; heat insulation surrounding said vessel of a thickness and character such that heat inflow through the insulation to said vessel is restricted to no more than about 5 B. t. u. per hour per square foot of surface of the vessel under a temperature differential of 200° C.; a service connection for consuming apparatus requiring gas material at a desired service pressure; means including an external vaporizer having connection to the gas and liquid spaces of said vessel and an automatic fluid control device for controlling the vaporization of portions of liquefied gas in response to pressure in said vessel to maintain the pressure therein at a predetermined substantially constant operating value; a withdrawal means comprising a liquid phase passage including a vaporizer between the liquid space of said vessel and said service connection; and an automatic valve in said passage responsive to the operating pressure for permitting flow to said service connection when the pressure therein tends to fall below the desired service pressure and stopping flow when the pressure in said vessel exceeds said operating pressure.

ODD A. HANSEN.

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<td>2,362,856</td>
<td>Bliss et al.</td>
<td>Nov. 22, 1944</td>
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<td>2,363,690</td>
<td>Hansen</td>
<td>Nov. 28, 1944</td>
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<td>2,386,459</td>
<td>Dana</td>
<td>Mar. 12, 1944</td>
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