Nov. 14, 1939. W. F. MESINGER 2,180,090

METHOD AND APPARATUS FOR DISPENSING GAS MATERIAL

Filed Feb. 18, 1936 3 Sheets-Sheet 1

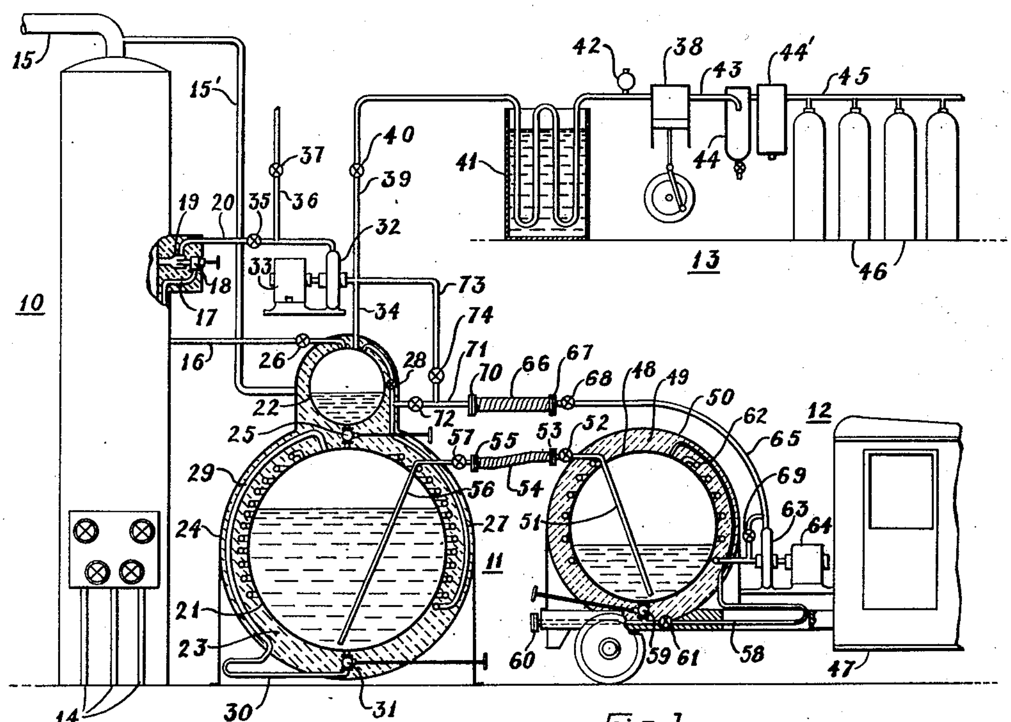

Fig. 1.

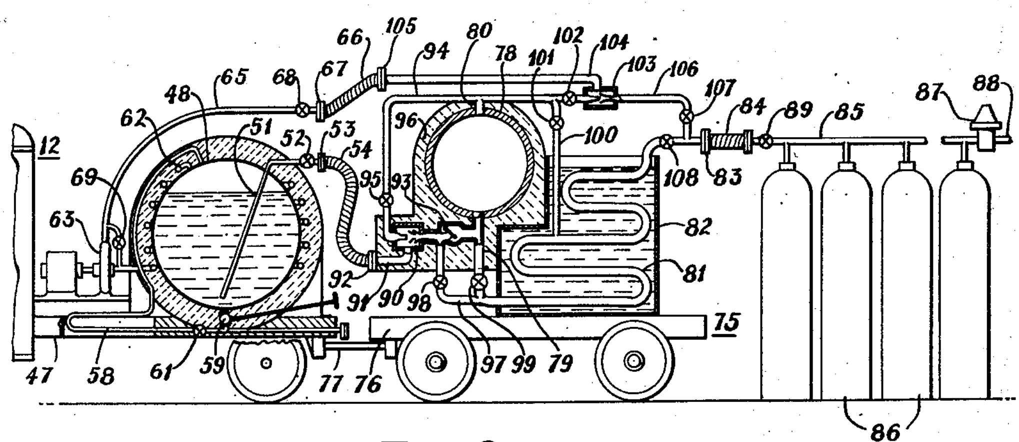

Fig. 2.

INVENTOR
William F. Mesinger
BY
Watson, Bristol, Johnson & Leavenworth
ATTORNEYS

Nov. 14, 1939. W. F. MESINGER 2,180,090

METHOD AND APPARATUS FOR DISPENSING GAS MATERIAL

Filed Feb. 18, 1936 3 Sheets-Sheet 2

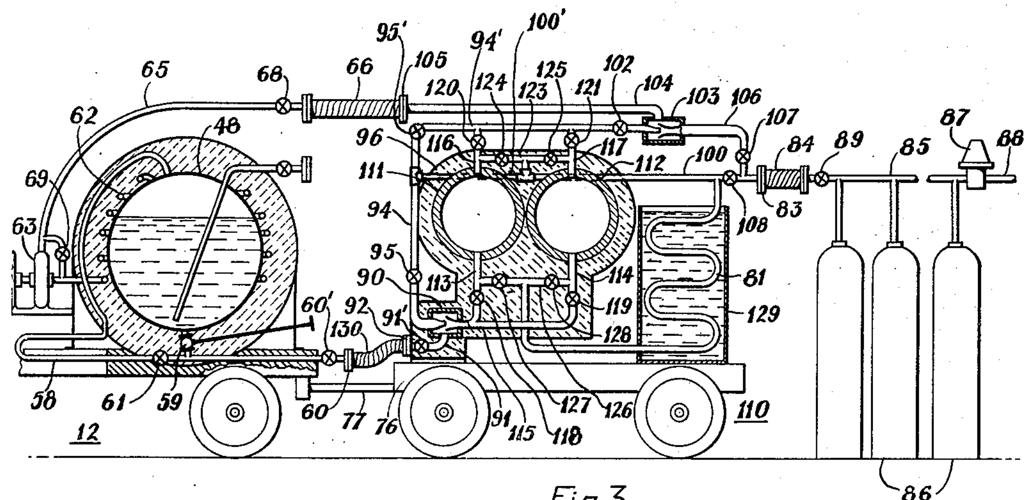

Fig. 3.

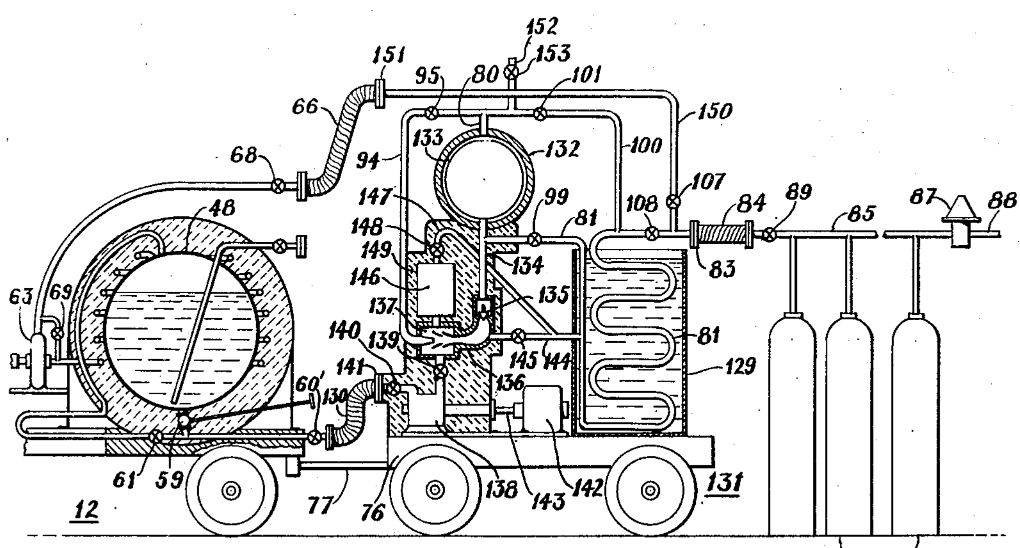

Fig. 4.

INVENTOR
William F. Mesinger
BY
Watson, Bristol, Johnson & Leavenworth
ATTORNEYS

METHOD AND APPARATUS FOR DISPENSING GAS MATERIAL

Filed Feb. 18, 1936 3 Sheets-Sheet 3

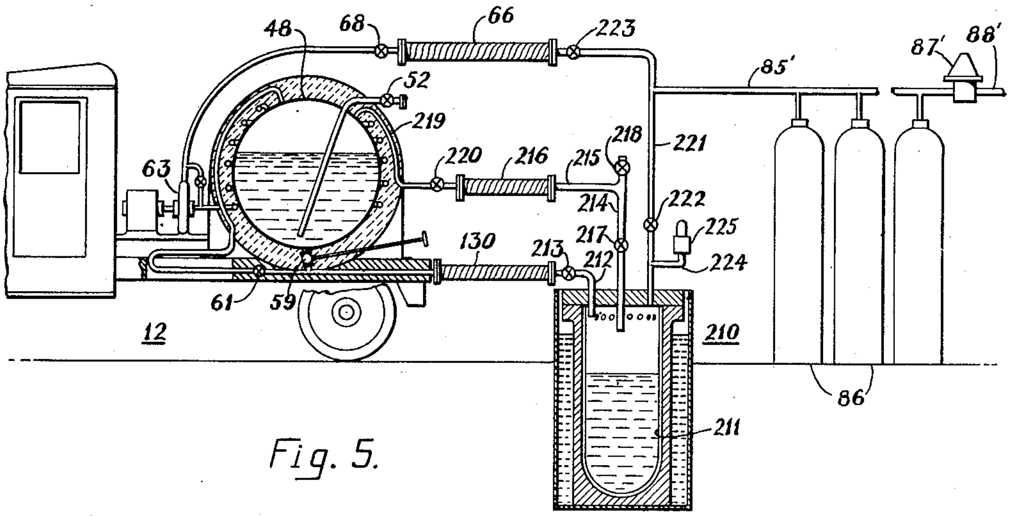

Fig. 5.

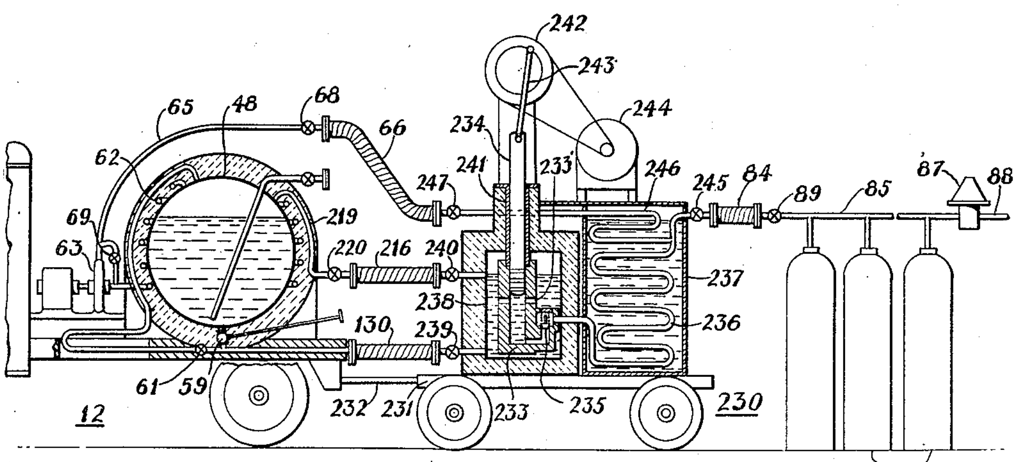

Fig. 6.

INVENTOR
William F. Mesinger
BY
Watson, Bristol, Johnson & Leavenworth
ATTORNEYS

Patented Nov. 14, 1939

2,180,090

UNITED STATES PATENT OFFICE

2,180,090

METHOD AND APPARATUS FOR DISPENSING GAS MATERIAL

William F. Mesinger, Mount Vernon, N. Y., assignor to The Linde Air Products Company, New York, N. Y., a corporation of Ohio

Application February 18, 1936, Serial No. 64,487

18 Claims. (Cl. 62—1)

This invention relates to a method and apparatus for dispensing gas material and particularly to a method and apparatus for dispensing and regasifying liquefied gases which have boiling point temperatures at atmospheric pressure below 273° K.

The invention has for its principal object generally to provide a method and apparatus for dispensing gas materials of the character indicated in a manner such that losses of gas may be kept low.

More specifically, the invention has for its object the provision of suitable steps and means for carrying the same into effect whereby the liquefied gas, at the production plant, is cooled to a temperature below its normal boiling point at atmospheric pressure to reduce the losses that occur by evaporation during the subsequent handling, transportation, and transfer of gas material to other containers.

It is another object to prepare and transport the liquefied gas under such conditions of temperature and pressure that the transfer of the gas material from the production plant to receiving containers at relatively high pressure is accomplished with relatively small losses.

It is still another object to provide means for transferring liquefied gas to a vaporizer at relatively high pressure utilizing injector action.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others, and the apparatus embodying features of the construction, combinations of elements and arrangement of parts which are adapted to effect such steps, all as exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

Fig. 1 is an elevational view partly in section showing an arrangement of apparatus at the production plant adapted for practicing the method according to the present invention;

Fig. 2 is a similar view of a form of apparatus for transferring liquefied gas by injector action and converting it into gas of desired pressure;

Fig. 3 is a similar view of still another form of apparatus in which the liquid is transferred by injector action;

Fig. 4 is a similar view of another form of the apparatus in which the liquid is transferred in two stages to the vaporizing means in accordance with the present invention;

Fig. 5 is a similar view of another form of apparatus for transferring liquefied gas by gravity flow to a warm converter, such as is disclosed in U. S. patent to Heylandt, Reissue 18,476; and

Fig. 6 is a similar view of another form of apparatus for transferring liquefied gas by mechanical forcing means into vaporizing means as disclosed in U. S. patent to Heylandt, Reissue 19,054.

Liquefied gases which are handled at temperatures below 273° K., such, for example, as liquid oxygen, have been stored and transported at substantially atmospheric pressure in vessels which are insulated from the influence of external heat and, since, in practice, the insulation is not perfect, there was a continuous evaporation of liquid within the vessels at a slow rate caused by the heat that leaks through to the liquid. Vapors so produced during transportation have been lost. When the liquid is transferred from one container to another, and particularly when it is transferred to vaporizers for converting into gas of a desired high pressure, further losses of gas have occurred as the tendency of a portion of the liquid to flash into vapor is great when the liquid is at its boiling temperature at the prevailing pressure.

By the present invention, losses of valuable gas material to the atmosphere are kept relatively low. The steps for accomplishing this involve providing a production plant where liquefied gas is produced and stored at a temperature substantially below the boiling point at atmospheric pressure. The temperature to which the liquefied gas is thus subcooled is such that a predetermined maximum, such as the boiling point at a standard atmosphere, will not be exceeded during the normal periods for which the liquefied gas is stored or transported. The liquefied gas thus produced is then transported to the place of use in a closed container which is preferably maintained under a sub-atmospheric pressure.

The gas material, heretofore lost to the atmosphere during a trip to the place of use, according to the present method is conserved. In accomplishing this, the gas material which normally arises by evaporation in the storage container at the production plant is now withdrawn and pressed into gas holders, such as cylinders, or reliquefied. Also, in the furtherance of this end, both the storage container and the transport container are insulated against heat leakage as completely as practical. To enhance the insulating value of the material normally employed it is here proposed to fill the interstices in the insulating envelope of the containers with an insulating gas that in the liquid phase has a boiling point at the pressure maintained in the insulation which is below the temperature to which the liquefied gas in the container is cooled. For example, when the liquid in the container is liquid oxygen, the interstices of the insulation are advantageously filled with gaseous nitrogen, or with air if maintained at a pressure sufficiently reduced to avoid the condensation of oxygen.

Referring now to the drawings and particularly to Fig. 1, there is illustrated according to the invention several items of equipment located at a liquid oxygen production plant and arranged cooperatively for the practice of the present method. A column for separating oxygen from air and providing the oxygen in the liquid state of a high degree of purity is shown generally at **10**, which delivers the liquid to a closable insulated storage container or tank shown generally at **11**. A second closable container or vessel upon a vehicle is shown generally at **12** for transporting the liquefied gas connected to the storage tank for receiving a charge of liquid to be transported to a place of use. At **13** is shown generally an apparatus for compressing gas evaporated from the liquefied gas into pressure storage containers.

The column **10** is supplied with compressed and processed air through conduits **14**, while the gaseous nitrogen product of the separation is discharged at **15** and the purified liquid oxygen is discharged through conduit **16**. A portion of the column casing is broken away to show a conduit **17** that conducts gas material from the lower portion of the column for discharge at an intermediate point into the upper portion of the column. The flow through the conduit **17** is controlled by a regulating valve **18** located at the upper end of the conduit and discharging into the nozzle of an aspirating device **19**, which draws gas out of a conduit **20** connected to the suction chamber of the aspirator. The combined gas materials are discharged into the column through the discharge portion of the aspirator, which is in communication with the interior of the column.

The storage tank comprises a main inner vessel **21** and a smaller auxiliary vessel **22** located above it and both surrounded by a common insulating envelope **23**, which is externally supported by a casing **24**. The insulation pores and spaces are filled with nitrogen which is led into the casing **24** by a conduit **15'** providing free communication between the casing and the nitrogen discharge conduit **15**, so that a flow of anhydrous nitrogen may pass in or out of the casing as the gas expands or contracts in response to temperature changes. The vessels **22** and **21** communicate through a connection joining the bottom of vessel **22** and the top of vessel **21**, which is controlled by stop valve **25**. The conduit **16** having a stop valve **26**, joins the upper portion of the auxiliary chamber **22** for leading the liquid oxygen therein as it is produced. The gas spaces of the two vessels are also joined by a conduit **27**, which conducts gas from the upper portion of vessel **21**, passing it through a portion coiled around the vessel **21** within the insulating envelope **23** to the upper portion of vessel **22**. This flow is controlled by a stop valve **28** located in the portion of conduit **27** nearest vessel **22**. A device for rapidly vaporizing a portion of the liquid to provide a temporary increase in pressure above the liquid in the vessel **21** comprises a conduit **29** having a portion **30** exposed to and arranged to be heated by the atmosphere and connected at points above and below the upper surface of the liquid in vessel **21**. A stop valve **31** at a point in the conduit close to the vessel is provided to control the flow of liquid into the conduit when desired.

Several means for drawing off gas from the top of vessel **22** are preferably provided. One such means comprises a centrifugal exhauster **32** driven by an electric motor **33**, the intake of the exhauster being connected in communication with the top of vessel **22** through a conduit **34** and its exhaust with conduit **20**, which is controlled by a valve **35** and has a branch **36** controlled by valve **37** communicating with the portion between valve **35** and the discharge of exhauster **32**. The exhauster **32** may be of the single or multiple stage type adapted to provide the desired pressure difference between its intake and discharge. The branch conduit **36** conducts gas when desired to a relatively low pressure storage holder, for example, a gasometer.

Another means for drawing off gas is shown at **13** and comprises a gas compressor **38** here shown diagrammatically as of the single stage type, but which may be of the multiple stage variety when desired to compress gas to a relatively high pressure. Gas is conducted to the intake of the compressor through conduit **39**, which communicates with conduit **34** and is controlled by a valve **40**. The conduit **39** is provided with an extended coil portion that is immersed in a heating fluid contained in a vessel **41**. A fluid for lubricating the piston and packing of the compressor is added to the gas admitted to the cylinder by means of a lubricant feeding device **42** communicating with the conduit **39**. When the gas is oxygen, a suitable non-combustible fluid is fed, for example, water. The compressor discharges through a conduit **43** that leads into a trap or separator **44**, provided for separating lubricant from the compressed gas. If desired, moisture in the vapor state may also be removed by causing the gas to contact with moisture-removing chemicals held in trap chamber **44'**. The compressed gas is carried from the trap by a manifold conduit **45** into the high pressure cylinders **46** communicating therewith. Thus gas may be drawn from vessel **22** through conduits **34** and **39** to be compressed and stored at high pressure in cylinders **46**. More effective moisture removal by trap **44** may be had by cooling the compressor discharge by heat exchange with cold gas passing through conduit **39**.

The liquid transport device at **12** comprises a motor truck **47**, upon which is mounted a liquid container and its auxiliary equipment. The liquid is carried in a closed vessel **48** disposed within heat insulation **49** supported by an outer casing **50**. The liquid is conducted into the vessel **48** by means of filling conduit **51** which leads to a point near the bottom of the liquid space and is provided with a stop valve **52** and a coupling **53** at a point external to the casing **50**. The coupling **53** is joined by a section of flexible conduit **54** to a similar coupling **55** located at the external end of a conduit **56**, which depends into the liquid in the storage vessel **21**. Flow from the conduit **56** is controlled by a valve **57** interposed at a point close to coupling **55**. The liquid spaces of vessels 21 and 48 can thus be placed in communication through conduits 56, 54 and 51. Means for rapidly developing a pressure in the vessel 48 is also provided and comprises conduit 58 having a portion exposed to the heat of the atmosphere and in communication with both the liquid and gas spaces of the vessel. Vessel 48 is also provided with the usual devices such as safety release valves and liquid level gauges. Admission of liquid to conduit 58 is controlled by a valve 59, shown as having an extended operating stem. A branch of conduit 58 leads to a coupling 60 located at the rear of the truck and normally sealed by a blank cover. A stop valve 61 is inserted in conduit 58 to be closed when it is desired to permit liquid to flow only through the branch leading to coupling 60. For drawing off gas there is provided a conduit 62 leading from the gas space of vessel 48 to the inlet of an exhauster 63, whose rotor is connected to and driven by an electric motor 64. The motor draws its electric energy from any suitable source, for example, from the storage battery carried by the truck. It is contemplated, however, that the exhauster may be mechanically coupled, for example, through gearing, to be driven by the propeller shaft of the truck, or by a power take-off shaft of the engine. The conduit 62 is provided with an extended coiled portion within the insulation 49, so that gas flowing out of vessel 48 may impart refrigeration to and draw heat out of the insulation. The exhauster discharges through a conduit 65 which is joined to a flexible conduit 66 by means of a coupling 67. Flow through the conduit 65 is controlled by a valve 68 and a bypass connection controlled by a valve 69 is provided from conduit 62 to conduit 65 to be opened when it is desired that gas should flow out without passing through the exhauster 63. Coupled to conduit 66 by means of coupling 70 is a conduit 71 controlled by a valve 72 and communicating with conduit 27. A branch conduit 73 having a valve 74 communicates with conduit 71 at a point between valve 72 and coupling 70 and with conduit 34. These conduits, being arranged so that gas discharged by exhauster 63, may be utilized in several ways as desired.

The operation of the apparatus located at the production plant shown in Fig. 1 for providing a charge of subcooled liquid oxygen in the vessel 48 will now be described. It will usually be preferable to reduce the liquid oxygen to the subcooled state when it issues from the production column 10. When no liquid is to be transferred to the transport device 12, the flow of gas material is as follows: The exhauster 32 is set in operation and all valves are closed except as described. Valve 35 is open so that gas drawn from the top of vessel 22 by the exhauster through conduit 34 is discharged through conduit 20 into the suction chamber of injector 19, where it is entrained with gas material discharging from nozzle valve 18 into the column. The valve 18 is regulated so that the flow through conduit 17 of gas material coming from the high pressure chamber of the column is limited to the desired rate. Gas drawn into the column through conduit 20 is reliquefied by providing sufficient excess refrigerating effect in the column in ways known in the art. If it is desired not to reliquefy the gas discharged by exhauster 32, it may be discharged to the gasometer by closing valve 35 and opening valve 37. Still another method for drawing off and disposing of the gas drawn from the top of vessel 22 is provided by the compressing unit 13, which when in operation draws gas through conduit 39, valve 40 being opened, heats it to a temperature above the freezing point of the lubricant, and compresses it to the desired pressure for storage in the cylinders 46. By these means, the pressure in the vessel 22 is maintained at the relatively low value which is equivalent to the pressure of equilibrium at the low temperature desired in the liquid. For example, if, in the case of oxygen, it is desired that the temperature of the liquid shall be brought down to 77.5° K., the pressure would be 162 mm. of mercury absolute.

The liquid produced by the column passes out through conduit 16 into vessel 22, the rate of flow being regulated by valve 26, which acts as a throttling or expansion valve since the liquid in column 10 is generally under a higher pressure. On passing expansion valve 26, part of the liquid will flash into vapor, the balance being cooled to the desired temperature. The gas is drawn off as described and the liquid falls to the lower part of vessel 22 from which it falls into the main vessel 21, when valves 25 and 28 are open. When thus cooling liquid oxygen from a normal temperature of 90.15° K., the boiling point at one atmosphere, to 77.5° K., approximately $\frac{1}{10}$ will be gasified. The gas so flashed off will contain a greater percentage of the lower boiling point impurities, such as nitrogen, and thus the purity of the liquid will be increased. The present method of subcooling, therefore, has the desirable effect of increasing the purity of the product. The subcooled liquid in the storage tank 11 has the capacity to absorb a large quantity of the heat that leaks in through the insulation 23 before its temperature reaches 90° K. The subcooling may also be effected by operating the low pressure compartment of the column under a sub-atmospheric pressure so that the use of exhauster 32 would be unnecessary but the production apparatus would be correspondingly more bulky.

When it is desired to charge the transport device 12 with a quantity of liquid, the flexible conduits 54 and 66 are coupled between couplings 53 and 55 and 67 and 70, valves 25 and 28 closed, and exhauster 63 placed in operation. When valves 68 and 72 are opened, gas contained in the transport vessel 48 is exhausted and discharged through conduits 65, 66, 71, 27 into the gas space of the vessel 21 until the pressure therein increases to the desired value, such that, when valves 57 and 52 are opened, a rapid flow of liquid occurs out of vessel 21 into vessel 48 through the conduits 56, 54 and 51. When the pressure in vessel 21 has been sufficiently increased, valve 72 is closed and valve 74 is opened to permit flow of gas to the other means for utilizing same, as previously described.

If the liquid in the storage vessel has become heated to a temperature higher than desired or if the liquid has been stored therein at approximately the temperature of its boiling point at one atmosphere pressure, the subcooling may be effected either during transfer of liquid into the vessel 48 or after it has been transferred. Cooling during transfer is effected by drawing gas out from the top of vessel 48 by causing the transfer as previously described, except that the valve 52 is manipulated to act as an expansion valve. The gas flashed off when the liquid passes into vessel 48 is drawn out at the top of the vessel through conduit 62 by exhauster 63, which may work in series with the several gas utilizing means to which the gas is conducted by conduits 65, 66, 71 and 73. When the vessel 48 is filled with subcooled liquid, valves 52, 68, 57, 72 and 74 are closed and valves 28 and 25 opened so that gas under pressure in storage vessel 21 may pass to the gas utilizing devices through conduit 27, while the liquid collected in vessel 22 drops down to the main vessel 21. The flexible conduits 54 and 66 are now disconnected to permit the transport device 12 to be driven off to a place where gas material is to be discharged at an elevated pressure. The subcooled liquid can be transported for a relatively long time before the heat leakage through the insulation will have raised its temperature to the boiling point temperature at one atmosphere. For example, in the case of liquid oxygen, if the heat leakage was such that when filled with oxygen at 90° K., the boiling point at one atmosphere, about 2 per cent. of the contents was evaporated in 24 hours, the same container when filled with liquid oxygen at 77.5° K. may be held for five days before the temperature is raised to 90° K. Thus, the liquid may be transported for long distances before it becomes necessary to start venting gas to the atmosphere for avoiding the development of super-atmospheric pressures. The stored refrigeration in the subcooled liquid is further utilized according to the present invention for reducing gas losses when the liquefied gas is transferred to vaporizing means and converted to gas of the desired high pressure for storage and consumption at a place of use, as will appear from the description of the remaining figures.

Referring to Fig. 2, there is shown the liquid transporting device 12 coupled to a portable conversion apparatus indicated generally by 75. The conversion apparatus is used for converting a desired portion of the liquefied gas into gas of the pressure desired for storage and use and is here shown as carried upon a vehicle 76 of the trailer type that is drawn by the motor vehicle 47, to which it is coupled by a draw bar means 77. The conversion device comprises a pressure resistant vessel or chamber 78 having a liquid connection 79 at the bottom and a gas connection 80 at the top. The lower connection 79 leads to and discharges liquid into a vaporizing coil 81 that is submerged in a bath of heating fluid held within a container 82. The vaporizing coil 81 terminates at its upper end in a coupling 83 provided for coupling the vaporizer to be in communication with a flexible portion 84 of a manifold conduit 85 that leads vaporized gas into a number of high pressure storage cylinders 86. A pressure reducing valve 87 provides communication between the manifold 85 and a conduit 88 that conducts the gas reduced to a desired substantially constant pressure for use by consuming apparatus not shown. The other end portion of the manifold 85 is controlled by stop valve 89.

The liquid is forced into the chamber 78 by the action of an injector 90, the liquid being drawn into the injector chamber 90 through conduit 91, which is placed in communication with the liquid in vessel 48 by being coupled at its external end to flexible conduit 54 at 92. The entrained gas material is forced into chamber 78 through a check valve 93 which communicates with connection 79. Gas containing the required heat energy is supplied to the nozzle of the injector 90 by conduit 94, which leads from connection 80 and is controlled by a valve 95. Insulation 96 surrounds both chamber 78 and the injector 90 to control the inflow of heat to these parts. A bypass conduit 97 controlled by valve 98 and communicating with the gas passage between the combining tube of the injector 90 and the check valve 93, leads to and joins the vaporizing conduit 81. Between this junction of conduits 97 and 81 and the junction of conduit 81 with connection 79, a control valve 99 is interposed in the conduit 81. Leading from a point of the vaporizing coils 81, the conduit 100 provides communication between conduit 81 and both connection 80 and conduit 94. Conduit 100 is controlled by a valve 101 located between the vaporizing coils and the point where a conduit controlled by valve 102 branches therefrom to supply gas to the actuating nozzle of an ejector 103. Gas is supplied to the suction chamber of the ejector through conduit 104 which is coupled to flexible conduit 66 by coupling 105. The ejector discharges through conduit 106, which is controlled by valve 107 and communicates with conduit 81 at a point close to coupling 83 which is here shown as located between coupling 83 and a stop valve 108, which controls the discharge from conduit 81.

The operation of the apparatus when coupled together as shown in Fig. 2 for delivering a supply of gas is as follows: The exhauster 63 is started and valves 68, 107 and 89 opened so that gas may be drawn from the top of vessel 48 to be conducted through conduits 65, 66, 104, 106, 84 and 85 to the cylinders 86, which are assumed to have been exhausted of gas. Some gas will be held in chamber 78 at relatively high pressure, this gas having been left in the chamber from a previous operation. Such stored high pressure gas is utilized for operating the ejector 103 by opening valve 102 so as to assist the exhauster 63 by providing another stage of compression. This preliminary transfer of gas is stopped and valve 102 closed when a sufficient back pressure in cylinders 86 has developed and when the liquid in vessel 48 has been sufficiently further cooled. But it is desirable to maintain a supply of gas under pressure in vessel 78 sufficiently higher than the pressure in receivers 86 for use in starting the injector 90; therefore, the pressures of gas in vessel 78 and receivers 86 should not be allowed to equalize. The preliminary gas transfer serves usefully to cool the liquid in vessel 48 to remove heat that entered during the journey and to prepare it for the next steps of the method. The liquid must now be subjected to a higher preliminary pressure. This is accomplished by opening valve 69 for a sufficient time to permit back flow of gas from vessels 86 to provide the desired pressure of gas in the gas space above the liquid. This pressure would preferably be about two atmospheres absolute. The valves 69, 68, 102 and 107 are now closed. If the pressure is not high enough in vessel 48, further increase in pressure may be had by the use of the pressure building coil 58. To this end, valves 61 and 59 are opened permitting liquid to run into coil 58, and vaporize to flow into the gas space and increase the pressure therein without heating the main body of liquid in the vessel 48. The heat exchange between the expelling gas and the liquid is very slow, so that pressure will be maintained for a considerable period of time before equilibrium conditions are restored.

Liquid is next transferred. Accordingly, valves 52, 98 and 108 are opened. Valve 95 is at the same time opened to supply gas from vessel 78 to the injector 90, which will draw liquid from vessel 48 through conduits 51, 54, and 91, entraining it in the combining tube with condensation of the gas. The mixture discharges through conduit 97 into vaporizer 81, where it is converted to gas and conducted into the cylinders 86. As soon as the injector is operating properly shortly after starting it, the valve 98 is closed and the liquid will be forced through check valve 93 and flow into chamber 78. Valve 101 is now opened so that pressures in chamber 78 and vaporizing coils 81 will equalize. When the chamber 78 has filled with liquid, the valve 98 is again opened to divert the liquid into the vaporizing coils 81. The injector action is continued until it fails, which will occur at a pressure such that the work of pumping requires as much or more gas than can be condensed by the liquid, upon which pressure being reached the valves 95 and 98 are closed and valve 99 is opened. The liquid in chamber 78 then flows by gravity through connection 79 into the vaporizing coils 81, where it is heated so that the pressure finally increases to a value which may be beyond the critical pressure, if desired. The exact value of this pressure is determined by the relative volumes of the chamber 78 and the combined volumes of the cylinders 86. When the pressures equalize and flow ceases, the valves are closed, conduit 84 uncoupled from coupling 83 and the transporting device 12 and converting device 75 driven away. It should be noted that true injector action is possible since the liquid oxygen has been provided with a temperature that is sufficiently lower than its boiling point temperature at the pressure under which it is supplied to the injector suction chamber so that the gaseous oxygen supplied through the nozzle is condensed in the combining tube at the required velocity.

Referring to Fig. 3, the liquid transport device 12 is shown coupled to a form of portable converting device 110 which is similar to the device 75 shown in Fig. 2, but differs in that two converting chambers are provided and that liquid flows to the injector 90 under the influence of a gravity head in addition to a pressure head. The converting device 110 mounted on the trailer 76, comprises two chambers 111 and 112 having liquid connections 113 and 114 each leading from their lowest portions to the discharge conduit 115 of the injector 90 and upper gas discharge connections 116 and 117, which provide communication between the chambers 111 and 112 and the portion 94' that conducts gas to the actuating nozzle of the injector 90. The connections 113 and 114 are controlled by valves 118 and 119, respectively, and the connections 116 and 117 are controlled by valves 120 and 121. The portions of connections 116 and 117 between the chambers and the control valves 120 and 121 are placed in communication through a connecting conduit 123 which is provided with control valves 124 and 125 and communicates with the conduit 100 joining heating coils 81 through connection 100' at the portion between the valves 124 and 125. Similarly, a conduit 126 joins the liquid connections 113 and 114 in the portions between the valves 118 and 119 and the chambers 111 and 112. Conduit 100 is extended to communicate with conduit 94 between stop valves 95 and 95'. The conduit 126 is controlled by valves 127 and 128 between which it communicates with the inlet end of the heating conduit 81. The vaporizing coils of the heating conduit 81 are submerged in the heating fluid held in container 129. The extension 94' of conduit 94 leading to the actuating nozzle of ejector 103 is controlled by the valve 102. In this form of the apparatus, liquid flows into the injector chamber 90 through the extension of conduit 58 leading to coupling 60. This extension is here provided with a valve 60' and communicates with the inlet conduit 91 through flexible conduit 130, which is coupled between couplings 60 and 92. The conduit 91 is provided with a valve 91'.

In this form of apparatus, the one chamber is filled with liquid by injector action, while the contents of the other is being discharged to the vaporizing conduit 81. After the liquid in vessel 48 has been subcooled to the desired degree, as described in connection with the apparatus shown in Fig. 2 and the gas pressure in vessels 111 and 112 reduced to relatively low value, the conversion of liquid to gas is first started by opening the valves 59, 60', 91', 118 and 119, 127 and 128, 124 and 125, 121, 102, 68 and 69. Liquid will then flow under the influence of gravity through conduits 130, 91, 115, 113 and 114 and 126 to the vaporizing conduit 81, where the liquid is vaporized, the gas flowing through conduits 100, 100', 123, 117, 94', 104, 66, 65, the bypass controlled by valve 69 and conduit 62 into the gas space above the liquid in vessel 48. This action is continued until the pressure in vessel 48 has risen to the desired value. All valves except 59, 60', 91', 118 are now closed. When valves 125 and 95 and valves 120, 102, 107 and 89 are next opened, liquid is driven into chamber 111 by the energy of gas supplied through conduit 94 from chamber 112, the liquid flowing in through conduit 113 and gas displaced from chamber 111 flowing to cylinders 86 through conduits 116, 94', 106, 84 and 85. When chamber 111 is sufficiently charged, or when flow stops, the valves are changed as follows: Valves 118, 125 are closed and valves 124, 127 and 108 are opened. The liquid charge of chamber 111 runs into vaporizer coils 81 by the action of gravity until the liquid is vaporized and the pressure in cylinders 86 further increased. The injector may now be operated to force liquid into chamber 112 and the vaporizing coil continuously until injector action ceases at a pressure under the critical pressure for the gas. For this step, the valves 95, 119, 124 are opened to start the injector operating, the liquid passing through conduits 115 and 114 to chamber 112. As soon as the injector is operating steadily and the pressure in chamber 112 has been raised to equal that in conduit 81 and cylinders 86, the valve 125 is opened. The chamber 111, as well as chamber 112, is permitted to receive liquid by opening also valve 118, and when filled, the valves 127 and 128 are opened just sufficiently to permit liquid to pass into the vaporizing coil 81 at a rate equal to the rate of discharge from the injector 90. When the injector stops discharging liquid, the valves 95, 118 and 119 are shut and valves 127 and 128 opened fully, so that the charge of liquid will run into the vaporizer to be vaporized and converted to gas having a higher pressure.

Another method of operating this form of the apparatus is to fill one chamber while the other discharges, for example, while chamber 111 is discharging to the vaporizing coils with valves 124 and 127 open and valves 118 and 120 closed, vessel 112 is being filled, the valves 119, 95, 102, 107 and 121 being open and the valves 95', 125, 108 and 128 being closed. When chamber 112 is filled, the valves are reversed, valves 119, 121, 124 and 127 being closed and valves 118, 120, 125 and 128 being opened. This alternate action may be continued until the desired quantity of liquid has been converted into gas and stored in the cylinders 86 at relatively high pressure.

In Fig. 4 is shown the transport device 12 coupled to still another form of converting device 131, which comprises an uninsulated chamber 132 of the heavy walled pressure resisting type having disposed within a thin walled receptacle 133 so supported that the conduction of heat from the chamber 132 to the receptacle 133 is reduced to a small rate. The chamber 132 is provided at its upper portion with the gas connection 80 and at the lower portion with a liquid conduit 134 that is in communication with the liquid space of the receptacle 133 at its upper end and with the discharge chamber of a check valve 135 at its lower end. The check valve 135 prevents back flow of fluids into the discharge chamber 136 of the injector 137. The conduit 94 controlled by valve 95 leads from connection 80 to supply the motivating fluid to the injector nozzle. Liquid is supplied to the injector by a rotary pump 138 through its discharge conduit controlled by valve 139. The pump 138 receives liquid through its inlet conduit, which is controlled by valve 140 and terminates externally with coupling 141, which is coupled to conduit 130. The pump is directly driven by electric motor 142 through the extended shaft 143. The vaporizing conduit 81 communicates with the liquid conduit 134 and is provided with the valve 99 located close to the junction. Communication between chamber 136 and coils 81 is provided through conduit 144 controlled by valve 145. To even the rate of supply of liquid to the injector, a surge chamber 146 communicating at its lower end with the injector chamber 137 and at its upper portion with a conduit 147 controlled by valve 148, is provided. The conduit 147 communicates at its other end with the conduit 144 between the valve 145 and conduit 81. Only the pump, injector, surge chamber 146 and the liquid conducting conduits need be protected from the heat of the atmosphere by insulation shown at 149, as the space between the walls of the chamber 132 and receptacle 133 provides sufficient resistance to the flow of heat into the liquid that enters receptacle 133. A conduit 150 communicates with flexible conduit 66, being joined thereto by coupling 151, and with conduit 81 between valve 108 and coupling 83. It is controlled by valve 107. A vent connection 152 controlled by valve 153 communicates with conduit 100 between valve 101 and connection 80 and is used for venting gas to the atmosphere when desired.

When this form of apparatus is coupled as shown, the operation of servicing the cylinders 86 with gas of the desired high pressure is started by opening valves 59, 60′, 140, 139, 148, 108 and 89 and starting the pump 138 into operation. The liquid is then drawn from vessel 48 through conduit 130 into the pump and forced thereby through the injector chamber 137 and surge chamber 146 and through conduits 147, 144, 81 and 85 into the cylinders 86, the liquid being converted into gas during its passage through the coils of conduit 81. When the chambers 137 and 146 have been cooled to the desired temperature, the valve 145 is opened and valve 148 closed, the liquid then passing through the injector chamber 137 and combining tube 136 to conduit 144. This action may be continued until a pressure is reached that approaches the maximum against which the pump 138 can discharge. The valve 95 is then opened to start the injector and gas under pressure, which has been stored in the chamber 132, flows to the injector nozzle to actuate same and force the combined fluids from the combining tube 136 through conduit 144, while the pump continues to supply liquid to the injector chamber 137. The pressure in chamber 132 will soon be reduced to equal that in the coils 81. When this occurs, valve 101 is opened so that warm gas for actuating the injector may flow from the coils 81. The valve 145 is next closed until the basket 133 in chamber 132 is filled with liquid, after which it is opened sufficiently to pass all the liquid pumped to the coils 81. The operation continues until the pressure becomes too high for further operation of the injector when valves 145 and 95 are closed, the pump 138 shut down and valve 99 opened. The liquid in the basket 133 wil then flow under hydraulic head into the coils 81 to be converted into gas of still higher pressure. If it should be desired to increase the pressure of gas in the cylinders 86 to a still higher value, the chamber 132 may be alternately filled with liquid and discharged to the vaporizer several more times. When this is to be done, valves 145, 99 and 101 are closed and the pressure in chamber 132 reduced to an expedient value lower than the critical pressure of the gas by releasing some gas through conduit 152. The pump is started and valve 95 opened. When the basket 133 is filled, valve 95 is closed and valves 99 and 101 opened to allow the charge to flow into coils 81 and be vaporized.

Referring to Fig. 5, the liquid transporting device 12 is shown in position for servicing a vaporizer of the warm converter type shown generally at 210 and so located with reference to the device 12 that liquid may run into it from the vessel 48 under the influence of gravity. The warm converter comprises a heavy walled pressure vessel having a gas-tight cover and a thin walled inner receptacle or basket 211. Three conduits lead through the cover of the converter; the first conduit 212 connecting at its outer end with conduit 130, is utilized for conducting liquid into the basket of the converter, and is controlled by a valve 213. A second conduit 214 is provided for discharging gas. This latter conduit leads to the atmosphere from a point in the converter below the row of holes in the basket, which is approximately the level to which it is desired to fill the basket, and is provided with a branch 215 connecting with a flexible portion 216. Stop valves 217 and 218 are provided in the conduit 214 on either side of the branch. A conduit 219, communicating with the gas space above the liquid in vessel 48 and externally with conduit 216 is provided for discharging gas from the converter into vessel 48 above the liquid therein. Conduit 219 is provided with a control valve 220. The third conduit 221 passing through the cover is the usual gas discharge conduit but here it communicates at its external end with the flexible conduit 66. It is also provided with two stop valves 222 and 223. Between valve 222 and the converter, there is provided a branch 224 for conducting gas to a safety release device 225 that releases gas if the pressure in conduit 221 should exceed a predetermined safe working value. The manifold conduit 85′ branches from conduit 221 from a point between valves 222 and 223 and conducts gas to the cylinders 86.

The form of gasifying plant shown in Fig. 5

is serviced and operated as follows: It will be assumed that the gas remaining in the converter has been reduced to the lowest pressure reached in conduit 88'. Valve 222 is closed and the exhauster 63 is placed in operation, then valves 68 and 223 are opened so that gas may be drawn from vessel 48 and discharged to the cylinders 86. Valves 217 and 220 are opened gradually so that gas will pass from the converter into vessel 48 and be drawn out again by the exhauster. The exhauster is operated until its upper discharge pressure limit is reached, after which valve 213 and 59 are opened and since the pressures in the converter and vessel become equalized at a relatively low value, liquid will flow under the influence of gravity from vessel 48 into the converter. The pressure level reached, however, will generally be greater than the pressure of equilibrium with the liquid. Since the liquid entering is in the subcooled condition, the heat stored in the metal of the basket will be absorbed by the liquid without excessively increasing the pressure, and, in addition, the mixing of the liquid with the gas in the converter will cause some heat transfer between gas and liquid, with the result that some gas will condense. In the event that the pressure in the converter was or becomes too high to be safely held in vessel 48, gas is released by opening valve 218 for a desired period. The quantity so released, however, will be far less than the amount usually released to the atmosphere by former methods of filling warm converters. The exhauster is stopped and valves 68 and 223 are closed. When the basket is filled, as shown by the discharge of liquid when opening valve 218, which indicates that the liquid level has reached the depending end of conduit 214, valves 59, 213, 217 and 220 are closed and valve 222 is opened. The transport device is disconnected and driven away, while gasification of the liquid in the converter proceeds as heat enters through the wall from the heating fluid in contact with the converter.

In Fig. 6 is shown the transport device 12 coupled to a portable pumping and vaporizing apparatus, shown generally at 230, which is arranged for forcing fluid into a vaporizer for conversion into gas. The pumping and vaporizing apparatus is carried by a trailer 231, which is drawn by the transport vehicle 12 through the medium of a draw bar coupling 232. The pumping means comprises a reciprocating pump having a chamber 233 designed to withstand a relatively high internal pressure and provided with inlet ports 233' which are uncovered by the lower end of a piston or plunger 234 working in the pump chamber. The discharge passage, controlled by non-return valve 235, communicates with the chamber 233 at its lower portion and with a vaporizing coil 236 disposed within heating jacket 237. The pump chamber 233 is disposed within a heat insulated container 238 provided with liquid inlet and gas outlet connections communicating with conduits 130 and 216, respectively, and controlled by stop valves 239 and 240. The piston 234 is elongated to increase the resistance to conduction of heat through it to the pump chamber and to this end passes through a relatively long packing gland 241. The piston 234 is reciprocated by the crank disk 242 through the agency of a connecting rod 243; the crank being actuated by a suitable prime mover, for example, by an electric motor 244 which preferably turns it at a relatively slow speed.

The vaporizing conduit 236 communicates at its external end with conduit 84 and is controlled by a valve 245 located in it close to the coupling. A conduit 246 branches from conduit 236 at a point between its coiled portion and valve 245 and is provided with a coiled portion in the heating fluid before it connects with conduit 66. It is controlled by a valve 247.

When the apparatus is coupled together as shown in Fig. 6, the liquid in vessel 48 may first be further subcooled by placing exhauster 63 in operation and opening valves 68, 247, 245 and 89, the gas drawn out of vessel 48 being forced over into the cylinders 86, which have previously been exhausted to a relatively low pressure. Such gas is warmed to the desired temperature on passing through the coil portion of conduit 246. When the desired cooling has been attained, or when the back pressure of gas in the cylinders 86 grows too high for the exhauster to act against, the exhauster is stopped, valve 69 is opened to allow sufficient back flow of gas into vessel 48 to create therein a desired temporary pressure, when valves 69, 247 and 68 are closed. Then valves 59, 239, 240 and 220 are opened, whereupon liquid will flow under the influence of gravity into the container 238, the gas displaced therefrom passing over to the vessel 48 through the conduits 216, 219. The connection controlled by valve 240 is so positioned that the liquid will rise in container 238 just sufficiently to cover the inlet ports 233' to a desired depth and to trap vapor in the space above this level. The motor 244 is energized by closing the electrical circuit between it and a suitable source of current, such as may be available at the location, or the storage battery of the transport vehicle 12. The upstroke of the piston 234 uncovers the inlet ports 233' so that liquid flows into the pump chamber by gravity, displacing gas therefrom, and the downstroke drives the charge of liquid out through the check valve 235 into the coils 236, where the liquid is heated and converted into gas of the desired pressure. This gas flows through conduit 84 and manifold 85 into the cylinders 86, where it is stored for supplying the consuming apparatus upon demand.

As the liquid entering the pump chamber is subcooled, the tendency to flash into vapor in the pump exhibited by liquids at their boiling points is not present. Therefore, the pump operates with greater efficiency. The sub-cooled liquid further has great power to cool the metal of the pumping device without excessive vaporization when pumping is first started. Gas vaporized in the pump passes over to the vessel 48, where it serves to create and maintain a non-equilibrium pressure above the liquid, whereby the tendency for flashing and the restriction of the flow into the pump are minimized. Gas remaining in the vessel 48 will gradually be condensed through heat exchange with the subcooled liquid that remains after discharging the desired quantity. When the cylinders 86 contain the desired quantity of gas, the liquid controlling valve 59 is first closed and pumping is continued for a short time to remove as much of the liquid from container 238 as possible; then the pump is stopped and the other valves closed.

Since certain changes in carrying out the above process and in the constructions set forth, which embody the invention, may be made without departing from its scope, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. Apparatus for dispensing gas material that has a boiling point temperature at normal atmospheric pressure below 273° K. which comprises the combination with a source for supplying liquefied gas at a relatively low pressure, of a thermally insulated container for receiving and holding a charge of liquefied gas at a relatively high pressure, conduit means for effecting a transfer of the charge into said container, means for cooling by expansion the charge being transferred, independent means for cooling the charge by withdrawing and conserving vapors generated within said container, and insulated receiving means connected for withdrawing the charge when cooled.

2. Apparatus for dispensing oxygen for industrial consumption which comprises the combination with a transportable container for liquid oxygen, of a receiving device associated with said container and adapted to receive gas material therefrom and provided with passages for dividing the gas material received into two portions, a vessel communicating with one of said passages for receiving and storing one of said portions, a vaporizing means connected with the other of said passages, and means for utilizing the energy of gas material at high pressure to accelerate the passage of gas material into said vaporizing means.

3. Apparatus for dispensing oxygen for industrial consumption which comprises the combination with a transportable container for liquid oxygen, of a receiving device associated with said container and adapted to receive gas material therefrom and provided with passages for dividing the received material into two portions, a vessel for temporarily receiving and storing one of said portions communicating with one of said passages, vaporizing means communicating with the other passage, a connection for delivering gas material directly from said vessel to said vaporizing means, and means associated with said device for withdrawing gas material in the gas phase and utilizing it at a relatively high pressure for assisting the transfer of gas material.

4. Apparatus for dispensing gas material that has a boiling point temperature at normal atmospheric pressure below 273° K., which comprises, in combination, a transportable container for holding a charge of liquefied gas, means for receiving the gas material from said container, and conduit means for conveying the gas material from said container into said receiving means and arranged to divide the same into two portions, said receiving means being heat insulated and including storage means communicating with said conduit means for receiving and temporarily storing one of said portions and vaporizing means connected to said conduit means for receiving and gasifying the other portion.

5. Apparatus for dispensing gas material which has a boiling point temperature at normal atmospheric pressure below 273° K., which comprises, in combination, a transportable container for holding a charge of liquefied gas, means for receiving the gas material from said container, and conduit means for conveying the gas material from said container into said receiving means and arranged to divide the same into two portions; said receiving means being heat insulated and provided with a vessel communicating with said conduit means for receiving and temporarily storing one of said portions, a vaporizing coil communicating with said conduit means for receiving the other portion, and means for warming said vaporizing coil.

6. In a method of dispensing gas material that has a boiling point at normal atmospheric pressure below 273° K., the steps which comprise storing and sub-cooling a body of liquefied gas, introducing at least a portion of said body in a condition subcooled to a temperature below the boiling point temperature which corresponds to a pressure at which it is subsequently to be handled into the receiving chamber of a thermally insulated pump, pumping said received portion by forcing the same from said pump chamber against a relatively high head of pressure, and withdrawing and conserving any vapors that flash from said received portion while being pumped.

7. In a method of dispensing oxygen for industrial purposes, the steps which comprise storing and subcooling a body of liquid oxygen, introducing at least a portion of the liquid oxygen so stored when subcooled to a temperature materially less than 90° K. into the receiving chamber of a thermally insulated pump, pumping said received portion of liquid oxygen by means of energy supplied from an external source to force said received portion from said pump chamber against a relatively high head of pressure, and during the pumping step withdrawing and conserving any gaseous oxygen that may flash from the portion while in transit through the pump.

8. Apparatus for dispensing liquefied gas material that has a boiling point temperature at normal atmospheric pressure below 273° K. for industrial consumption which comprises the combination with a source for supplying such liquefied gas at relatively low pressure, of a closable container that is protected by insulation and has a connection for receiving a charge of liquefied gas transferred from said source at said low pressure, said container having a wall of a strength adapted to resist a pressure of a relatively high value which may be attained when said container is closed, and cooling means associated with said container for lowering the temperature of the charge therein to a value materially below the boiling point at the pressure at which said charge is transferred, said cooling means consisting of a pair of independent devices, one of which comprises a means for cooling by expansion the liquid transferred and the other a mechanism for cooling the liquid transferred by evaporation.

9. Apparatus for dispensing oxygen for industrial consumption which comprises the combination with a source for supplying liquid oxygen at a relatively low pressure, of a closable container that is protected by thermal insulation and has a connection for receiving a charge of liquid oxygen transferred from said source at said relatively low pressure, a cooling device comprising an expansion valve in said connection for lowering the temperature of the charge transferred, and an additional cooling device connected to said container and including a suction pump adapted to withdraw gaseous oxygen from the upper part of said container to effect cooling of the charge in the container by evaporation and assist in transferring liquid oxygen thereto.

10. Apparatus for dispensing oxygen for industrial consumption which comprises the combination with a closable transportable container for liquid oxygen, of a device for receiving gas material from said container and having passages for dividing the same into a plurality of por-

tions, a vessel communicating with one of said passages for receiving and storing temporarily one of said portions, a vaporizing means communicating with another of said passages, a connection for passing the stored material from said vessel to said vaporizing means, gas phase withdrawal means having branches leading from said container and vessel, one branch including a pump for effecting positive removal of gas material in the gas phase from said container, and a receiving system provided with mechanism for detachably connecting it to said gas phase withdrawal means.

11. Apparatus for dispensing oxygen for industrial consumption which comprises the combination with a closable transportable container for liquid oxygen, of a device for receiving gas material from said container and provided with passages for dividing the same into two portions, a vessel communicating with one of said passages for receiving and temporarily storing one of said portions, a vaporizing device communicating with the other passage, a communication for passing gas material directly from said vessel to said vaporizing device, gas phase withdrawal means having branches leading from said container and said vessel, one branch having a compressor for elevating the gas withdrawn to a relatively high pressure, a pair of injectors associated with the other branch for assisting the passage of gas material, one of said injectors being disposed at an entrance to said vessel, and a receiving system arranged to be connected jointly to said compressor branch and said other injector branch.

12. The method of handling normally gaseous material to provide for the delivery of a predetermined quantity in bulk form from a production plant to a consuming installation, which method comprises segregating, in a container protected by insulation and mounted on a transportable vehicle, a charge of said material in the liquid phase sufficient in quantity not only to offset evaporation losses occasioned by the handling of the charge at the production plant but also to insure the delivery of said predetermined quantity, and subcooling said charge of liquid to a temperature sufficiently low to offset the leakage of heat into the container through the insulation and to insure that said charge will be at a temperature below its boiling temperature at the existing pressure when delivered.

13. The method of handling oxygen for industrial use in consuming systems which comprises producing liquid oxygen at a production plant at a pressure of a value not greatly different from atmospheric, segregating a charge of the liquid oxygen so produced in a closable container that is protected by insulation, said charge being in an amount such as to leave a space of predetermined volume for vapor above the liquid in the container, subcooling the liquid oxygen introduced within said container to a temperature below a value taken sufficiently low to offset any heat leakage into the container at a known rate during a predetermined period such as that required for transportation, said subcooling being practiced by expanding a portion of the liquid and by withdrawing gaseous oxygen from the space in the container, and thereafter discharging at least a portion of the liquid oxygen within the container while in said subcooled condition to a consuming system.

14. The method of handling oxygen for industrial use in consuming systems which comprises charging a closable container that is protected by insulation with a body of liquid oxygen, subcooling said body to a temperature which is sufficiently below 90° K. to permit heat leakage at a known rate for a predetermined period without exceeding 90° K., withdrawing gaseous oxygen from said container to effect further subcooling of the charge therein, compressing said withdrawn gaseous oxygen and conserving the same by storage in a receiver at relatively high pressure, transferring a portion of said subcooled charge to receiving means containing gaseous oxygen under a pressure less than said relatively high pressure, withdrawing and employing the gas under pressure from said receiving device for assisting the transfer of said portion of subcooled liquid, discontinuing said transfer and vaporizing said transferred portion of liquid to generate a pressure in excess of said relatively high pressure for storage in said receiving means.

15. The method of handling gas material which in the liquid phase has a boiling point temperature at normal atmospheric pressure below 273° K., which method comprises charging a closable transport container that is protected by insulation with a body of liquefied gas which has been subcooled to a temperature materially below a boiling point temperature corresponding to a pressure of predetermined permissible value attainable during a period when the liquis is being transported, transporting said container while closed to the atmosphere during said period and with the pressure therein less than said predetermined value, building a discharge head of pressure in a portion delivered from said container by imparting kinetic energy thereto, and discharging said portion to receiving means when the discharge head is in excess of the pressure obtaining in said receiving means.

16. The method of handling gas material which in the liquid phase has a boiling point temperature at normal atmospheric pressure below 273° K., which method comprises charging a closable transport container that is protected by insulation with a body of liquefied gas which has been subcooled to a temperature materially below a boiling point temperature corresponding to a pressure of a predetermined permissible value attainable during a period when the liquid is being transported, transporting said container while closed to the atmosphere during said period and with the pressure therein less than said predetermined value, building a discharge head of pressure in a portion delivered from said container by imparting heat thereto to vaporize the same, and discharging said portion to receiving means when the discharge head is in excess of the pressure obtaining in said receiving means.

17. The method of handling gas material which in the liquid phase has a boiling point temperature at normal atmospheric pressure below 273° K., which method comprises charging a closable transport container that is protected by insulation with a body of liquefied gas which has been subcooled to a temperature materially below a boiling point temperature corresponding to a predetermined permissible value of pressure attainable during a period when the liquid is being transported, transporting said container while closed to the atmosphere during said period and with the pressure therein less than said predetermined value, building a discharge

head of pressure in a portion delivered from said container by imparting thereto both kinetic energy and heat energy, and discharging said portion to receiving means when said discharge head is in excess of the pressure obtaining in said receiving means.

18. The method of handling oxygen for industrial use in a consuming system, which method comprises charging a closable transport container that is protected by insulation with a body of liquid oxygen at a pressure below atmospheric and subcooled to a temperature sufficiently below 90° K. to offset heat leakage at a known rate for a predetermined period without attaining 90° K., transporting said container while closed for discharge at a consuming system and with the pressure therein higher than that of the charging pressure but not greatly different from atmospheric, then building a head of pressure in the container, discharging liquid oxygen under said head to the system, vaporizing a portion of the discharged liquid oxygen, increasing the pressure of said vaporized portion to a head of desired value by imparting energy in kinetic form to the vapor generated from a supply of gas at a relatively high pressure, thereafter heating a remaining portion in a vaporizer to provide additional gaseous oxygen at a pressure of desired head value, and then delivering all of the gaseous oxygen so provided to receiving means when the pressure head is in excess of the pressure obtaining in said consuming system.

WILLIAM F. MESINGER.