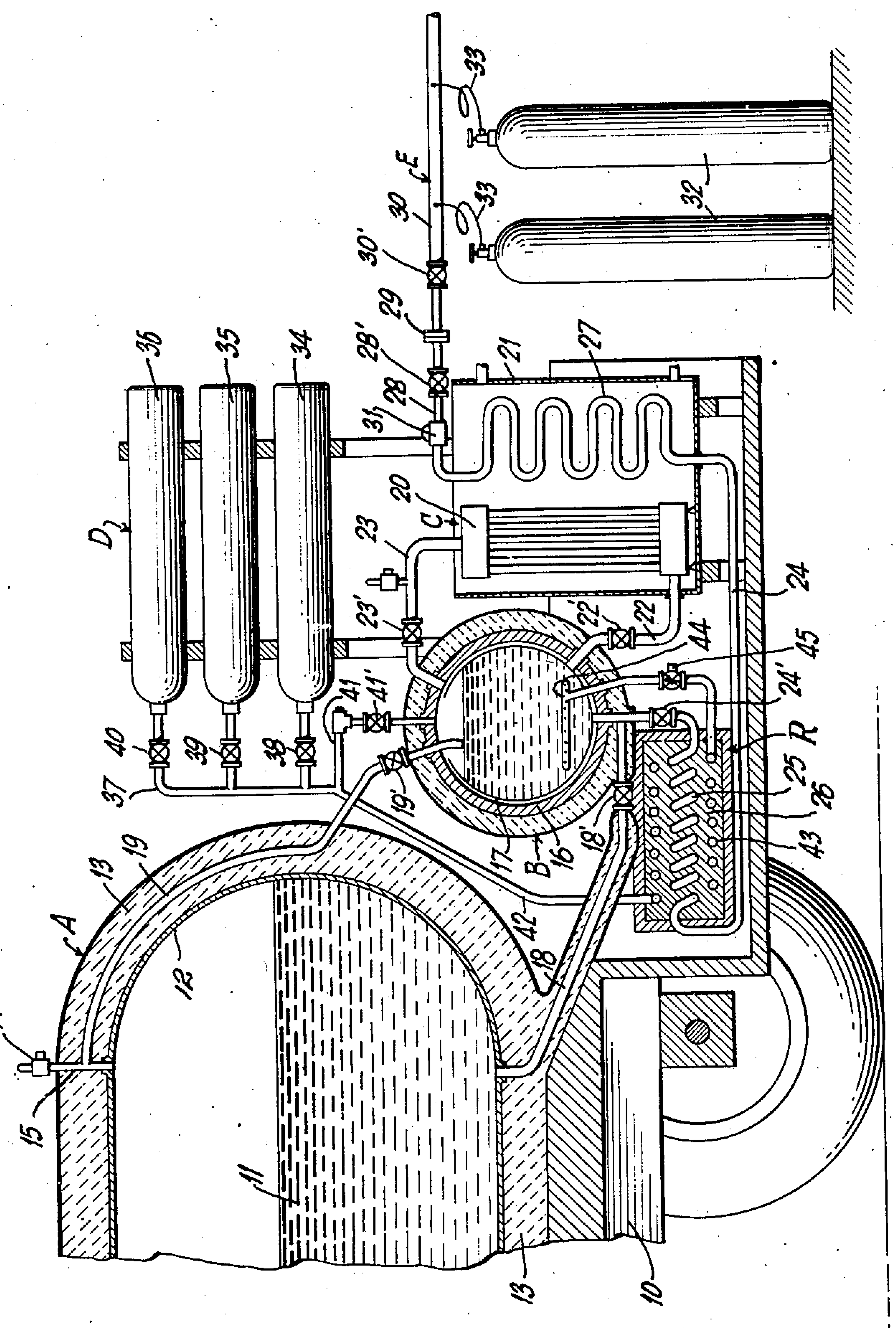
May 5, 1936. W. F. MESINGER 2,040,059

METHOD AND APPARATUS FOR DISPENSING GAS MATERIAL

Filed June 18, 1935 3 Sheets-Sheet 1

FIG. 1.



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Filed June 18, 1935 3 Sheets-Sheet 2

Fig. 2.

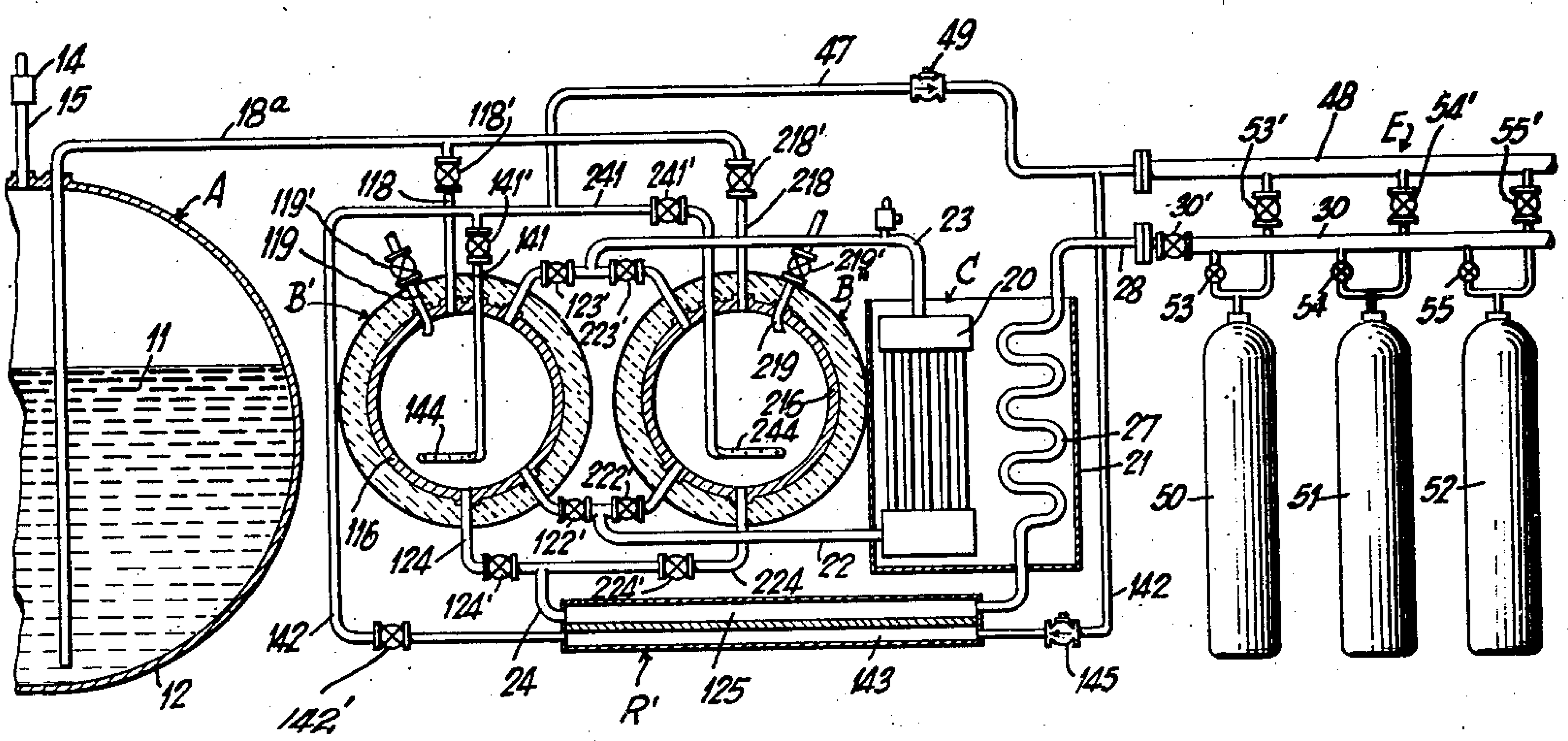
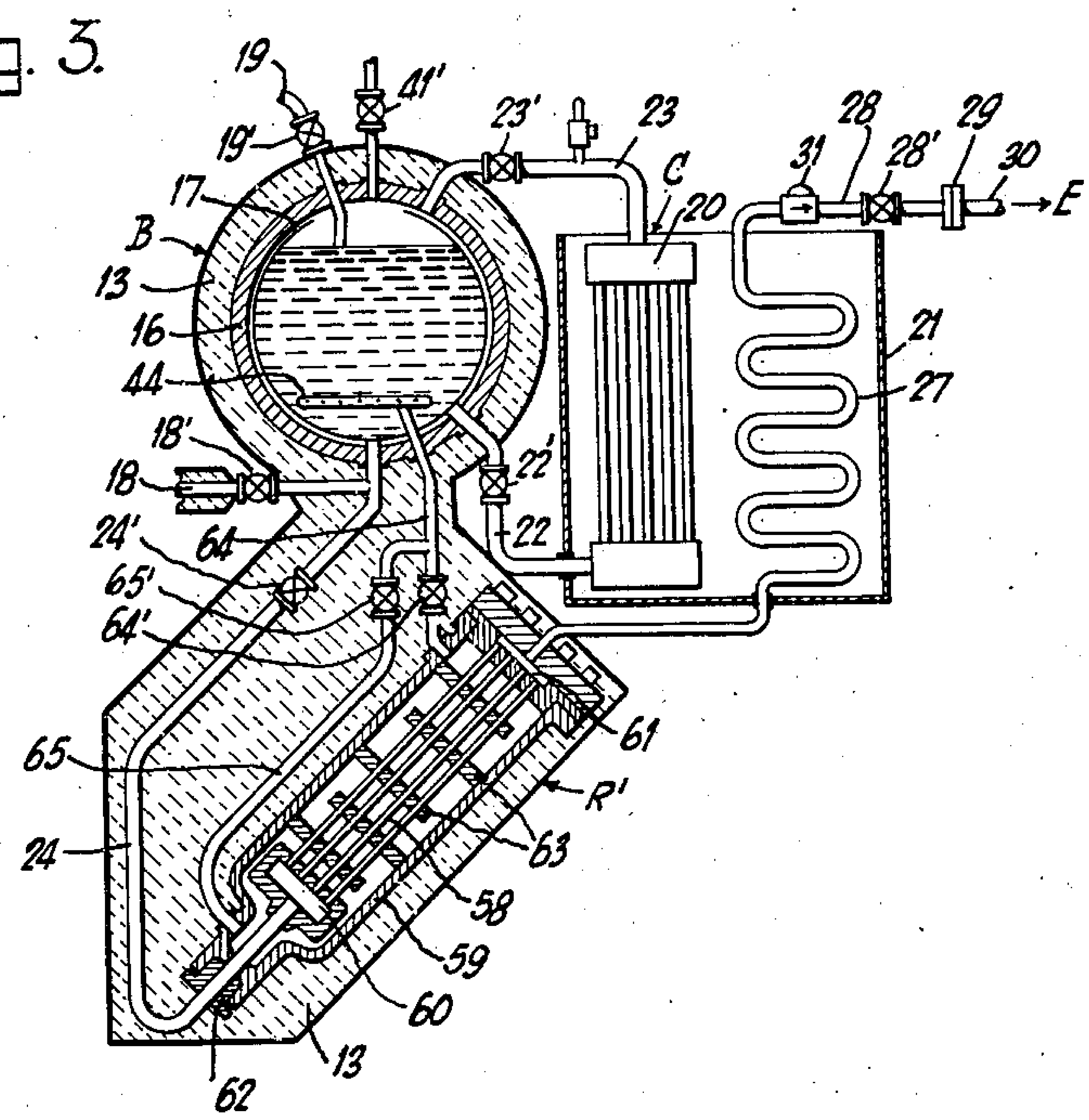


Fig. 3.



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Filed June 18, 1935 3 Sheets-Sheet 3

Fig. 4.

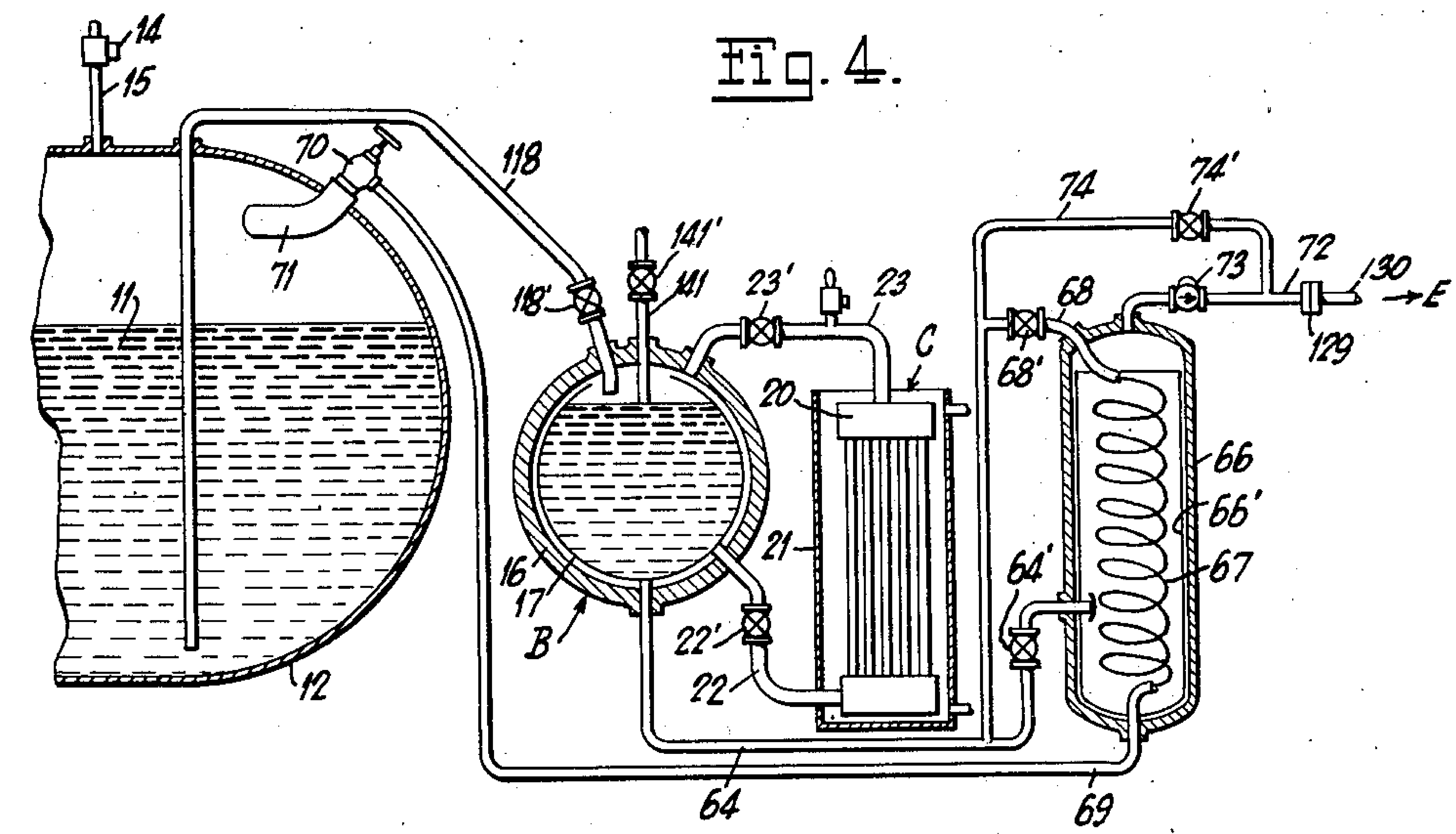
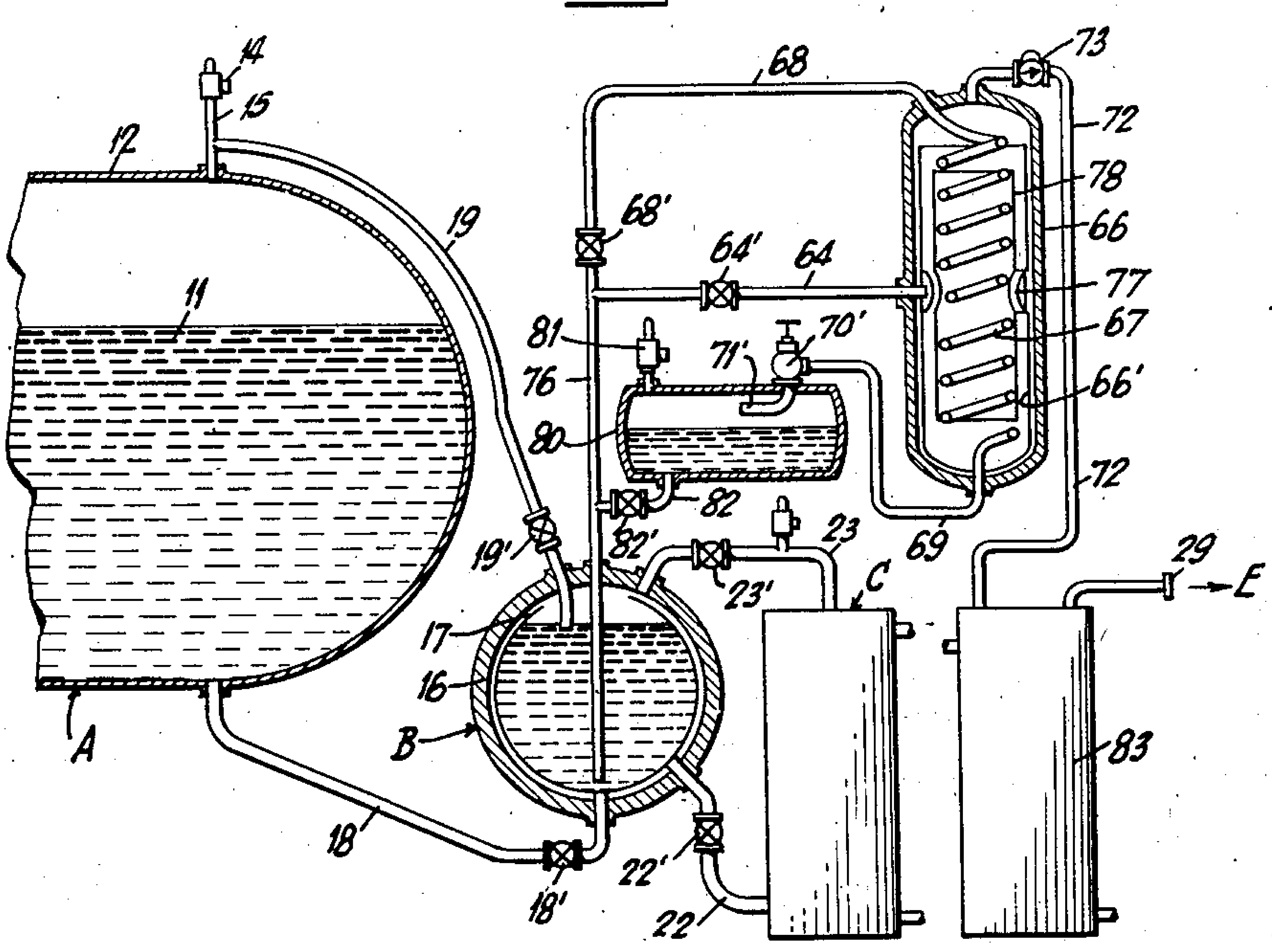


Fig. 5.



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Patented May 5, 1936 2,040,059

UNITED STATES PATENT OFFICE

2,040,059

METHOD AND APPARATUS FOR DISPENSING GAS MATERIAL

William F. Mesinger, Flushing, N. Y., assignor, by mesne assignments, to Union Carbide and Carbon Corporation, a corporation of New York

Application June 18, 1935, Serial No. 27,154

19 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 transferring liquefied gas to receivers at relatively high pressure by means of a transfer vessel with recovery and condensation of residual gas.

The invention has for its object generally an improved procedure and arrangement of apparatus of the character indicated whereby a liquefied gas having a relatively low boiling point, such as liquid oxygen, liquid nitrogen, and the like, is transferred to receivers at a relatively high pressure in an efficient and economical manner and in which gas provided for displacing charges from the transfer vessel is condensed largely to liquid and admixed with liquefied gas being transferred whereby blowdown losses are reduced.

More specifically, it is an object of the invention to provide a method and apparatus for carrying the same into effect whereby successive charges of liquefied gas are passed by means of a single transfer vessel from a transport container where it is held at a relatively low pressure and temperature to receivers at relatively high pressure in which the charges are expelled from the transfer vessel by providing a regasified liquefied gas having the desired pressure for displacing the charge. The gas material is conserved by withdrawing the displacing gas during the interim between charges, temporarily storing and partially liquefying the same for admixture with liquefied gas being transferred.

Another object is to provide for the temporary storage of the displacing gas in any of several ways according to the conditions to be met; one method including the temporary storage of the displacing gas in the gas phase at one or several pressure levels followed by cooling and recondensation; a second method including the temporary storage of the displacing gas after partial liquefaction; and a third including the temporary storage of the displacing gas after partial liquefaction by heat exchange with a temporarily stored charge of liquefied gas that is being transferred.

Still another object is to provide for the conservation of displacing gas in a system where transfer vessels are operated in parallel by the above mentioned methods of temporary storage during certain periods of operation.

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 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 a view partly in section and partly in elevation showing a form of the apparatus according to the invention wherein the displacing gas is temporarily stored in the gas phase;

Fig. 2 is a similar view showing an apparatus according to the invention, having two transfer vessels arranged for parallel operation together with a modification of the receiver means for temporarily storing displacing gas;

Fig. 3 is a fragmentary view mainly in section showing a portion of the apparatus modified to provide for the condensation and temporary storage of the displacing gas in the liquid phase;

Fig. 4 is a view mainly in vertical section of another form of the apparatus in which charges of liquefied gas are temporarily stored for heat exchange with displacing gas being cooled and partially condensed; and

Fig. 5 is a similar view of still another form of the apparatus in which the displacing gas, after heat exchange with temporarily stored charges of liquefied gas is temporarily stored after partial liquefaction for addition to liquefied gas being transferred according to the invention.

Heretofore it has been proposed to provide a supply of gas having a relatively high pressure at a place of use by transporting liquefied gas in an insulated container under relatively low pressure to the place of use and there converting a desired portion of the liquid into gas at high pressure by means of a vaporizing vessel or "converter". Such a vessel was supplied with a charge of liquefied gas when at a low pressure and closed; if then heat were applied to the charge, it expanded and became converted to gas having the desired high pressure for passage into the receivers located at the place of use. Before refilling such a vessel the gas remaining therein was released to the atmosphere so that liquefied gas from the transport container where it is held at relatively low pressure would flow in unimpededly.

It has been proposed to avoid the loss of gas material due to such blowdown by mechanically compressing the gas released to the desired high pressure for use. However, the provision of a compressor is attended with numerous difficulties such as providing the necessary mechanical energy and other complications which are greatly increased when it is desired to handle gases such as oxygen.

By the present invention the blowdown loss is reduced to an immaterial amount by providing for the temporary storage of displacing gas, its condensation through heat transfer with liquefied gas being transferred and admixture of the condensed gas with liquefied gas being transferred. To this end, there is provided in addition to a pressure resistant transfer vessel arranged for receiving charges of liquefied gas from a supply container, a means for providing in the vessel an increased gas pressure which forces a desired portion of the charge to receivers, and a means for conserving a substantial portion of the gas remaining in the transfer vessel prior to blowdown to the relatively low pressure desired when recharging, by the withdrawal, temporary storage and partial liquefaction of the gas to be conserved. The liquefaction is achieved by the utilization of a refrigerating effect of the liquefied gas being transferred.

Referring now to the drawings and particularly to Fig. 1, there is shown a vehicle 10 upon which is carried an apparatus for dispending liquefied gas according to the invention comprising a liquefied gas holding and transporting container shown generally at A, charge expelling means shown generally at B and C, and temporary gas storage vessels shown at D. Gas receivers at the place of use shown at E are to be serviced with a supply of gas under relatively high pressure for consumption upon demand.

The transport container A holds a supply body of liquefied gas 11 within a sealable vessel 12, the wall of which is made heavy enough to resist only moderate pressures and is surrounded by a heat insulating envelope 13. Customary devices for filling, discharging, indicating pressures and liquid levels, and for releasing gas when the pressure exceeds a desired limiting value, are preferably provided in conjunction with container A. Of these only a pressure releasing valve is shown at 14 communicating with container 12 through connection 15; the showing of the others being omitted in the interest of clearness of illustration in the drawings.

The transfer vessel B comprises a heavy walled pressure resistant vessel 16 which preferably has within it a relatively thin walled liquid holding vessel or "basket" 17 disposed in spaced relation to the inner wall of vessel 16 and supported therefrom by means of interposed spacers of a character that retards the flow of heat across the interval. For filling the basket 17 of vessel B with a definite or measured charge of liquid, there are provided separate liquid and gas conduits communicating with container 12 at predetermined points, as shown at 18 and 19 respectively. Conduit 18 connects the lower portions of both container 12 and basket 17 while conduit 19 conducts gas from a selected point in the upper portion of the interior of basket 17 which determines the level to which filling with liquid is limited, thereby determining the desired amount.

For expelling the charge of liquid from the vessel B, gas having the desired pressure is introduced to the space above the liquid in vessel 16. A preferred means for accomplishing this is shown at C in the form of a so-called "thermal leg" in which a heating element 20 is arranged to receive heat from a heating medium in a jacket 21 and heat and vaporize the gas material at a rapid rate and raise the same to a relatively high temperature. The lower portion of element 20 is placed in communication with the liquid in basket 17 at a point below the normal liquid level by means of conduit 22 controlled by a valve 22' that is normally open, while the upper portion of element 20 communicates with the space above the liquid level through a conduit 23 which has a control valve 23' that is normally open. Valves 18' and 19' controlling conduits 18 and 19 respectively are also provided.

The charge in basket 17 is expelled to the receivers through a conduit 24 which leads from the bottom of the basket and is controlled by valve 24'. This conduit may, when desired, conduct the gas material directly into receivers according to the invention. However, in the form here shown, the conduit 24 is provided with two portions in which heat is imparted to the gas material discharged. One of these portions comprising a pipe coil 25 is heated by a heat storage material 26 which is disposed in contact therewith. The heat storage material and associated support is hereinafter termed a "regenerator", and is generally indicated at R. Such material may be of any suitable substance having the desired heat storage capacity; for example, a body of cast metal or a mixture of mineral salts or a fluid in which the coils are embedded. The second heat receiving portion of conduit 24 is shown in the form of an extended portion at 27 disposed to be enveloped in the heating medium in jacket 21 and is termed a "heater", since it receives and heats the gas material and discharges the same at the temperature desired. The heater 27 has an exit connection 28 which is connected by means of a coupling 29 to a service conduit or distributing manifold 30. Connection 28 is controlled by a stop valve 28' and a check valve 31, while manifold 30 is controlled by stop valve 30'. One or more receivers 32 are connected to the manifold 30 to receive the discharge, the connection being preferably made through flexible connections 33.

The temporary gas storage means D may consist of one or more pressure resistant gas receiving vessels or containers, a plurality being shown, and each being provided with an individually controlled inlet for holding gas at a corresponding number of different pressure levels according to the degree of efficiency in conserving gas desired. Here such containers are shown respectively at 34, 35 and 36, and have connections to a manifold 37, which are controlled respectively by valves 38, 39 and 40. The manifold 37 communicates with the interior of vessel 16 through two passages, the one formed by connection 41 which is controlled by valve 41' for passing gas from the vessel 16 to the containers D, the other passage being formed by a conduit 42 which has a coiled portion 43 in thermal contact with regenerator material 26 for imparting heat thereto. The conduit 42 conducts gas from manifold 37 through coiled portion 43 to a distributor 44 which is disposed in the lower portion of the liquid holding space of basket 17. Flow through conduit 42 is limited in direction to that toward vessel 16 by means of a check valve 45 which is also arranged to provide a throttling action on the gas flowing in the permitted direction.

The regenerator R is preferably enclosed within heat insulating material. The normal flow of gas material through its passages is preferably in countercurrent directions when a temperature gradient is preferably maintained from one end to the other.

The size of the transfer vessel B is determined by selecting the maximum amount of liquid charge that it is desired to transfer at one time. This may be so small that it would fill only one receiver 32 or it may be larger where more than one receiver is to be filled by the transfer of one or more charges, depending on the conditions to be met. The capacities of the several containers 34, 35 and 36 need not be the same, and for the lower pressures containers may be relatively large.

In the operation of servicing a consumer's receivers E with liquefied gas using this apparatus, the container A is filled with liquefied gas at a gas liquefying and producing plant, transported to the place of use and the connection 28 coupled to manifold 30. All the valves are assumed to be closed except those of receivers 32. The basket 17 is filled to the desired level with a charge of liquefied gas by opening valves 18' and 19' so that the liquid flows over under the influence of gravity while the gas displaced or vaporized during the filling flows into container 12 wherein the pressure is increased. Should the pressure in container 12 rise to the desired limiting value, further input of gas will cause the relief valve 14 to open and release gas to the atmosphere. Vaporization of liquid entering vessel 16 caused by heat inflow transferred from the walls of the vessel 16 is held to an inconsequential amount by virtue of the insulating effect of the space interval about the basket 17.

The predetermined charge is next expelled from vessel B by closing valves 18' and 19' and opening valves 24', 28', 30', 22' and 23'. Thermal leg C immediately receives some liquefied gas through connection 22, heats it to a relatively high temperature and discharges the resulting warm gas into the space above the liquid level and builds pressure therein rapidly to a value exceeding that in receivers 32. The thermal leg acts in accordance with the principles described in copending application, Serial No. 3,249, filed in the name of G. H. Zenner. The major portion of the charge is forced out through conduit 24 reaching finally the receivers 32. In passing through coils 25 the refrigeration or heat absorbing power of the gas material extracts heat from the regenerator 26 and cools it to a relatively low temperature. The gas material discharged is finally heated to desired temperature when passing through heater 27.

The vessel B, after expulsion of the charge, contains displacing gas of relatively high temperature and pressure applied by the thermal leg C, which gas is withdrawn from vessel B in order that it may be recharged. To accomplish this and at the same time conserve a substantial amount of the displacing gas, portions of gas are passed to the storage containers D. Since in this case there are three such containers, the passage is effected in three steps as follows: With valves 22', 23' and 24' closed, valves 38 and 41' are opened and gas will pass from vessel B to container 34 until the pressures equalize. Valve 38 is next closed and valve 39 opened until the pressures of vessel B and container 35 equalize at a lower value. Finally valve 39 is closed and valve 40 opened and equalization of pressures between vessel B and container 36 takes place at a still lower value, after which valves 40 and 41' are closed.

While the displacing gas is temporarily stored in containers D, vessel B is recharged as before with liquid from container A and when so charged valves 18' and 19' are closed and valve 40 opened. Gas now flows from container 36 through manifold 37 and conduit 42 and into vessel B where it is introduced into the liquid charge by distributor 44. On passing through coil portion 43, the displacing gas imparts heat to the regenerator 26, being cooled thereby so that it may more readily be condensed. Refrigeration contained in the charge that was expelled is thus usefully transferred to the displacing gas which is being condensed. On issuing from distributor 44 the cooled gas mixes with the charge which is at first at a relatively low temperature and pressure and is partially condensed. In consequence both the temperature and pressure of the charge rise a relatively small degree and the pressure of gas in container 36 is reduced a desired amount. In similar manner containers 35 and 34 are discharged successively to vessel B by closing valve 40, opening valve 39, then closing valve 39 and opening valve 38 which is closed after the pressures of container 34 and vessel B equalize. On passing check valve 45, which is constructed to provide a throttling action on the gas flowing toward vessel B, the gas is further cooled by the Joule-Thompson effect caused by the throttling action when the pressure differences are great enough.

The charge, now augmented by the displacing gas that was added to it, is expelled to the receivers by the action of the thermal leg C as explained in connection with the expulsion of the previous charge. The cycle of expulsion, displacing gas storage, charging, and displacing gas condensation is repeated until the receivers E have been charged with gas to a desired pressure. After the final charge required for filling the receivers E has been expelled from vessel B, the displacing gas is preferably stored in containers D and vessel B and transported with the apparatus to another place of use where it may be added to the first charge to be expelled to another set of receivers.

The step of precooling by regenerator action the displacing gas to be condensed is not an essential element of the invention and may be omitted where it is desired not to heat gas material being expelled from vessel B. Omission of the regenerator where discharge is to be stored as a medium pressure liquid is not an advantage. The same energy must be transferred to the liquid from the residual gas or must be blown to the atmosphere. Use of a regenerator would permit lower equalization pressures and consequent lower losses, without appreciably changing the temperature of the liquid discharge to the storage unit. Thus, a similar method of operation may be practiced with an apparatus modified by the omission of the regenerator or heat exchanger passes from the conduits carrying gas material expelled from vessel B and the displacing gas to be condensed. As an example, the regenerator would not be used when the liquefied gas is to be expelled into an insulated receiver for storage therein at a relatively low temperature and moderately elevated pressure. In such a case, the discharge conduit 24 would be modified to connect directly to the receiver and heat receiving portions 25 and 27 omitted. The displacing gas is then fed directly into the liquid charge and cooled and partially condensed thereby.

When efficient recovering of displacing gas according to the present invention is practiced, it is economically feasible to transfer a desired quantity of liquefied gas by passing a succession of segregated charges of the liquid through a relatively small transfer vessel which is readily portable. The discharge from a single vessel is discontinuous to allow intervals during which the vessel is charged. To provide relatively continuous transfer and to shorten the time necessary for transferring a desired quantity of liquid, two or more transfer vessels may be operated in parallel. Hence, in any of the forms of the present invention described, it is contemplated that parallel systems may be operated and that certain portions of the apparatus may be common to both systems. For example, in each of the forms illustrated in the several figures of the drawings, the transfer vessel B may be provided in duplicate with conduits and control valves arranged so that they may be operated in parallel to be alternately charged from the common supply container and alternately discharged by a common thermal leg C furnishing the displacing gas. The means for temporarily holding and/or condensing displacing gas may also be common to both transfer vessels.

Referring now to Fig. 2, there is shown a modified form of apparatus in which two transfer vessels B′ and B″ are provided and the receivers at E are arranged to function also as containers for temporarily storing displacing gas to hold the same until a fresh charge is available for equalization. The containers D are omitted and the displacing gas is passed to a selected consumer's receiver by means of conduit 47 which conducts the gas from vessels B′ and B″ to an auxiliary manifold 48. Each of the receivers 50, 51, 52, etc. is connected to each of the manifolds by connections controlled respectively by valves 53, 53′, 54, 54′, 55, 55′; admission of gas from manifold 30 to cylinders 50, 51, 52 being controlled by the group of valves 53, 54, 55, while that from manifold 48 is controlled by the group of valves 53′, 54′, 55′. The receivers 50, 51, etc. may consist each of a single cylinder or of interconnected groups of cylinders which are charged as a unit.

In this form of the apparatus, the transport container A is not sufficiently elevated with respect to the transfer vessels B′ and B″ to allow gravity flow of liquid at all times when charging. Transfer of liquid is therefore effected by providing a superatmospheric pressure on the liquid in container A to force liquid under the influence of difference of pressure through the transfer conduit 18*a* into either of the transfer vessels. Conduit 18*a* is connected to both vessels 116 and 216 by connections 118 and 218 respectively. The transfer vessels are vented when desired through connections 119 and 219 which lead gas from the upper portions of vessels 116 and 216 respectively. The discharge conduit 24 is provided with two branches 124 and 224 leading from the lowermost portions of vessels 116 and 216 and also has interposed a pass 125 of the regenerator R′. The other pass 143 of the regenerator is interposed in the conduit 142 which conducts gas from manifold 48 into the transfer vessels. The conduit 142 has branches 141 and 241 which conduct the gas through the vessel walls to the diffusers 144 and 244 which are disposed in the lower portions of vessels 116 and 216 respectively. The conduit 47 joins conduits 141 and 241 at their junction with conduit 142. Operative connection of the vessels 116 and 216 with the thermal leg C is had by branches of the conduit 23 controlled by valves 123′ and 223′ and by branches of the conduit 22 controlled by valves 122′ and 222′ respectively.

Valves for controlling the conduits are provided. Thus, valves 118′, 218′, 119′, 219′, 124′, 224′, 141′, 142′, 241′ control the conduits 118, 218, 119, 219, 124, 224, 141, 142, 241, respectively. Check valves are provided in conduits 47 and 142; in the former, the check valve 49 for permitting flow only in the direction toward manifold 48, and in the latter, check valve 145 for allowing flow to take place only away from manifold 48.

In operation, the two transfer vessels are alternately charged, for example, vessel 116 is charged by opening valves 118′ and 119′ for the desired period, the displaced gas being vented through connection 119 to the atmosphere to provide the required pressure difference for the flow of liquid. Valves 118′ and 119′ are closed after vessel 116 has been properly filled. Gas is now drawn from the receivers which are selected for temporary storage of displacing gas, for example, from receiver 52 by opening valves 55′, 142′ and 141′ to permit gas to flow from receiver 52 through the conduits 48, 142 and 141 to diffuser 144 where the gas is mixed with and partially condensed by the liquid in vessel 116. Gas may similarly be removed from receiver 51 by closing valve 55′ and opening valve 54′ until the pressures equalize, after which the valves are closed.

Thermal leg C is next connected to vessel 116 by opening valves 122′ and 123′ to build the pressure to the desired value and valves 124′, 30′ and 53 are opened to permit discharge toward the receiver 50 through the system of conduits 124, 24, 125, 27, 28, 30 and connection controlled by valve 53. During this discharge, the vessel 216 is filled by opening valves 218′ and 219′ for the proper interval.

When the flow of gas material out of vessel 116 substantially stops valves 122′, 123′ and 124′ are closed and valves 141′ and 54′ opened so that gas flows from vessel 116 into receiver 51 through connection 47 and check valve 49 until the pressures equalize. Similarly, the pressures of vessel 116 and receiver 52 are equalized at a lower value by closing valve 54′ and opening valve 55′ for the desired period. If desired, a cross-equalization between vessels 116 and 216 may be practiced at this time to still further reduce the amount of displacing gas remaining in vessel 116. This is accomplished by closing valve 142′ and opening valve 241′ (valve 141′ being open). Some gas will thereupon flow from vessel 116 into the fresh charge of liquid in vessel 216 through the system 144, 141, 241, 244. Valve 141′ is closed and charging of vessel 116 is now started while gas temporarily stored in receivers 52 and 51 is caused to flow to vessel 216 by opening individually and successively for the desired period the valves 55′ and 54′ respectively. The cycle of events is repeated until the receiver system represented by receiver 50 is charged with gas to the desired pressure. When this occurs, valve 53 is closed and valve 54 is opened, so that receiver 51 may be charged to the desired pressure while other receivers are selected to provide for the temporary storage of displacing gas.

In the form of apparatus shown in Fig. 3, the function of temporary storage of displacing gas is provided, not by containers for holding this gas in the gas phase at normal temperatures, but by means associated with the regenerator for holding the displacing gas partially liquefied. The vessel B with its associated thermal leg C are substantially similar to those shown in Fig. 2, equivalent parts being denoted by the same symbols. The discharge conduit **24**, however, has interposed in it a multi-tubular inner pass **58** of the regenerator generally indicated at R'. The regenerator R' comprises a pressure resistant shell **59** within which is disposed the multi-tubular pass **58** whose tubes terminate in lower header chamber **60** and upper header chamber **61**. Conduit **24** connects with lower header **60** after passing through a joint sealing packing **62** in the lower end of shell **59**. The heater **27** has a conduit connected with the chamber **61** for conducting the gas from the regenerator into the heater. The shell **59** contains heat storage or regenerator material **63** of suitable form, such as a series of baffles disposed about the tubes of pass **58**. The shell **59** is sufficiently large to provide a substantial space within and about the tubes **58** to afford temporary storage of cooled and partially liquefied displacement gas. For conducting displacing gas into the shell there is provided a conduit **64** leading from distributor **44** through the wall of vessel **16** to the upper part of the interior of shell **59** which conduit is controlled by valve **64'**. The displacing gas is discharged from the shell **59** through connection **65** controlled by valve **65'**, which connects the lower portion of the shell **59** with conduit **64** at a point between the valve **64'** and vessel **16**.

When dispensing gas material with this modification of the apparatus, vessel B, having been charged with a predetermined amount of liquefied gas as described in connection with Fig. 1, is discharged by opening the valves **22'** and **23'** for placing thermal leg **20** in communication with the vessel. When valves **24'** and **28'** are opened, the charge is expelled and flows to the receivers at E through conduit **24**, tubular pass **58** of regenerator R', heater **27** and manifold **30**. In the regenerator, heat is abstracted from and refrigeration trasferred to the heat storage material **63** and associated metal parts such as the surrounding metal walls of chamber **60** and tubes **58** which are cooled to a relatively low temperature. Since the gas material is warmed on its passage through the inner pass **58**, the end of the regenerator adjacent chamber **61** will not be cooled to so great a degree as the end adjacent the chamber **60**.

When the desired amount of charge has been expelled, valves **22'**, **23'** and **24'** are closed, and displacing gas is passed into the regenerator by opening valve **64'**. This gas flows through distributor **44**, conduit **64** and through the passages between baffles **63** and around the tube **58** toward the lower end of regenerator R'. Heat is abstracted from the displacing gas by the cold regenerator material to a degree which causes partial liquefaction and a large reduction of the pressure of the displacing gas with the result that the mass of displacing gas remaining in vessel B is reduced to a desired small amount.

The portion of the displacing gas that is liquefied collects in the lower portion of the regenerator adjacent the chamber **60**. Valve **64'** is closed to temporarily hold displacing gas in the regenerator R' while vessel B is recharged. If it is desired not to increase the pressure of gas in the transport container, the valve **41'** may be opened for a sufficient time for releasing gas, for example, to the atmosphere, after which the vessel B may be recharged by opening valves **18'** and **19'**. After charging is completed and valves **18'**, **19'** are closed, valve **65'** is opened so that displacing gas conserved will return to vessel B and mix with the charge therein. The flow occurs from the colder lower end of regenerator R' through conduit **65** and part of conduit **64** to distributor **44** so that a further amount of displacing gas is condensed by the fresh charge and the pressure of gas in the regenerator reduced to a substantially lower value. This pressure is further reduced when the regenerator is cooled by the passage of the charge of liquid in vessel B which is next expelled. Then valve **65'** is closed, valves **22'**, **23'** and **24'** are opened and the charge is expelled by heated displacing gas. The expelled charge which flows through the pass **58** cools the regenerator material **63** as before described which in turn further cools gas remaining in the regenerator with consequent pressure reduction so that the regenerator has a relatively increased ability for receiving the following charge of displacing gas.

In the form of apparatus of Fig. 4, the condensation of displacing gas is provided for by a temporary storage of a charge of liquefied gas after it is expelled from the vessel B, which again may comprise a heavy-walled chamber **16** having a basket **17**. The vessel B and the expelling device or thermal leg C are of similar form to that already described. However, the vessel B is not filled with liquid by gravity flow, but the liquid charge is displaced from transport container **12** into the transfer vessel by means of a difference of pressure through conduit **118** controlled by valve **118'**. This conduit leads from a point in the lower part of the liquid body **11** into the upper part of vessel B. For releasing gas and determining the desired filling level the conduit **141** controlled by valve **141'** is provided, passing through the upper part of vessel B, and has its internal opening at the desired liquid level. The liquid is discharged from vessel B through conduit **64** which conducts it from the lower part of basket **17** into a high pressure charge storage vessel **66**, which preferably is provided with an inner lining vessel or basket **66'**. Disposed within the basket is heat exchange means in the form of a coiled pipe **67** which has an inlet portion **68** controlled by valve **68'** connected with conduit **64** and an outlet portion **69** passing through the lower part of vessel **66** and conducting to an expansion valve **70** whose discharge **71** enters the upper portion of vessel **12**. The discharge conductor **71** is arranged to diffuse the gas discharged from valve **70** into the gas space above the liquid in container **12**. A conduit **72** controlled by a check valve **73** leads gas from the top of vessel **66** to coupling **129** and service conduit **130**, which conducts the gas discharged to consuming devices E that may include a heater, when desired. A by-pass connection **74** controlled by valve **74'** is also provided between conduit **64** and conduit **72** joining the latter between check valve **73** and coupling **129**. The conduit **64** is controlled by valve **64'** at a point adjacent vessel **66**.

In operating this form of apparatus, vessel B is filled with a predetermined charge of liquid by opening valves **118'** and **141'**, so that the escape of gas at conduit **141** reduces the pressure in vessel B below that in container A and liquid is displaced through conduit **118** until the liquid level in basket 17 rises to the opening of conduit 141. Then valves 118' and 141' are closed and thermal leg C placed into communication to expel the charge. The liquid expelled flows through conduit 64, valve 64' being open, into the basket 66' which has a capacity outside of the coils 67 for holding substantially the complete charge, whereby the latter is temporarily stored in the vessel 66. When the desired amount has been expelled, valve 64' is closed and valve 68' opened. Displacing gas then flows from vessel B through conduit 64, connection 68, coil 67, conduit 69, and expansion valve 70, which is set at the desired opening to provide a throttling of the gas material passing, and into container 12. On its passage through coil 67 the displacing gas is cooled to a relatively low temperature and partially liquefied, and when passing through throttle valve 70, the gas is further cooled and liquefied. In the diffuser 71, a separation of liquid and gas phases takes place, the liquid portion dropping to join with the body of liquid so that it mingles with liquefied gas being transferred, and the gaseous portion assists in building up the pressure in container A up to the value at which the releasing valve 14 is set to act.

Vessel B is refilled with another charge and the charge expelled in the same way as described. The second charge, however, displaces the first stored charge from vessel 66 through conduit 72 to the receivers E. The by-pass valve 74 is opened when it is desired to avoid adding to vessel 66, gas discharged from vessel B which is of too high a temperature to augment the condensing capacity of the material in vessel 66. The by-passing is accomplished toward the end of the expelling period by opening valve 74' and closing valve 64'.

The modification of apparatus shown in Fig. 5 provides for storage of the displacing gas in the partially liquefied state as well as for temporary storage of an expelled charge. The vessel B is shown as arranged for filling by gravity from container A, as in Fig. 1, and its charge is expelled by means of a thermal leg device C shown enclosed in its heating jacket. The vessel 66 is shown located above the thermal leg, which is a convenient location but is adapted mainly in the interests of clearness of the drawings. The charge is expelled from vessel B through conduit 76 which conducts gas material from a point near the bottom of the basket to conduit 64 which it joins. Conduit 64, when its control valve 64' is open, conducts the gas material into vessel 66 at an intermediate point, where it passes through the wall of the basket 66' into a ring form diffusing passage 77 that is provided with numerous inwardly opening passages. A cylindrical open ended thin metal baffle 78 is disposed within the basket 66' in such a manner as to surround the heat exchange coil 67 and be spaced uniformly away from the wall of the basket, whereby a circulation passage is provided. The coil inlet connection 68 also connects to and communicates with the conduit 76 for withdrawing displacing gas. The outlet connection 69 of the coil 67 conducts cooled displacing gas to the expansion or throttle valve 70' and its diffuser 71' which is here arranged to discharge into an auxiliary storage chamber 80. The chamber 80 is constructed to withstand a desired intermediate pressure and is preferably heat insulated as well as vessels 16 and 66 and container A. Chamber 80 is provided with a relief valve 81 and a discharge connection 82 controlled by a valve 82' for providing communication between the lower portion of chamber 80 and the conduit 76. A communicating passage from chamber 80 into vessel A may be also provided when desired. The discharge conduit 72 of vessel 66 is shown passing through a separate heater jacket 83 wherein it is provided with an extended portion and finally joining coupling 29 to which receiving devices are coupled.

The operation of this form of apparatus is similar to that described in reference to Fig. 4 with slight modification. The vessel B is charged and its charge expelled as before described. Since the gas material flowing into vessel 66 through conduit 64 is colder at the start of the expulsion period than at the end, it is desirable that the colder gas material settle to the lower portion of the basket 66' and the warmer gas material collect at the upper portion of vessel 66 from which it is discharged. This separation is effected by the action of the diffuser 77, which reduces the turbulence created by the inflowing gas, and by the baffle 78 which allows the warmer gas to circulate upward without turbulence. When expulsion is completed to the desired degree and valves 22', 23' and 64' are closed, valves 68' and 70' are opened, the first fully, and the latter partially to provide a throttling action. The displacing gas thereupon flows from vessel B, through coil 67 where it is cooled by the stored gas material surrounding the coil, and into chamber 80 in a partially or completely liquefied state. The relief valve 81 is adjusted to release gas when a certain pressure in chamber 80 is exceeded, which pressure is generally selected to provide a maximum recovery of displacing gas. When displacing gas stops flowing, valve 68' is closed and vessel B is recharged with liquefied gas. When basket 17 is filled to the desired level, valves 18' and 19' are closed and valve 82' opened, whereupon displacing gas conserved in chamber 80 flows into and is mixed with the charge in basket 17. When the pressures equalize the valve 82' is closed and valves 22', 23' and 64' are opened to expel the charge, which on entering vessel 66 displaces the warmer gas from the upper portion thereof to the receiving apparatus at E.

With the forms of apparatus shown in Figs. 4 and 5, it will be seen that there is provided a method of conserving the displacing gas after the final charge of liquefied gas has been expelled. It is contemplated also that still more effective conservation of displacing gas may be obtained by a combination of the method of temporarily storing portions of the displacing gas in the gas phase as practiced when using the apparatus of Figs. 1 and 2, with the method of temporarily storing displacing gas in the liquid phase according to the arrangements in Figs. 3 and 5, and with the method of temporarily storing the charge expelled for purpose of heat exchange according to Figs. 4 and 5.

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. A method of transferring a liquefied gas that is volatile at normal atmospheric pressure from a supply vessel where it is held at relatively low pressure and temperature to receivers at rela-

tively high pressure and elevated temperature by means of a transfer vessel, which comprises delivering a definite charge of liquid from said supply vessel into said transfer vessel while at relatively low pressure, expelling a major portion of said charge to receivers at relatively high pressure by the introduction of heated gas into said vessel above the charge of liquid, withdrawing a substantial portion of the gas remaining in the transfer vessel after the desired amount of the liquefield gas charge has been expelled to receivers, releasing gas from said transfer vessel for reducing its pressure to the relatively low value desired for refilling, and utilizing a refrigeration effect of the liquefied gas being transferred for recondensing a substantial portion of said withdrawn gas.

2. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employment of a transfer vessel, which comprises transporting a body of liquefied gas held at a low pressure and temperature to a destination, segregating a measured portion of liquefied gas in a transfer vessel leaving a desired gas space therein, increasing the pressure of gas in said gas space to a relatively high value, expelling under the action of said pressure a desired portion of segregated liquefied gas to a receiver, withdrawing gas from said transfer vessel, displacing additional gas from said transfer vessel when refilling with another measured portion of liquefied gas, and cooling and recondensing said withdrawn gas by thermal contact with liquefied gas being transferred whereby loss of such material in the gas phase is reduced.

3. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer, from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employment of a transfer vessel, which comprises passing a substantial portion of the gaseous residue of a previous operation left in the transfer vessel under pressure into temporary storage containers, reducing the pressure of gas in said transfer vessel to a relatively low value, displacing gas from said transfer vessel with a metered charge of liquid drawn from said supply source, liquefying a major portion of the gas passed to temporary storage containers by heat exchange with volatile liquid being transferred, admixing the gas so liquefied with other volatile liquid being transferred whereby the loss of gas by blowdown of the transfer vessel is reduced, and expelling a desired portion of said metered charge from the transfer vessel to said receiver by the application of heat.

4. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer, from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employing of a transfer vessel, which comprises isolating a metered charge of liquefied gas in said transfer vessel into which it has been introduced under a relatively low pressure, raising the pressure environment of said charge to a value exceeding said relatively high pressure by flowing a portion of the charge through a heated region for heating and vaporizing the same while maintaining the balance of said charge substantially unheated, discharging a desired portion of said charge to said receiver leaving a gas phase remainder in said transfer vessel, passing a substantial portion of said remainder into temporary holding means, cooling and partially recondensing said portion of remainder by means of the refrigerating effect of liquefied gas being transferred, and admixing said cooled and partially condensed portion with volatile liquid being transferred.

5. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer, from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employment of a transfer vessel, which comprises passing a metered charge from the supply vessel into the transfer vessel when at its lowest pressure, isolating said charge from communication with the supply vessel, supplying regasified liquefied gas having a relatively high temperature into the transfer vessel above the normal liquid level therein until the pressure acting on said charge exceeds the pressure of material in the receiver, discharging a desired portion of said charge to the receiver leaving a gas phase remainder in said transfer vessel having a relatively high pressure, preparing said transfer vessel for reception of another charge by first withdrawing a substantial portion of said remainder to temporary holding means and secondly releasing gas from said vessel until said lowest pressure is substantially reached, and thereupon cooling, partially recondensing and admixing said withdrawn remainder with liquefied gas being transferred.

6. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer, from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employment of a transfer vessel, which comprises charging a heat insulated transport container with a body of liquefied gas where it is maintained at a relatively low pressure and temperature when transported, discharging liquefied gas from said container through a portable transfer vessel to a receiver at relatively high pressure in a succession of metered charges, conserving desired portions of the gas displaced from said transfer vessel by each charge by withdrawing said portions, and partially liquefying and admixing said portions with liquefied gas being transfered.

7. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer, from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employment of a transfer vessel, which comprises interposing a transfer vessel between said container and receiver, delivering a metered charge from said container into said transfer vessel, discharging the liquid contents of said transfer vessel to said receiver through displacement by gas provided by heating a portion of said charge, withdrawing and condensing at least a portion of the displacing gas during the interim between discharges, and adding the condensate to volatile liquid being transferred.

8. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer, from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employment of a transfer vessel, which comprises transferring successive charges of liquefied gas to said transfer vessel at a relatively low pressure, expelling each charge from said vessel to receivers by displacement with gas of relatively high temperature and pressure, withdrawing displacement gas after it

has effected the desired expulsion, temporarily storing withdrawn displacement gas, and partially liquefying and admixing displacement gas with liquefied gas being transferred whereby to conserve gas material.

9. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer, from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employment of a transfer vessel, which comprises transferring successive charges of liquefied gas into said transfer vessel at a relatively low pressure, expelling each charge from said vessel to receivers by displacement with gas of relatively high temperature and pressure, withdrawing displacement gas after it has effected the desired expulsion, temporarily storing displacement gas at a plurality of successively lower pressure levels, and partially liquefying and admixing stored displacement gas with liquefied gas being transferred, said admixing being effected at successively higher pressure levels.

10. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer, from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employment of a transfer vessel, which comprises transferring successive charges of liquefied gas into said transfer vessel at a relatively low pressure, expelling each charge from said vessel to receivers by displacement with gas of relatively high temperature and presure, withdrawing displacement gas after it has effected the desired expulsion, cooling said displacement gas by means of a refrigerating effect of gas material expelled from the transfer vessel, and partially liquefying and admixing displacement gas with liquefied gas being transferred whereby losses of gas by blowdown are immaterial in amount.

11. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employment of a transfer vessel, which comprises transferring successive charges of liquefied gas into said transfer vessel at a relatively low pressure, expelling each charge from said vessel to receivers by displacement with gas of relatively high temperature and pressure, withdrawing displacement gas after it has effected the desired expulsion, cooling and partially condensing the withdrawn displacement gas by utilizing a refrigerating effect of gas material expelled from the transfer vessel, temporarily storing the partially condensed displacement gas during the interim of charging the transfer vessel, and admixing a substantial portion of the displacement gas with charges of liquefied gas being transferred.

12. A method of transferring a liquefied gas that has a gas phase evolved due to heat gained in the transfer, from a supply source where it is held at a relatively low pressure to a receiver at a relatively high pressure by the employment of a transfer vessel, which comprises cooling the withdrawn displacement gas by heat exchange with gas material having a refrigerating effect expelled from the transfer vessel, further cooling and partially liquefying the withdrawn displacement gas by expansion from a higher to a relatively lower pressure, and admixing liquefied displacement gas with the other liquefied gas.

13. Apparatus for dispensing gas material comprising the combination with a heat insulated container for holding a charge of liquefied gas at relatively low pressure, of a heat insulated pressure resistant transfer vessel arranged to receive portions of said charge and to expel gas material at a desired relatively high pressure, means for receiving the gas material expelled, and means for temporarily holding and recondensing gas withdrawn from said transfer vessel after the desired amount of gas material has been expelled to the receivers.

14. Apparatus for dispensing gas material comprising the combination with a heat insulated container for holding a charge of liquefied gas at relatively low pressure, of a receiver for receiving gas material at a relatively high pressure, a transfer vessel interposed between the container and the receiver arranged to receive successive portions of said charge when at low pressure and to expel gas material to said receiver at relatively high pressure, means for providing gas to effect such expulsion by displacement, means for withdrawing and temporarily storing displacement gas after it has effected said expulsion, and means for partially liquefying and admixing displacement gas with liquefied gas.

15. Apparatus for dispensing gas material comprising the combination with a heat insulated container for holding a charge of liquefied gas at relatively low pressure, of a receiver for receiving gas material at a relatively high pressure, a transfer vessel interposed between the container and the receiver arranged to receive successive portions of said charge when at low pressure and to expel gas material to said receiver at relatively high pressure, means for providing gas to effect such expulsion by displacement comprising a thermal leg communicating with the transfer vessel at points above and below the normal liquid filling level during the expulsion period, means for withdrawing and temporarily storing displacement gas material after it has effected said expulsion, and means for admixing displacement gas material with liquefied gas.

16. Apparatus for dispensing gas material comprising the combination with a heat insulated container for holding a charge of liquefied gas at relatively low pressure, of a receiver for receiving gas material at a relatively high pressure, a transfer vessel interposed between the container and the receiver arranged to receive successive portions of said charge when at low pressure and to expel gas material to said receiver at relatively high pressure, means for providing gas to effect such expulsion by displacement, means for withdrawing and temporarily storing at a plurality of successively lower pressures displacement gas after it has effected said expulsion, and means for admixing at successively higher pressures temporarily stored displacement gas with liquefied gas being transferred.

17. Apparatus for dispensing gas material comprising the combination with a heat insulated container for holding a charge of liquefied gas at relatively low pressure, of a receiver for receiving gas material at a relatively high pressure, a transfer vessel interposed between the container and the receiver arranged to receive successive portions of said charge when at low pressure and to expel gas material to said receiver at relatively high pressure, means for providing gas to effect such expulsion by displacement, means for withdrawing displacement gas

after it has effected said expulsion, means for cooling the withdrawn displacement gas by utilizing a refrigerating effect of gas material expelled from the transfer vessel, and means for admixing cooled displacement gas with liquefied gas being transferred.

18. Apparatus for dispensing gas material comprising the combination with a heat insulated container for holding a charge of liquefied gas at relatively low pressure, of a receiver for receiving gas material at a relatively high pressure, a transfer vessel interposed between the container and the receiver arranged to receive successive portions of said charge when at low pressure and to expel gas material to said receiver at relatively high pressure, means for providing gas to effect such expulsion by displacement, means for withdrawing displacement gas after it has effected said expulsion, means for cooling the withdrawn displacement gas by utilizing a refrigerating effect of gas material expelled from the transfer vessel and for storing the same in a partially liquefied state, and means for admixing partially liquefied displacement gas with liquefied gas being transferred.

19. Apparatus for dispensing gas material comprising the combination with a heat insulated container for holding a charge of liquefied gas at relatively low pressure, of a receiver for receiving gas material at a relatively high pressure, a transfer vessel interposed between the container and the receiver arranged to receive successive portions of said charge when at low pressure and to expel gas material to said receiver at relatively high pressure, means for providing gas to effect such expulsion by displacement, means for withdrawing displacement gas after it has effected said expulsion, means for cooling the withdrawn displacement gas by utilizing a refrigerating effect of gas material expelled from the transfer vessel, means for additionally refrigerating the withdrawn displacement gas by expansion, and means for admixing the expanded displacement gas with liquefied gas being transferred.

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