Dec. 4, 1956 J. J. SHANLEY 2,772,545

LIQUEFIED GAS PRESSURIZING SYSTEMS

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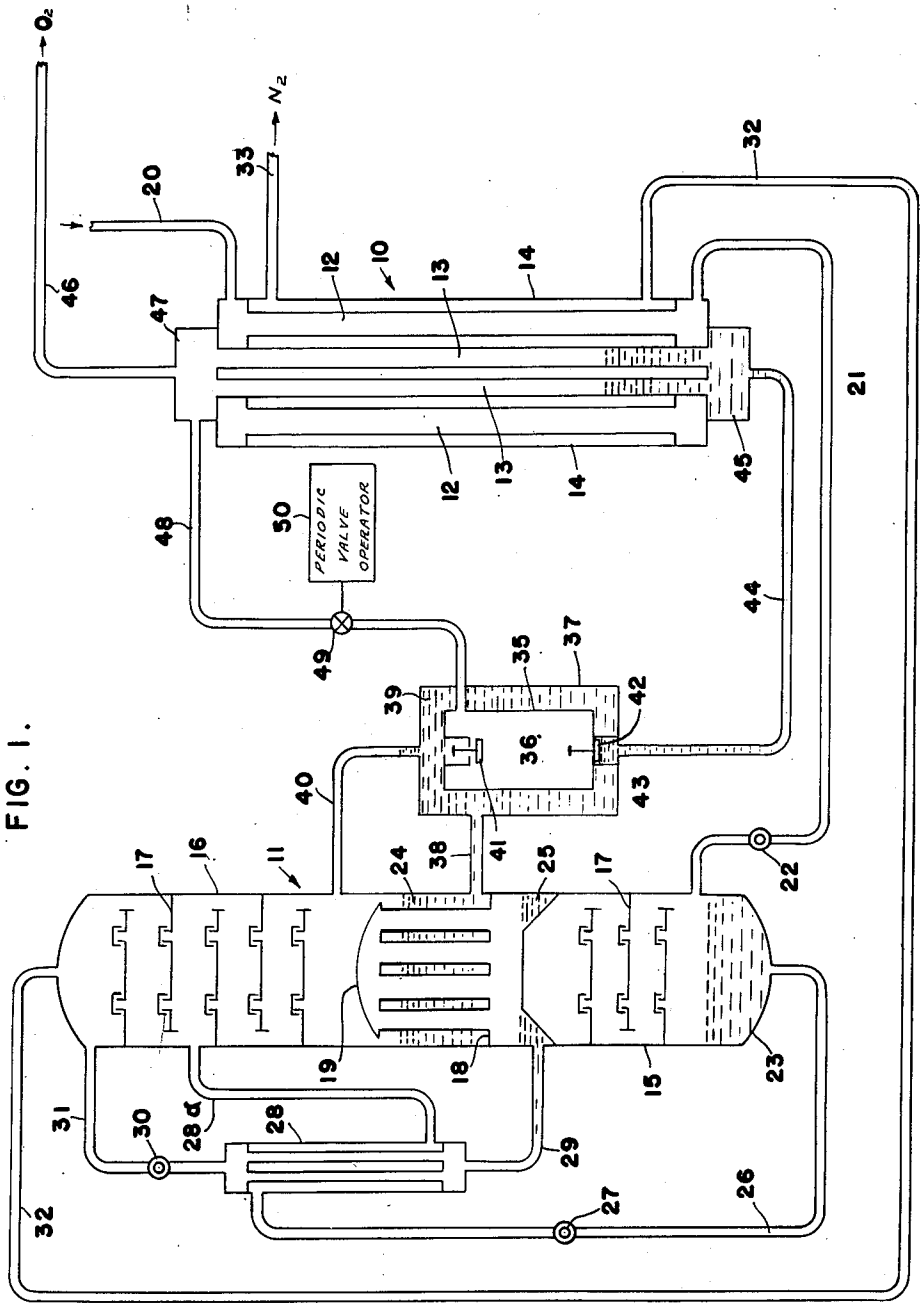


FIG. 1.

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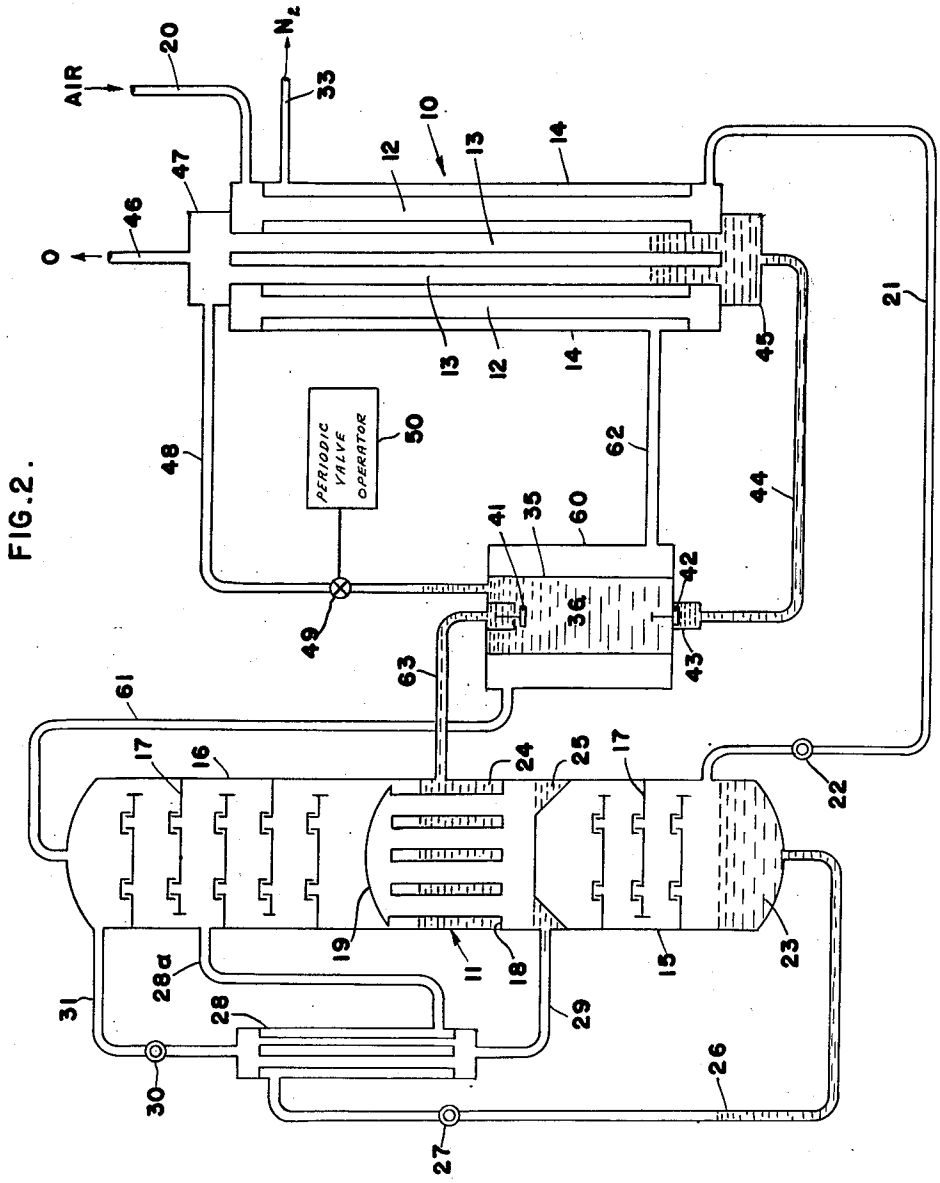
James J. Shanley

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LIQUEFIED GAS PRESSURIZING SYSTEMS

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FIG. 2.



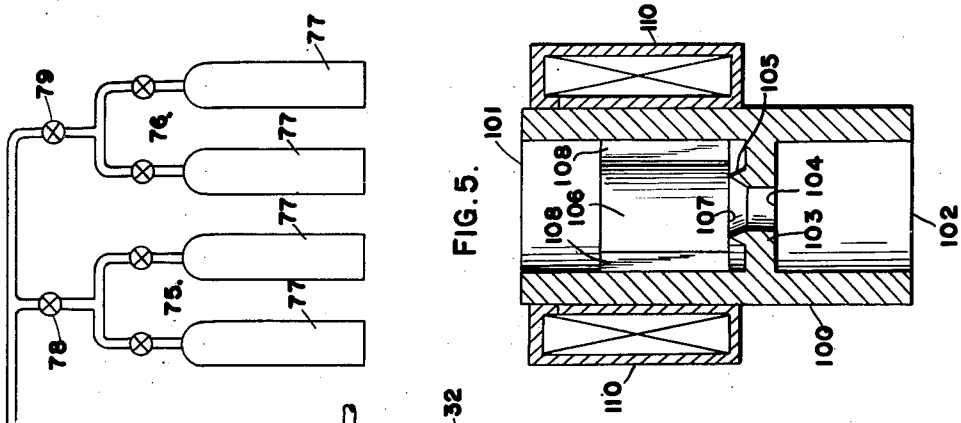
INVENTOR.

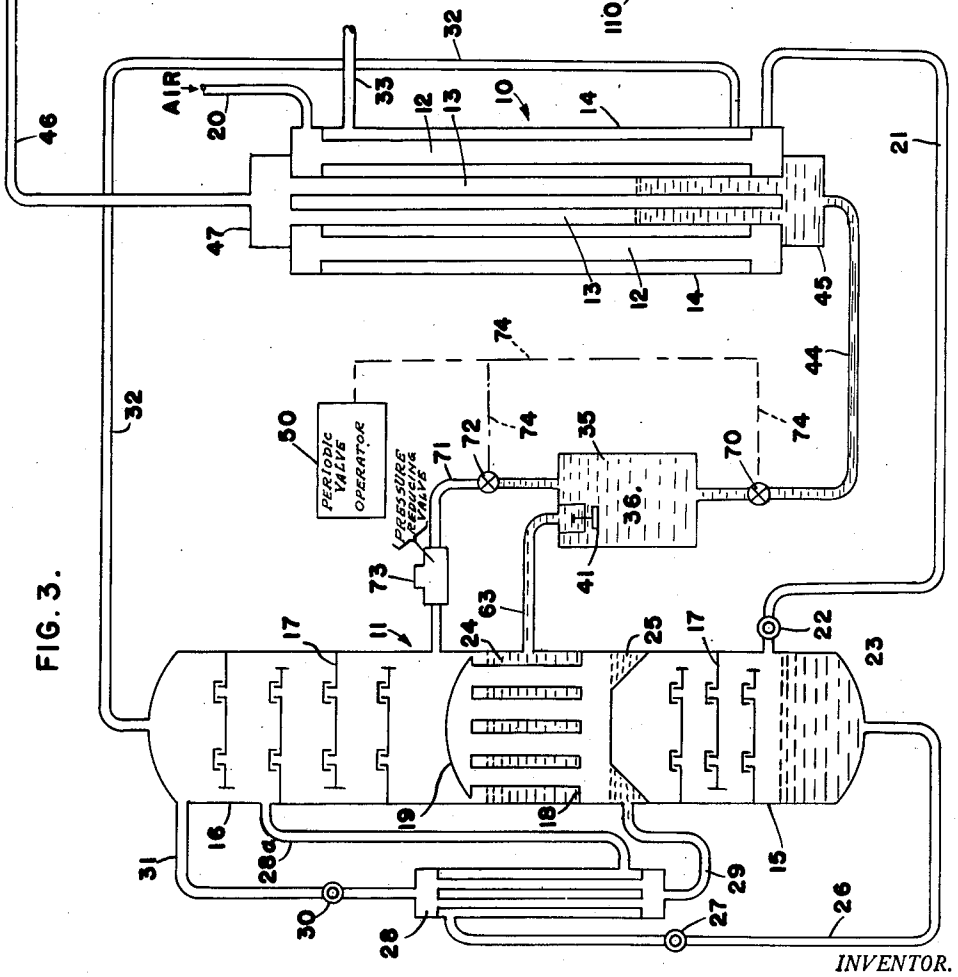
James J. Shanley

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LIQUEFIED GAS PRESSURIZING SYSTEMS

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INVENTOR.

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LIQUEFIED GAS PRESSURIZING SYSTEMS

Filed May 13, 1952 4 Sheets-Sheet 4

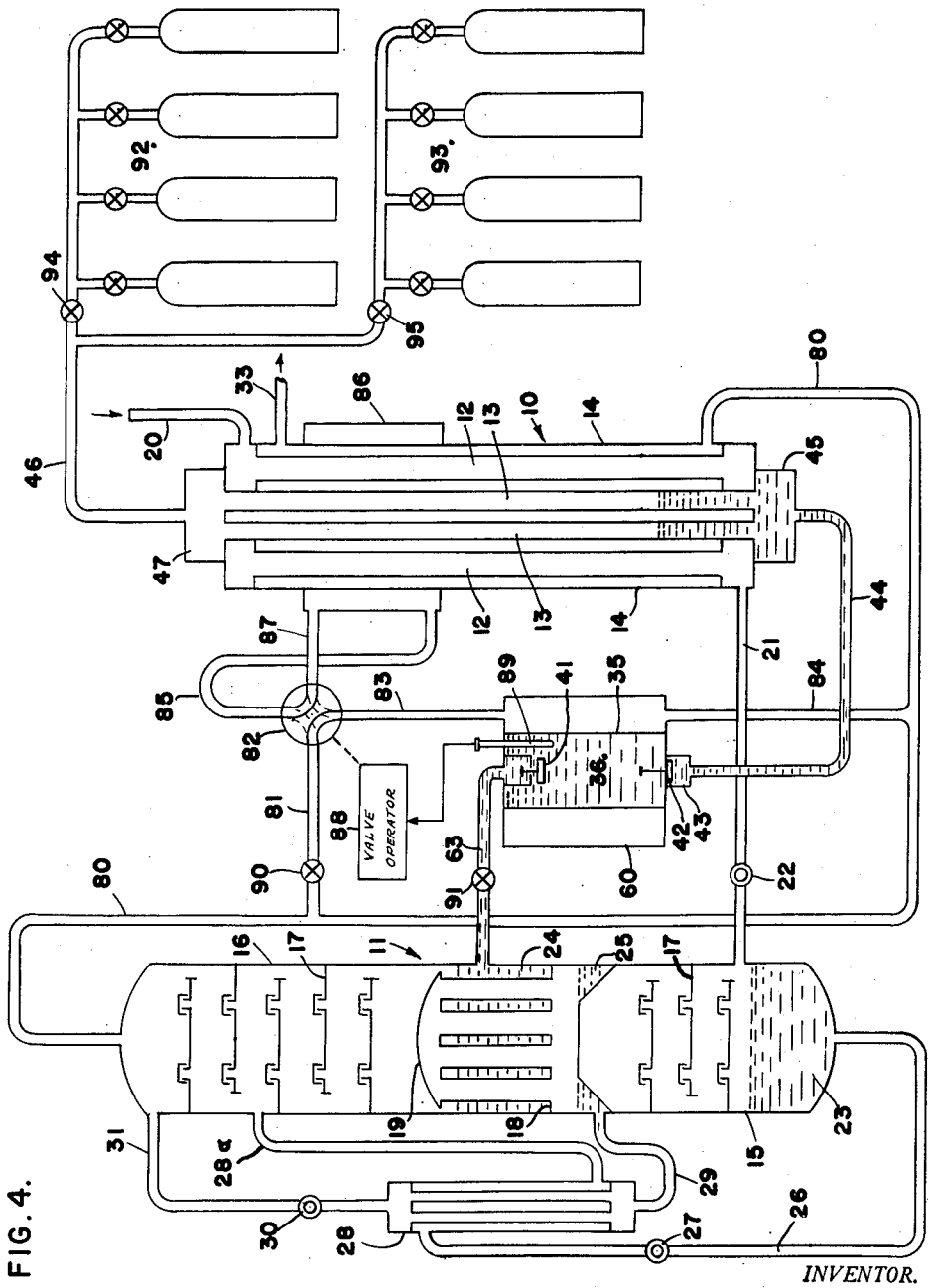


FIG. 4.

INVENTOR.

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United States Patent Office 2,772,545 Patented Dec. 4, 1956

2,772,545

LIQUEFIED GAS PRESSURIZING SYSTEMS

James J. Shanley, Bethesda, Md., assignor to Air Products, Incorporated, a corporation of Michigan

Application May 13, 1952, Serial No. 287,650

23 Claims. (Cl. 62—122)

This invention relates to pumping of liquefied gases, in liquid phase. More particularly, it relates to methods of and apparatus for transferring a volatile liquid from a supply source at low pressure to a receiving means under a relatively high pressure, such as the liquid product of a gas separation operation in which a gaseous mixture is fractionated to produce a volatile liquid as a product.

As is well known, volatile liquids held at low pressure, such as liquid oxygen and nitrogen or liquefied petroleum gases, have extensive utility in gaseous phase at relatively high pressure. In general there are two methods for transferring volatile liquid at low pressure into gaseous form at a relatively high pressure. According to the first method the volatile liquid is vaporized at the low pressure and thereafter compressed in gaseous phase to the desired high pressure. Practice of this method requires a gas holder of large over-all dimensions and presents serious gas compression problems, such as lubrication of the compressor and explosion hazards especially in the case of compressing gaseous oxygen. In the second method the volatile liquid is pumped in liquid phase to the desired relatively high pressure and then the high pressure liquid is converted into gaseous form by a suitable vaporizing process. The volatile liquid is pumped in liquid phase to the desired high pressure by means of a mechanical pump usually of the plunger type designed especially for pumping highly volatile liquids. This method requires that the liquid be subcooled before entering the pump and the pump must have special plunger packing and include insulating means to prevent heat infiltration and cold losses. For best performance, provision is made for cooling the liquid conveying end of the pump with a fluid colder than the liquid being pumped to prevent pump stoppages due to vapor lock. While liquid pump arrangements of the foregoing character have proven quite adequate and by far the best system available they are not capable of continuous and uninterrupted performance inasmuch as the moving elements and packing require replacement as in the case of all mechanical machines including moving parts. This is especially the case in pumps of this character where the packing and other elements are designed to minimize heat of friction.

It is therefore an object of the present invention to provide a novel method of and apparatus for pumping volatile liquids without employing moving mechanical elements for producing the pumping force.

Another object is to provide a novel method of and apparatus for pumping volatile liquids without requiring the use of pump packing or similar materials.

Another object is to provide a novel method of and apparatus for pumping highly volatile liquids which completely eliminates the problem of pump stoppages due to vapor lock or flashing of the liquid during the pumping process.

Still another object of the present invention is to provide a novel method of and apparatus for transferring in liquid phase a volatile liquid from a fractionating operation to a receiving means under a relatively high pressure.

Still another object is to provide a novel method of and apparatus for transferring in liquid phase a volatile liquid from a fractionating operation to a receiving means under a relatively high pressure by utilizing the influence of gravity and only a small quantity of additional energy that may be obtained from the fractionating operation and readily replaced by merely slightly varying the temperature or pressure of the gaseous mixture feeding the fractionating operation.

Still another object is to provide a novel method of and apparatus for transferring in liquid phase a volatile liquid material from a storage reservoir to a receiver under a relatively high pressure through a transfer zone relatively positioned to receive liquid from the storage reservoir and deliver liquid to the receiver under the influence of gravity.

Still another object is to provide a novel method of and apparatus for transferring in liquid phase a volatile liquid from a fractionating operation to a receiver under a relatively high pressure through a transfer zone relatively positioned to receive liquid from the fractionating operation and deliver liquid to the receiver under the influence of gravity responsively to different pressure conditions established by employing fluids from the fractionating operation without substantial effect upon fractionating efficiency.

A still further object of the present invention is to provide a novel method of and apparatus for fractionating a gaseous mixture and for providing a liquid product from the fractionation in gaseous phase under a relatively high pressure by pumping the liquid product to a relatively high pressure and passing the high pressure liquid product in heat exchange relation with the gaseous mixture on its way to the fractionation without employing mechanical pumping apparatus or device requiring pump packing or equivalent structure, in a substantially continuous operation.

A still further object is to provide a fractionating operation for separating gaseous mixtures including a novel volatile liquid product pumping method and apparatus which effects operation of the fractionating operation to compensate for certain temperature fluctuations which occur during certain phases of operation.

Other objects and features of the present invention will appear more fully from the following detailed description considered in connection with the accompanying drawings which disclose several embodiments of the invention. It is expressly understood however that the drawings are designed for the purpose of illustration only and not as a definition of the limits of the invention, reference for the latter purpose being had to the appended claims.

In the drawings, wherein similar reference characters denote similar elements throughout the several views:

Fig. 1 is a diagrammatic view illustrating one form of the present invention in connection with a fractionating cycle;

Fig. 2 is a diagrammatic view illustrating a modified form of the invention;

Fig. 3 is a diagrammatic view illustrating a fractionating cycle including another form of the present invention;

Fig. 4 is a diagrammatic view illustrating a fractionating cycle including still another form of the present invention, and

Fig. 5 is a diagrammatic view in section illustrating a solenoid operated valve that may be used with the present invention.

According to the present invention a transfer zone or vessel is provided for alternately receiving a low pressure volatile liquid from a supply source and for delivering

the liquid to a receiving means under a relatively high pressure. The flow of liquid to and from the transfer vessel is determined by alternately establishing predetermined pressure conditions in the transfer vessel and by mounting the supply source, the transfer vessel and the receiving reservoir at such relative elevations for the flow of liquid from the source to the transfer vessel and from the transfer vessel to the reservoir under the influence of gravity when the proper relative pressure conditions exist. During one of the predetermined pressure conditions the internal pressure of the transfer vessel is at least equal to the low pressure of the supply source, while during the other condition the internal pressure is at least equal to the relatively high pressure of the receiving means. Establishment of the relative high pressure condition determines the time of the pump strokes or pressurizing action, while the frequency of the occurrence of this condition is a measure of the pump capacity. Transfer vessel low pressure conditions occur at the same frequency and in proper time relation with the high pressure conditions to allow high speed pumping. The energy required to operate the pump is low inasmuch as the actual transfer of liquid takes place under the influence of gravity while energy is employed only to establish equalized pressure conditions to allow this phenomenon to take place. Thus when the principles of the present invention are incorporated in a fractionating cycle, as disclosed, very little energy is taken from the cycle for the pumping operation with a substantially immaterial reduction in fractionating efficiency which may be easily compensated for by merely slightly increasing the pressure of the gaseous mixture feeding the cycle, where that is possible. While the several embodiments of the invention are disclosed in connection with fractionating cycles for the separation of air into its major constituents oxygen and nitrogen, it is to be expressly understood that the principles of the present invention are equally applicable in fractionating apparatus for separating gaseous mixture other than the atmosphere and may be utilized in cycles other than fractionating cycles.

A pumping system embodying the principles of the present invention is disclosed in Fig. 1 of the drawings in connection with a fractionating cycle including a primary heat interchanger 10 and a fractionating column 11. The heat interchanger 10 includes two banks of tubes 12, 12 and 13, 13 surrounded by an outer shell 14 to provide three passageways in heat exchange relation with one another. The fractionating column is of the conventional two stage type including a high pressure zone 15 and a low pressure zone 16, however the present invention may be utilized in connection with single stage fractionating columns. The high and low pressure zones are each provided with a stack of bubbling plates 17 and are separated by a partition 18 and a conventional refluxing condenser 19. The gaseous mixture to be fractionated, which may comprise compressed and cooled air free from moisture and other impurities, enters the system through a conduit 20 and passes through the tubes 12, 12 of the primary heat interchanger in heat exchange relation with cold products of the fractionation cycle. The air stream leaves the lower portion of the primary heat interchanger at a substantially lower temperature, and is conducted by way of a conduit 21 through an expansion valve 22, where its temperature and pressure are reduced, from which it enters the lower end of the high pressure zone 15 at or near its point of liquefaction. In the high pressure zone a preliminary fractionation of the air takes place producing gaseous nitrogen rising into the condenser 19 and a liquid rich in oxygen collecting in a pool 23 in the base of the column. The gaseous nitrogen is liquefied by heat interchange with a pool 24 of boiling liquid oxygen surrounding the condenser. A portion of the liquefied nitrogen collects in a pool 25, while the remainder falls downwardly as reflux for the high pressure zone. A stream of oxygen rich liquid is removed from the pool 23 by way of a conduit 26, passed through an expansion valve 27 and a secondary heat interchanger 28 and is introduced by way of a conduit 28a at a medial point in the low pressure zone as feed. A stream of liquid nitrogen is withdrawn from the pool 25 and conducted by a conduit 29 through another pass of the heat interchanger 28 in heat exchange relation with the stream of oxygen rich liquid. Thereafter, the subcooled liquid nitrogen is passed through an expansion valve 30 and introduced into the top of the low pressure zone as reflux by way of a conduit 31. In the low pressure zone the fractionation process is completed producing substantially pure oxygen in liquid phase collecting in the pool 24 above the plate 18, and gaseous nitrogen which flows upwardly and leaves the column through a conduit 32. The gaseous nitrogen is conducted by the conduit 32 to the shell 14 of the primary interchanger 10, in which it passes in heat exchange relation with the incoming air stream, and leaves the cycle at substantially atmospheric temperature and pressure by way of a conduit 33 connected to the top of the primary interchanger 10.

In accordance with the principles of the present invention a novel method and apparatus are provided for transferring the liquid oxygen product from the pool 24 to a receiving means under a substantially high pressure with respect to the pressure in the low pressure zone, such as to the vaporizer section 13, 13 of the heat interchanger 10 in which the liquid oxygen product forfeits cold to the incoming air stream and emerges from the heat interchanger in gaseous phase. For this purpose a pressure or transfer vessel 35 is provided. The transfer vessel may be of cylindrical or rectangular shape to form a closed chamber 36, and is constructed of suitable material to withstand a pressure in the chamber at least equal to the relatively high pressure developed in the receiving means. For a purpose that will be described below, the transfer vessel is preferably constructed of stainless steel or any other material having a comparatively low thermal conductivity, or, if constructed of a material having good thermal conductivity characteristics, is then provided with suitable insulation to reduce the rate of heat transfer from within to without the chamber. The transfer vessel is centrally mounted in an enlarged vessel 37. The vessel 37 is mounted at an elevation with its top below the normal liquid level of the pool 24 and is in continuous communication with the liquid oxygen through a conduit 38. With this arrangement liquid oxygen normally fills the chamber 39 surrounding the transfer vessel 35. A vapor conduit 40 is connected between the top of the vessel 37 and a point in the low pressure zone above the liquid level of the oxygen pool for the removal of oxygen vapor that may be developed in the vessel 37 during the pumping operation. The transfer vessel is provided with inlet and outlet valves 41 and 42 located at the upper and lower ends of the vessel, respectively. The inlet valve opens inwardly to allow the flow of liquid oxygen from the chamber 39 to the chamber 36 except when the pressure in the chamber 36 exceeds the pressure of the liquid oxygen in the low pressure zone. The outlet valve 42, mounted in a well 43 formed in the bottom of the transfer vessel, allows the flow of liquid oxygen from the transfer vessel to an output conduit 44 except when the pressure in the conduit 44 exceeds the pressure in the chamber 36. The conduit 44 is connected to the lower end or bottom portion 45 of the vaporizer section 13, 13. The lower end of the primary heat interchanger is at an elevation sufficiently below the vessel 37 to allow liquid oxygen in the chamber 36 to flow, under the influence of gravity, to the vaporizer section when the required pressure relationships exist. The liquid oxygen in the vaporizer section forfeits cold to the incoming air stream and leaves the interchanger in gaseous phase by way of a conduit 46 connected to the upper end or top portion 47 of the vaporizer section. The gaseous oxygen builds up to a relatively high pressure in the vaporizer section of

a valve depending upon the manner of employing the gaseous oxygen delivered by the conduit 46.

The arrangement for effecting the transfer of low pressure liquid oxygen in the chamber 36 to the vaporizer section of the heat interchanger under a relatively high pressure comprises a pressure equalizing conduit 48 forming a connection between the upper end 47 of the vaporizer section and the chamber 36 of the transfer vessel 35. The equalizing conduit is provided with a valve 49 controlled by a periodic valve operator 50. The valve operator functions to open the valve 49 at regularly spaced intervals and to maintain the valve open for a predetermined duration which is short as compared to the period of the spaced intervals. The valve operator may comprise an electrical or mechanical timing device including an arrangement for producing a control signal at an adjustable frequency, while the valve 49 may be of any suitable structure capable of the foregoing operation. For example, the valve may include a steel valve member in a brass casing and a solenoid positioned outside the casing to operate the valve member as described more fully hereinafter.

It is understood that the fractionating column, the heat interchanger and the vessel 37 and associated conduits are suitably insulated in accordance with conventional practice. Also, the various elements of the apparatus such as the transfer vessel 35, the vessel 37 and the vaporizer section are disclosed primarily to provide an adequate illustration of the invention, and it is expressly understood that the drawings do not necessarily represent the relative sizes of the components of the apparatus.

In operation, the fractionating column functions in a conventional manner producing a gaseous nitrogen fraction and a liquid oxygen fraction as final products from the incoming air feed. The gaseous nitrogen is removed from the top of the column by the conduit 32 and passed in heat exchange relation with the incoming air stream, while the liquid oxygen fraction collects in the pool 24. The liquid oxygen flows from the pool 24 through the conduit 38 into the chamber 39 surrounding the transfer vessel 35. When the level of the liquid oxygen pool reaches the height of the top of the transfer vessel, and when the internal pressure of the transfer vessel is not greater than the pressure of the liquid oxygen in the low pressure zone, liquid oxygen will flow from the chamber 39 into the chamber 36 past the valve 41. Also, when the pressure in the transfer vessel is equal to or greater than the pressure in the conduit 44, liquid oxygen flows, under the influence of gravity, from the chamber 36 past the valve 42 into the lower end 45 of the vaporizer section 13, 13 by way of the conduit 44. The liquid oxygen is converted to gaseous phase in the vaporizer section by forfeiting cold to the incoming air stream, and builds up to a relatively high pressure therein as determined by the controls and/or receiving means associated with the output conduit 46. Eventually the pressure in the vaporizer section exceeds the low pressure in the chamber 35 and the valve 42 is caused to move to its closed position isolating the transfer vessel from the vaporizer section. Thereupon the chamber of the transfer vessel will completely fill with liquid oxygen at the low pressure. Under these conditions the apparatus will transfer the maximum quantity of liquid oxygen upon equalization of pressure between the transfer vessel and the vaporizer section. The pressure equalization occurs when the periodic valve operator 50 functions to open the valve 49 so that the high pressure oxygen vapor from the upper end 47 of the vaporizer section is conducted to the chamber 36 through the conduit 48. Upon equalization of the pressures in the chamber 36 and in the conduit 44, the valve 42 opens and liquid oxygen flows under the influence of gravity from the transfer vessel into the lower portion of the vaporizer section through the conduit 44 at whatever pressure may exist in the vaporizer section. The valve operator closes the valve 49 after a predetermined period of time sufficient to allow the liquid oxygen to flow from the chamber 36 trapping a quantity of oxygen vapor in the transfer vessel. Since the transfer vessel is surrounded by the cold liquid oxygen in the chamber 39 the trapped oxygen vapor is cooled producing a pressure drop in the transfer vessel causing the valve 42 to move to its closed position isolating the transfer vessel from the vaporizer section. Thereupon oxygen vapor in the chamber 36 continues to forfeit heat to the surrounding cold liquid oxygen until such time that the internal pressure of the transfer vessel corresponds to the vapor pressure of the oxygen in the pool 24. Under these conditions the valve 41 opens allowing liquid oxygen to flow into and fill the chamber 36. Thereupon the valve 49 is again opened to initiate the pumping cycle.

It was mentioned above that the walls of the transfer vessel 35 are constructed of a material having a low thermal conductivity, such as stainless steel, or the transfer vessel is provided with suitable insulation to establish a low rate of heat transfer between the chambers 36 and 39. This arrangement controls the rate of condensation of the high pressure oxygen vapor in the chamber 36 to insure establishment of the pressure equalization and a rapid transfer of the liquid oxygen from the chamber 36 while at the same time allowing the oxygen vapor to be condensed following closure of the valve 49 so that the chamber 36 may be refilled with liquid oxygen within a reasonable period of time. Of course, for maximum pumping efficiency, the period of the periodic valve operator should never exceed the total time required for the liquid oxygen to flow from the chamber 36 and for the chamber to be refilled with liquid oxygen. The total time will be dependent in part upon the volume of the chamber 36, and it may be desirable in some cases to provide a transfer vessel of comparatively small volume and to operate the periodic valve operator at a high frequency. This arrangement may aid in maintaining a substantially constant liquid oxygen level in the vaporizer section and thus tend to stabilize the air feed temperature.

During the time the oxygen vapor is being condensed in the chamber 36, heat is added to the liquid oxygen surrounding the transfer vessel and any oxygen vapor that may evolve is returned to the low pressure zone of the column by way of the conduit 40. Since the condensation takes place at a slow rate large slugs of heat are not abruptly introduced into the column and the relatively large volume of refluxing liquid and oxygen product substantially completely maintain a constant temperature level so that the column operation is not materially effected. Also, since this heat was removed from the incoming air stream, the air stream enters the high pressure zone at a corresponding lower temperature with the result that the same heat is applied to the column during a given period of operation including a number of pumping operations as in the case of conventional operation.

The feature of mounting the transfer vessel in the enlarged vessel 37 so that only the small volume of liquid oxygen in the chamber 39 is in direct heat interchange with the transfer vessel aids in reducing disturbing effects upon column operation inasmuch as only a small portion of the liquid oxygen is directly subjected to the heat evolved from the high pressure oxygen vapor.

It was mentioned above that the maximum operating frequency of the periodic operator 50 is determined in part by the characteristics of the transfer vessel 35. In cases where the desired pumping capacity cannot be obtained, a pair of transfer vessels may be employed and arranged so that one vessel is transferring liquid oxygen at high pressure while the other is receiving low pressure liquid oxygen for subsequent transfer. Ordinarily, a single transfer vessel may be properly designed to provide the necessary pumping capacity to supply the desired quantity of gaseous oxygen at the required pressure and purity.

The form of the invention illustrated in Fig. 2 of the drawings is similar to the apparatus described above except that a different arrangement is provided for cooling the equalizing high pressure oxygen vapor and for controlling the heat evolved during the condensing process. As shown, the transfer vessel 35 is provided with a cylindrical heat exchanger 60 through which a cold fluid from the fractionating operation passes in heat interchange relation with the transfer vessel, such as gaseous nitrogen on its way to the primary heat interchanger. A conduit 61 conducts the gaseous nitrogen from the fractionating column to the heat exchanger 60, while a conduit 62 forms the connection between the transfer vessel heat exchanger and the shell 14 of the primary heat interchanger. In this arrangement liquid oxygen in the pool 24 is fed directly to the input valve 41 by way of a conduit 63.

In operation, liquid oxygen from the pool 24 flows into the chamber of the transfer vessel 35 and is conducted therefrom under the influence of gravity at the relatively high pressure into the vaporizer section of the heat interchanger 10 at a frequency controlled by the periodic valve operator 50. When the valve 49 closes to terminate the pressure equalizing interval, the cold gaseous nitrogen flowing through the heat exchanger 60 cools the high pressure oxygen vapor in the transfer vessel producing a pressure drop in the chamber 36 to thus effect closure of the output valve 42 and eventual opening of the input valve 41. Thus, the heat evolved upon condensation of the oxygen vapor is conducted away from the fractionating column by the gaseous nitrogen flowing to the heat interchanger 10. As a consequence, the temperature of the column is substantially unaffected by the pumping operation. The temperature of the gaseous nitrogen entering the heat interchanger will intermittently rise and fall thus tending to fluctuate the air feed temperature, while at the same time the temperature of the air entering the heat interchanger will fall and rise due to removal of the oxygen vapor to effect the pressure equalization. These opposite fluctuations in the air feed temperature tend to compensate each other with a resulting substantially constant air feed temperature.

The form of the invention illustrated in Fig. 3 of the drawings includes different arrangements for establishing the equalized pressure conditions for gravity flow of liquid oxygen from the column to the transfer vessel under low pressure and for gravity flow of liquid oxygen from the transfer vessel the vaporizer under relatively high pressure. These arrangements are disclosed in connection with a fractionating cycle having a primary heat interchanger 10 and a fractionating column 11 of the type disclosed in Figs. 1 and 2, together with the transfer vessel 35 connected in the liquid oxygen path between the column and the heat interchanger. As shown, the transfer vessel 35 is fed from the liquid oxygen collecting space 24 of the column through the conduit 63 controlled by the inlet valve 41, and is connected to the lower end 45 of the vaporizer section for gravity flow through the conduit 44. In this form of the invention a mechanically operated valve 70 controls the conduit 44 in place of a pressure actuated valve as employed in the previously described embodiments. Also, the conduit 44 functions to form an equalizing connection between the transfer vessel and the vaporizer section as well as providing a path for conducting the liquid oxygen to the vaporizer section. The arrangement for equalizing the pressures in the transfer vessel and the column includes a conduit 71 connected between the upper end of the transfer vessel and the vapor space in the low pressure zone 16 above the pool 24 of liquid oxygen. Flow through the conduit 71 is controlled by a mechanically actuated valve 72 and a pressure reducing valve 73. The valves 70 and 72 are ganged together as indicated by the broken lines 74 and are controlled by a periodic valve operator 50 of the type described before. In particular, the valve operator functions to simultaneously move the valves 70 and 72 to their open or closed positions at a fixed predetermined frequency. When the valve 70 is moved to its open position, at which time the valve 72 is simultaneously moved to its closed position, it will remain open for a period of time sufficient for the liquid oxygen in the chamber 36 to drain therefrom under the influence of gravity. When the valve 70 closes, the valve 72 will open allowing the high pressure oxygen vapor in the chamber 36 to bleed through the pressure reducing valve. Thus the valves 70 and 72 are alternately opened and closed, however the valve 72 is open for a greater portion of the period of the valve operator. The high pressure gaseous oxygen conduit 46 is shown connected to two banks 75 and 76 of high pressure gas cylinders 77 through valves 78 and 79. It may be advantageous in some instances to design the apparatus so that the volume of liquid oxygen fed to the vaporizer section during each transfer operation is sufficient to produce the necessary quantity of gaseous oxygen to fill a bank of cylinders at the desired pressure. It is understood that the arrangements shown in Figs. 1 and 2 may be designed for this character of operation if desired.

In operation, liquid oxygen from the column flows past the valve 41 and fills the chamber 36 of the transfer vessel when the pressure in the transfer vessel is equal to or less than the pressure of the liquid oxygen in the pool 24. Thereafter, when the periodic valve operator 50 functions to open the valve 70, the high pressure existing in the vaporizer section is transmitted to the chamber 36 by way of the conduit 44. Since there will be some degree of vaporization in the chamber 36 the liquid oxygen will flow under the influence of gravity from the transfer vessel to the vaporizer section. At a time after the liquid oxygen has drained from the transfer vessel the periodic valve operator moves the valve 70 to its closed position and opens the valve 72. High pressure vapor in the chamber 36 then bleeds into the vapor section of the low pressure zone 16 through the conduit 71 and the pressure reducing valve 73. The pressure reducing valve 74 lowers the pressure of the oxygen vapor to correspond to the pressure in the column above the liquid oxygen pool 24. During this process the temperature of the oxygen vapor is materially reduced and consequently a corresponding quantity of heat is precluded from being introduced into the column. Since the pressure reducing valve 73 bleeds the transfer vessel at a low pressure the valve 72 may be omitted if desired. In such case the periodic valve operator 50 would control only the valve 70. This form of the invention eliminates the requirement of an equalizing conduit and control valve connected between the high pressure end of the vaporizing section and the transfer vessel and provides a simplified arrangement for reducing the transfer vessel pressure to correspond to the column pressure. Systems embodying these features comprise a compact arrangement capable of operating at high pumping efficiency with minimum disturbing effects upon column operation.

The form of the invention illustrated in Fig. 4 of the drawings includes another arrangement for establishing the pressure conditions in the transfer vessel necessary to effect the pumping action. In this arrangement the high pressure condition is achieved by adding sufficient heat in the liquid oxygen in the transfer vessel to raise its temperature to the value at which its vapor pressure exceeds the high pressure in the vaporizer section. In particular, the transfer vessel may be similar to the Fig. 2 arrangement being provided with inlet valve 41 and outlet valve 42 and connected between the liquid oxygen collecting pool 24 of the column and the vaporizer section of the heat interchanger by means of conduits 63 and 44. The transfer vessel is also provided with the heat exchanger 60 for conducting fluids in heat exchange relation therewith. A substream of gaseous nitrogen from the low pressure zone of the fractionating column is passed directly to the heat interchanger 10 by

way of a conduit 80 while the other substream is passed in heat exchange relation with the transfer vessel 35 before entering the primary heat interchanger. For the latter purpose, a conduit 81, two position valvular means 82, and conduits 83 and 84 are provided for connecting the heat exchanger 60 in parallel relation with a portion of the conduit 80. The two position valvular means 82 is provided for conducting warmed gaseous nitrogen product in heat exchange relation with transfer vessel when it is desired to increase the temperature of the chamber 36, or cold gaseous nitrogen product when a pressure reduction is required. With the valvular means 82 in the position shown, cold gaseous nitrogen product is passed in heat exchange relation with the transfer vessel to reduce the temperature and hence the pressure of the material in the chamber 36. When the valvular means is moved to its other position, as shown in broken lines, the cold gaseous nitrogen product is conducted from the valvular means to a conduit 85, a secondary heat exchanger 86 and a conduit 87 before it is passed in heat exchange relation with the transfer vessel 35 by way of the conduit 83. The secondary heat exchanger 86 is positioned about the shell 14 at the high temperature end of the primary heat interchanger, and the conduits 85 and 87 are connected thereto in such a manner as to provide efficient heat transfer. The valvular means 82 may be provided with a valve operator of the type disclosed in Figs. 1 and 2 or with a valve operator 88 which may comprise a spring loaded solenoid arrangement operating in response to the temperature in the transfer vessel. For the latter purpose, a suitable temperature responsive control device 89, such as a thermocouple, is positioned in the transfer vessel and coupled to the valve operator. The pumping rate or frequency may be determined by controlling the rate of nitrogen product flow in heat exchange with the transfer vessel by means of a valve 90 positioned in the conduit 81, or by controlling the rate of liquid oxygen flow to the transfer vessel with a valve 91 inserted in the conduit 63. The high pressure gaseous oxygen conduit 46 is shown connected to two banks 92 and 93 of high pressure gas cylinders through valves 94 and 95. As discussed above, it may be advantageous in some instances to design the apparatus so that the volume of liquid oxygen fed to the vaporizer section during each transfer operation is sufficient to produce the necessary quantity of gaseous oxygen to fill a bank of cylinders at the desired pressure. Of course it is understood that the apparatus may be employed to feed other receivers in addition to banks of high pressure cylinders.

After starting up, a substantial pressure will build up in the vaporizer section and, with the valvular means 82 in the position shown, cold gaseous nitrogen product will pass through the heat exchanger 60 to condition the transfer vessel to receive liquid oxygen from the column. When the transfer vessel becomes filled with liquid oxygen, a lowest temperature condition exists in the chamber 36. In response to this temperature condition, the temperature responsive device 89 functions to control the valve operator 88 which moves the valvular means 82 into the position shown in broken lines. In this position, warmed gaseous nitrogen product passes in heat exchange relation with the transfer vessel. This heat exchange adds heat to the liquid oxygen in the chamber 36 to eventually raise its temperature to that value required to establish a vapor pressure corresponding to the pressure in the vaporizer section of the heat interchanger 10. When the high vapor pressure is established, the valve 42 opens and liquid oxygen flows under the influence of gravity from the chamber 36 into the lower end of the vaporizer section. After the liquid oxygen has drained from the transfer vessel, oxygen vapor will remain in the chamber 36 at relatively high temperature. The valve operator 88 responds to this high temperature to move the valvular means 82 to the position shown for the passage of cold gaseous nitrogen product in heat interchange with the transfer vessel. The high temperature at which the condensing process may be most efficiently initiated is best determined by experiment since the primary consideration is the time required for the liquid oxygen to flow from the transfer vessel. In some instances therefore, the critical high temperature may correspond to the temperature necessary to establish the critical vapor pressure in the chamber 36 or to some slightly higher temperature. With the system operating at its natural frequency, the quantity of liquid delivered to the vaporizer section may exceed the demand and flood the vaporizer or the purity of the product may be affected. In order to control the pumping rate or frequency, the valves 90 or 91 may be adjusted. The valve 90 controls the flow of nitrogen in heat exchange with the transfer vessel to control the time required to establish the high and lower critical pressures in the chamber 36, while the valve 91 controls the flow of liquid oxygen to the transfer vessel and thus determines the time of occurrence of the low critical temperature.

When an empty bank of cylinders is coupled to the conduit 46 and liquid oxygen is transferred to the vaporizer section, the temperature of the boiling oxygen in the interchanger will fall, and its temperature will subsequently increase as the vaporization process takes place and the oxygen gas pressure rises. This temperature fluctuation is somewhat compensated for in the Fig. 3 arrangement. The gaseous nitrogen entering the heat interchanger 10 is intermittently warmed in heat exchanger 60 due to the process of condensing high pressure oxygen vapor trapped in the transfer vessel. These periods of gaseous nitrogen warming fall within the low pressure intervals of the vaporizer section and thus tend to compensate for the variations in the temperature of the boiling oxygen in the interchanger.

A form of valve that may be employed for the valves 49 of Figs. 1 and 2 or for the valves 70 and 72 of Fig. 3 is shown in Fig. 5 of the drawings. This valve includes a hollow cylindrical body portion 100 provided with an inlet opening 101 and an outlet opening 102 both of which may be provided with suitable adapters, not shown, for serially inserting the valve in a conduit to be controlled thereby. The body portion 100 is provided with a cylindrical bore including an inwardly extending flange 103 forming a concentric opening 104 of reduced diameter. A circumferential valve seat 105 of knife-edge cross-section is formed on the upper side of the flange 103, as viewed in the drawing, adjacent the opening 104. A cylindrical valve member 106 is slideably mounted in the body portion 100 above the flange 103 and includes a lower face 107 which is adapted to contact the valve seat 105 and close communication through the opening 104. The valve member 106 has a diameter substantially less than the diameter of the cylindrical bore and is provided with a plurality of radially positioned vanes 108 for slideably mounting the valve member 106 in the valve body portion in concentric relation with the bore while allowing fluid flow around the valve member. The vanes 108 have one edge secured to the valve body 105 with the other edge slideably contacting the internal surfaces of the cylindrical bore. The diameter of the face 107 is substantially greater than the diameter of the valve seat 105 to reduce the pressure differential across from valve member 106. The valve is actuated by means of a solenoid coil 110 positioned externally of the valve body 100. For this purpose the valve body portion 100 is fabricated from suitable non-magnetic material, such as brass, while the valve member 106 is constructed from steel or other highly magnetic material. The solenoid coil 110 is properly positioned with respect to the valve member 106 to move the valve member upwardly upon energization of the coil 110 allowing the fluid to flow past the valve member 106 between the vanes 108 over the valve seat 105 and into the outlet 102 through the opening 104. The pressure differential across the valve member 106 is sufficiently reduced to a valve for solenoid operation. The

valve may be positioned as shown with movement of the valve member 106 along a vertical axis so that the valve member will move in closed position under the influence of gravity or the presence of a relatively higher pressure at the inlet 101 may be relied upon to close the valve. Of course it is understood that the valve member may be spring biased to a closed position or arranged to be moved to closed position upon energization of a suitably positioned coil.

There is thus provided by the present invention novel methods of an apparatus for transferring in liquid phase volatile liquids from a supply source where it is held under a low pressure to a receiving means under a relatively high pressure. One of the primary features of the invention comprises the provision of a volatile liquid pumping process and apparatus capable of increasing the pressure of highly volatile liquids from atmospheric pressure up to 2500 pounds per square inch gauge for example without experiencing the common difficulty of flashing and vapor lock and without employing mechanical devices such as plunger type pumps requiring packing material to maintain a substantially liquid tight system. The principles of the present invention have special utility in connection with processes for the fractionating of gaseous mixtures, such as air into oxygen and nitrogen, however the invention is clearly not limited to this example, wherein the energy for the pumping process is derived from the normal operation of the fractionating equipment or from products of the process, and wherein the over-all efficiency of the cycle is substantially unchanged as compared to the efficiency of fractionating equipment employing conventional pumping devices for delivering high pressure gaseous oxygen for example.

Although the invention has been shown and described in several different forms, it is to be expressly understood that various changes and substitutions may be made therein without departing from the spirit of the invention. For example, the principles of the present invention are not restricted to use in connection with fractionating systems but may be used to pump any form of liquid, especially volatile liquids. Also, the invention may be employed equally well with single or double stage fractionating columns and with apparatus for fractionating gaseous mixtures other than air, such as in the processing of natural gas and petroleum oils. Reference therefore will be had to the appended claims for a definition of the limits of the invention.

What is claimed is:

1. The method of transferring in liquid phase liquefied gas at its boiling point from a supply reservoir where it is held at a low pressure to a receiving chamber under a relatively high pressure, which comprises conducting under the influence of gravity liquefied gas from the supply reservoir to a transfer zone at a level lower than the supply reservoir, establishing a pressure in the transfer zone corresponding to the relatively high pressure, conducting liquefied gas under the influence of gravity in the transfer zone to the receiving chamber, and passing a relatively cold fluid in heat exchange relation with the transfer zone to reduce the pressure in the transfer zone to the low pressure after the liquefied gas has been conducted from the transfer zone and then placing the transfer zone in communication with the supply reservoir, the relatively cold fluid being at least as cold as the low pressure liquefied gas.

2. The method of transferring in liquid phase liquefied gas at its boing point from a supply reservoir where it is held at a low pressure to a receiving chamber under a relatively high pressure, which comprises conducting under the influence of gravity liquefied gas from the supply reservoir to a transfer zone at a level lower than the supply reservoir, establishing a pressure in the transfer zone corresponding to the relatively high pressure, conducting liquefied gas under the influence of gravity at the relatively high pressure in the transfer zone to the receiving chamber, passing a relatively cold fluid in heat exchange relation with the transfer zone to cool high pressure vapor remaining in the transfer zone after liquefied gas has been conducted from the transfer zone to reduce the pressure in the zone and then placing the transfer zone in communication with the supply reservoir to receive liquefied gas from the supply reservoir at the low pressure, the relatively cold fluid being at least as cold as the low pressure liquefied gas.

3. The method of transferring in liquid phase liquefied gas at its boiling point from a supply reservoir where it is held at low pressure to a receiving chamber under a relatively high pressure through an intermediate transfer vessel located below the supply reservoir, which method comprises conducting under the influence of gravity liquefied gas from the supply reservoir to the transfer vessel at the low pressure, establishing a pressure in the transfer vessel corresponding to the relatively high pressure in the receiving chamber, conducting under the influence of gravity liquefied gas at the relatively high pressure in the transfer vessel to the receiving chamber, and passing a relatively cold fluid in heat exchange relation with the intermediate transfer vessel to cool relatively high pressure vapor remaining in the transfer vessel after the liquefied gas is conducted to the receiving chamber to equalize the pressure between the supply reservoir and the transfer vessel, the relatively cold fluid being at least as cold as the low pressure liquefied gas.

4. The method of transferring in liquid phase liquefied gas at its boiling point from a supply reservoir where it is held at a low pressure to a receiving chamber under a relatively high pressure through a transfer vessel located below the supply reservoir, which method comprises the steps of transferring under the influence of gravity liquefied gas at the low pressure from the supply reservoir to the transfer vessel, subjecting liquefied gas transferred to the transfer vessel to a vapor pressure corresponding to the relatively high pressure of the receiving chamber and simultaneously isolating the transfer vessel from the supply reservoir, transferring under the influence of gravity isolated liquefied gas at the relatively high pressure from the transfer vessel to the receiving chamber, passing a relatively cold fluid in heat exchange relation with the transfer vessel to liquefy high pressure vapor remaining in the transfer vessel after the liquefied gas is transferred to the receiving chamber to reduce the pressure in the transfer vessel, and placing the transfer vessel in communication with the supply reservoir to receive liquefied gas from the supply reservoir at the relatively low pressure, the relatively cold fluid being at least as cold as the low pressure liquefied gas.

5. The method of transferring in liquid phase liquefied gas at its boiling point from a supply reservoir where it is held at a low pressure to a receiving chamber under a relatively high pressure, which comprises conducting under the influence of gravity liquefied gas at the low pressure to an isolated zone located below the supply reservoir, passing high pressure vapor from the receiving chamber to the isolated zone to increase the pressure of the liquefied gas in the isolated zone to correspond to the relatively high pressure, conducting under the influence of gravity liquefied gas at the relatively high pressure in the isolated zone to the receiving chamber, passing a relatively cold fluid in heat exchange relation with the isolated zone to cool high pressure vapor remaining in the isolated zone after the liquefied gas is conducted to the receiving chamber, and placing the isolated zone in communication with the supply reservoir to receive liquefied gas from the supply reservoir, the relatively cold fluid being at least as cold as the low pressure liquefied gas.

6. The method of transferring in liquid phase liquefied gas at its boiling point from a supply reservoir where it is held at a low pressure to a storage chamber under

a relatively high pressure through an intermediate transfer vessel located below the supply reservoir, which method comprises conducting under the influence of gravity liquefied gas from the supply reservoir to the transfer vessel at the low pressure, passing vapor from the storage chamber to the transfer vessel to increase the pressure in the transfer vessel to correspond to the relatively high pressure in the storage vessel, conducting under the influence of gravity liquefied gas at the relatively high pressure in the transfer vessel to the storage chamber, and passing a relatively cold fluid in heat exchange relation with the intermediate transfer vessel to condense relatively high pressure vapor remaining in the transfer vessel after the liquefied gas is conducted to the storage chamber to equalize the pressure between the transfer vessel and the supply reservoir, the relatively cold fluid being at least as cold as the low pressure liquefied gas.

7. The method of transferring in liquid phase liquefied gas at its boiling point from a supply reservoir where it is held at a low pressure to a storage chamber under a relatively high pressure through an intermediate transfer vessel located below the supply reservoir, which method comprises conducting under the influence of gravity liquefied gas from the supply reservoir to the transfer vessel at the low pressure, establishing a vapor pressure in the transfer vessel at least equal to the relatively high pressure in the storage chamber to increase the pressure of the liquefied gas in the transfer vessel to correspond to the relatively high pressure in the storage chamber, conducting under the influence of gravity liquefied gas at the relatively high pressure in the transfer vessel to the storage chamber, and passing a cold fluid in heat exchange relation with the transfer vessel to condense high pressure vapor remaining in the transfer vessel after the liquefied gas is conducted to the storage chamber to equalize the pressure between the supply reservoir and the transfer vessel, the relatively cold fluid being at least as cold as the low pressure liquefied gas.

8. The method of transferring in liquid phase liquefied gas at its boiling point from a supply reservoir where it is held at a low pressure to a storage chamber under a relatively high pressure through an intermediate transfer vessel located below the supply reservoir, which method comprises conducting under the influence of gravity a stream of liquefied gas from the supply reservoir to the intermediate transfer vessel at the low pressure, periodically establishing a vapor pressure in the transfer vessel at least equal to the relatively high pressure in the storage chamber, conducting under the influence of gravity liquefied gas at the relatively high pressure in the transfer vessel to the storage chamber, and passing a relatively cold fluid in heat exchange relation with the intermediate transfer vessel to condense high pressure vapor remaining in the transfer vessel after the liquefied gas is transferred to the storage chamber to reduce the pressure in the transfer vessel to at least equal the low pressure in the supply reservoir, the relatively cold fluid being at least as cold as the low pressure liquefied gas, the period for establishing a vapor pressure in the transfer vessel at least equal to the relatively high pressure being longer than the total time required for the transfer of liquefied gas from the transfer vessel, the condensation of high pressure vapor remaining in the transfer vessel and the transfer of liquefied gas from the supply reservoir to the transfer vessel.

9. The method of transferring in liquid phase liquefied gas at its boiling point from a supply reservoir where it is held at a low pressure to a storage chamber under a relatively high pressure through an intermediate transfer vessel located below the supply reservoir, which method comprises conducting under the influence of gravity liquefied gas from the supply reservoir to the transfer vessel at the low pressure, passing a warm fluid in heat exchange relation with the transfer vessel to establish a vapor pressure in the transfer vessel corresponding to the relatively high pressure in the storage chamber, conducting under the influence of gravity liquefied gas at the relatively high pressure in the transfer vessel to the storage chamber, and passing a cold fluid in heat exchange relation with the transfer vessel to cool high pressure vapor remaining in the transsfer vessel after the liquefied gas is conducted to the storage chamber and equalize the pressure in the transfer vessel and the supply reservoir, the relatively cold fluid being at least as cold as the low pressure liquefied gas.

10. The method of transferring in liquid phase liquefied gas at its boiling point from a storage reservoir where it is held at a low pressure to the reservoir of a vaporizer under a relatively high pressure through an intermediate transfer vessel located below the supply reservoir, the vaporizer being operable to deliver liquefied gas in gaseous phase under the relatively high pressure, which method comprises conducting under the influence of gravity liquefied gas from the supply reservoir to the transfer vessel, transferring heat from the vaporizer to the transfer vessel to increase the pressure of the liquefied gas in the transfer vessel to correspond to the relatively high pressure in the vaporizer, isolating the transfer vessel from the storage reservoir in response to the relatively high pressure in the transfer vessel and conducting under the influence of gravity liquefied gas at the relatively high pressure to the reservoir, vaporizing liquid material in the reservoir, isolating the transfer vessel from the reservoir at the beginning of the vaporizing step, passing a relatively cold fluid in heat exchange relation with the transfer vessel to reduce the pressure in the transfer vessel to the low pressure, and conducting liquefied gas from the supply reservoir to the transfer vessel during the vaporizing step, the relatively cold fluid being at least as cold as the low pressure liquefied gas.

11. The method of transferring in liquid phase liquefied gas at its boiling point from a supply vessel where it is held at a low pressure to a receiving chamber under a relatively high pressure, which comprises conducting under the influence of gravity liquefied gas from the supply reservoir to a transfer zone located below the supply vessel, establishing a pressure in the transfer zone corresponding to the relatively high pressure responsively to the temperature in the transfer zone, conducting liquefied gas under the influence of gravity at the relatively high pressure in the transfer zone to the receiving chamber, and passing a relatively cold fluid in heat exchange relation with the transfer zone to reduce the pressure of high pressure vapor remaining in the transfer zone after the liquefied gas has been conducted from the transfer zone and placing the transfer zone in communication with the supply reservoir responsively to the temperature in the transfer zone, the relatively cold fluid being at least as cold as the low pressure liquefied gas.

12. The method of transferring in liquid phase liquid product of a fractionating operation to a receiving chamber at a relatively high pressure, in which operation compressed and cooled gaseous mixture is fractionated into a gaseous fraction and a liquid fraction as the product, which method comprises conducting under the influence of gravity liquid product from the fractionating operation to an isolated zone, establishing a pressure in the zone corresponding to the relatively high pressure, conducting under the influence of gravity liquid product at the relatively high pressure in the zone to the receiving chamber, and passing cold fluid from the fractionating operation in heat exchange with high pressure vapor remaining in the zone after liquid product is conducted to the receiving chamber, and placing the zone in communication with the fractionating operation to receive liquid product from the fractionating operation.

13. The method of transferring in liquid phase liquid product of a fractionating operation to a receiving chamber at a relatively high pressure through an intermediate

transfer vessel, in which operation compressed and cooled gaseous mixture is fractionated into a gaseous fraction and a liquid fraction as the product, which method comprises conducting under the influence of gravity liquid product from the fractionating operation to the transfer vessel, transferring heat from the receiving chamber to the transfer vessel to increase the pressure of liquid product in the transfer vessel to correspond to the relatively high pressure in the receiving chamber, conducting under the influence of gravity liquid product at the relatively high pressure in the transfer vessel to the receiving chamber, and passing cold fluid from the fractionating operation in heat exchange relation with the transfer vessel to cool high pressure vapor remaining in the transfer vessel after liquid product is conducted to the receiving chamber and place the transfer vessel in communication with liquid product in fractionating operation.

14. The method of transferring in liquid phase liquid product of a fractionating operation to a vaporizing process under a relatively high pressure through an intermediate transfer vessel, in which operation compressed and cooled gaseous mixture is fractionated into gaseous fraction and liquid fraction as the product and in which process liquid product is converted into gaseous phase at the relatively high pressure by heat exchange with gaseous mixture on its way to the fractionating operation, the method comprising withdrawing liquid product from the fractionating operation and conducting under the influence of gravity liquid product to the transfer vessel at the pressure of liquid product in the fractionating operation, establishing a vapor pressure in the transfer vessel corresponding to the relatively high pressure in the vaporizer, conducting under the influence of gravity liquid product at the relatively high pressure in the transfer vessel to the vaporizer, and passing cold fluid from the fractionating operation in heat exchange relation with the transfer vessel to cool vapor remaining in the transfer vessel after liquid product is conducted to the vaporizer and establish a pressure equalization between liquid product in the fractionating operation and the transfer vessel.

15. The method of transferring in liquid phase liquid product of a fractionating operation to a vaporizing process under a relatively high pressure through transfer vessel, in which operation a compressed and cooled gaseous mixture is fractionated into gaseous fraction and liquid fraction as the product and in which process liquid product is converted into gaseous phase at the relatively high pressure by heat exchange with gaseous mixture on its way to the fractionating operation, the method comprising withdrawing liquid product from the fractionating operation and conducting under the influence of gravity liquid product to the transfer vessel at the pressure of the liquid product in the fractionating operation, periodically establishing a vapor pressure in the transfer vessel corresponding to the relatively high pressure, conducting under the influence of gravity liquid product at the relatively high pressure in the transfer vessel to the vaporizing process, passing cold fluid from the fractionating operation in heat exchange relation with the transfer vessel to liquefy high pressure vapor remaining in the transfer vessel after liquid product is conducted to the vaporizing process and equalize the pressure between liquid product in the fractionating operation and the transfer vessel, the period of the periodic establishment of vapor pressure in the transfer vessel being longer than the total time required to conduct high pressure liquid product to the vaporizing process, to liquefy high pressure vapor remaining in the transfer vessel and to conduct liquid product from the fractionating operation to the transfer vessel.

16. The method of transferring in liquid phase liquid product of a fractionating operation to a vaporizing process under a relatively high pressure through a transfer vessel, in which operation compressed and cooled gaseous mixture is fractionated into gaseous fraction and liquid fraction as the product and in which process liquid product is converted into gaseous phase at the relatively high pressure by heat exchange with gaseous mixture on its way to the fractionating operation, the method comprising withdrawing a portion of liquid product from the fractionating operation and conducting under the influence of gravity withdrawn liquid product to the transfer vessel at the pressure of liquid product in the fractionating operation, conducting high pressure vapor from the vaporizing process to the transfer vessel to increase the pressure of liquid product in the transfer vessel to correspond to the relatively high pressure in the vaporizing process, conducting under the influence of gravity liquid product at the relatively high pressure in the transfer vessel to the vaporizing process under the influence of gravity, and passing cold fluid from the fractionating operation in heat exchange relation with the transfer vessel to liquefy high pressure vapor remaining in the transfer vessel after conducting liquid product to the vaporizing process and equalize the pressure between the transfer vessel and liquid product in the fractionating operation.

17. The method of transferring in liquid phase liquid product of a fractionating operation to a vaporizing process under a relatively high pressure through a transfer vessel, in which operation compressed and cooled gaseous mixture is fractionated into gaseous fraction and liquid fraction as the product and in which process liquid product is converted into gaseous phase at the relatively high pressure by heat interchange with gaseous mixture on its way to the fractionating operation, the method comprising withdrawing liquid product from the fractionating operation and conducting under the influence of gravity liquid product to the transfer vessel at the pressure of the liquid product in the fractionating operation, passing warmed fluid from the vaporizing process in heat exchange relation with the transfer vessel to establish a vapor pressure in the transfer vessel corresponding to the relatively high pressure in the vaporizing process, conducting under the influence of gravity liquid product at the relatively high pressure in the transfer vessel to the vaporizing process, passing cold fluid from the fractionating operation in heat exchange relation with the transfer vessel to cool high pressure vapor remaining in the transfer vessel after liquid product is conducted to the vaporizing process and equalize the pressure between the transfer vessel and liquid product in the fractionating operation, and controlling the flow of warmed fluid and the flow of cold fluid in heat exchange relation with the transfer vessel in accordance with the temperature of the transfer vessel.

18. The method of transferring in liquid phase liquid product of a fractionating operation to a vaporizing process under a relatively high pressure through a transfer vessel, in which operation compressed and cooled gaseous mixture is fractionated into gaseous fraction and liquid fraction as the product and in which process liquid product is converted into gaseous phase at the relatively high pressure by heat exchange with gaseous mixture on its way to the fractionating operation, the method comprising withdrawing a portion of liquid product from the fractionating operation and conducting under the influence of gravity withdrawn liquid product to the transfer vessel at the pressure of the liquid product in the fractionating operation, passing warmed fluid from the vaporizing process in heat exchange relation with the transfer vessel in response to a low temperature in the transfer vessel approaching the temperature of the liquid product, the heat exchange between the warmed fluid and the transfer vessel establishing a vapor pressure in the transfer vessel corresponding to the relatively high pressure in the vaporizing process, conducting under the influence of gravity liquid product in the transfer vessel at the relatively high pressure to the vaporizing process,

passing cold fluid from the fractionating operation in heat exchange relation with the transfer vessel in response to a high temperature in the transfer vessel approaching the temperature of the vapor at the ratively high pressure, the heat exchange between the cold fluid and the transfer vessel liquefying high pressure vapor remaining in the transfer vessel after liquid product is conducted to the vaporizing process and establishing pressure equalization between the transfer vessel and liquid product in the fractionating operation.

19. Apparatus for transferring in liquid phase a volatile liquid product from a fractionating operation to a heat interchanger under a relatively high pressure in which heat exchange liquid product forfeits cold to a compressed gaseous mixture on its way to the fractionating operation and emerges in gaseous phase under the relatively high pressure, and in which operation the cooled gaseous mixture is fractionated to produce volatile liquid at a low pressure as the product, comprising a transfer vessel, means for conducting under the influence of gravity liquid product from the fractionating operation to the transfer vessel at the low pressure and for conducting under the influence of gravity liquid in the transfer vessel to the heat interchanger at the relatively high pressure, the last-named means including means for periodically establishing a pressure in the transfer vessel at least equal to the relatively high pressure in the heat interchanger and means for passing cold fluid from the fractionating operation in heat interchange relation with the transfer vessel to cool high pressure vapor remaining in the transfer vessel after liquid is conducted to the heat interchanger and reduce the pressure in the transfer vessel to a value at least equal to the pressure of liquid product in the fractionating operation.

20. Apparatus for transferring in liquid phase a volatile liquid product from a fractionating operation to a heat interchanger, under a relatively high pressure in which heat interchanger liquid product forfeits cold to gaseous mixture on its way to the fractionating operation and emerges in gaseous phase under the relatively high pressure, and in which operation the gaseous mixture is fractionated to produce volatile liquid as a product, comprising a transfer vessel, and means for conducting under the influence of gravity liquid product from the fractionating operation to the transfer vessel at the pressure of the liquid product in the fractionating operation and conducting under the influence of gravity liquid in the transfer vessel to the heat interchanger at the relatively high pressure, the last-named means including an equalizing conduit connected between the heat interchanger and the transfer vessel, periodically operable valvular means for intermittently opening and closing the equalizing conduit, and means for passing cold fluid from the fractioning operation in heat exchange relation with te transfer vessel.

21. An apparatus of the character set forth in claim 20 in which the transfer vessel is positioned in an auxiliary vessel filled with volatile liquid product from the fractionating operation and in which the transfer vessel is constructed of a material having a low thermal conductivity.

22. Apparatus for transferring in liquid phase a liquid product from the liquid product collecting space of a fractionating operation to a heat interchanger under a relatively high pressure, in which heat interchanger liquid product forfeits cold to gaseous mixture on its way to the fractionating operation and emerges in gaseous phase under the relatively high pressure, and in which operation the gaseous mixture is fractionated to produce volatile liquid as a product, comprising a transfer vessel, conduit means connecting the transfer vessel between the liquid product collecting space and the heat interchanger for liquid flow under the influence of gravity from the fractionating operation through the transfer vessel to the heat interchanger, valvular means operative responsively to a pressure in the transfer vessel no greater than the pressure of liquid product in the fractionating operation for the flow of liquid under the influence of gravity from the fractionating operation to the transfer vessel and operative responsively to another pressure in the transfer vessel at least equal to the pressure in the heat interchanger for the flow of liquid under the influence of gravity from the transfer vessel to the heat interchanger, a heat exchanger surrounding the transfer vessel, conduit means including valvular means for alternately passing cold fluid from the fractionating operation and warmed fluid from the fractionating operation through the heat exchanger, means for operating the valvular means and means responsive to the temperature of the transfer vessel for controlling the last-named means.

23. Apparatus for transferring in liquid phase a volatile liquid product from a fractionating operation to a heat interchanger under a relatively high pressure in which heat exchange liquid product forfeits cold to a compressed gaseous mixture on its way to the fractionating operation and emerges in gaseous phase under the relatively high pressure, and in which operation the cooled gaseous mixture is fractionated to produce volatile liquid at a low pressure as the product and a cold gaseous fraction, comprising a transfer vessel, means for conducting under the influence of gravity liquid product from the fractionating operation to the transfer vessel at the low pressure and for conducting under the influence of gravity liquid in the transfer vessel to the heat interchanger at the relatively high pressure, the last-named means including means for periodically establishing a pressure in the transfer vessel at least equal to the relatively high pressure in the heat interchanger and means for passing cold gaseous fraction from the fractionating operation in heat interchange relation with the transfer vessel to cool high pressure vapor remaining in the transfer vessel after liquid is conducted to the heat interchanger and reduce the pressure in the transfer vessel to a value at least equal to the pressure of liquid product in the fractionating operation.

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