

Jan. 15, 1957

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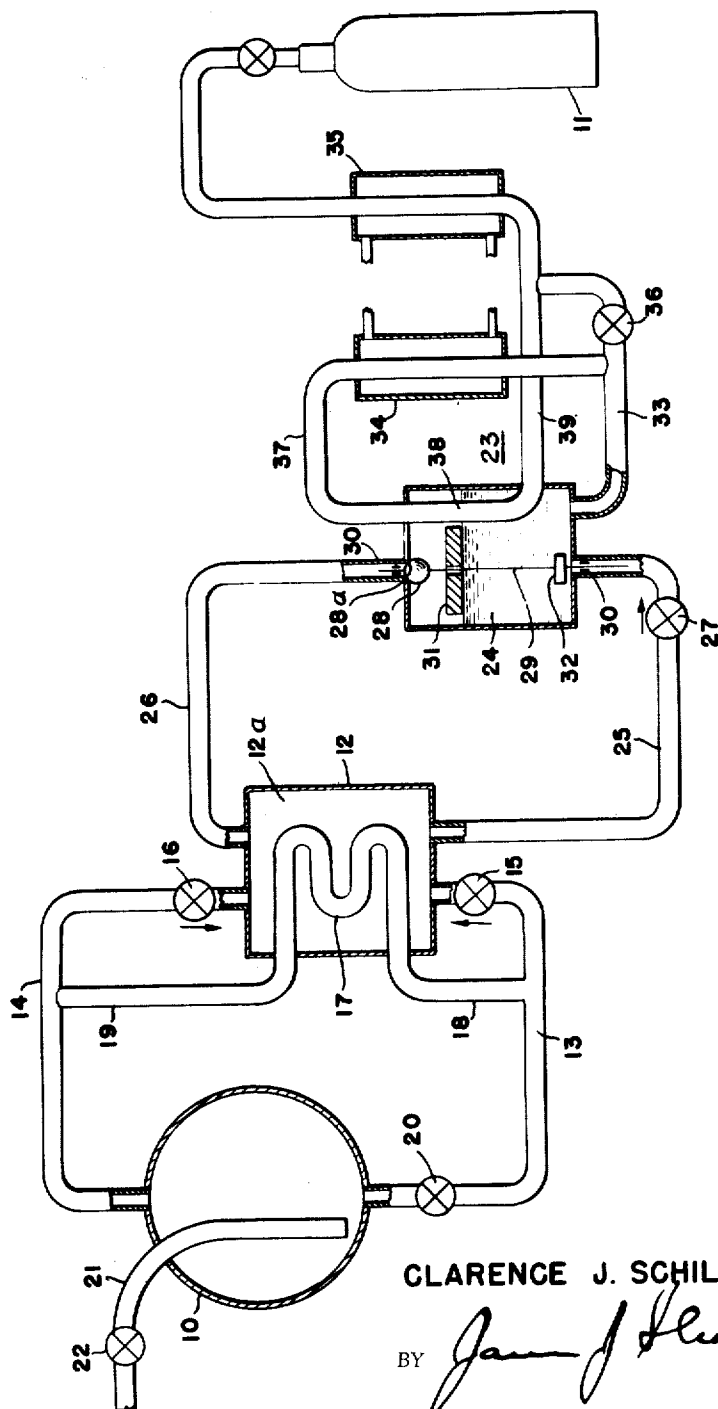
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LIQUID PUMPING AND VAPORIZING SYSTEMS

Filed Aug. 13, 1952

2 Sheets-Sheet 1

FIG. 1.



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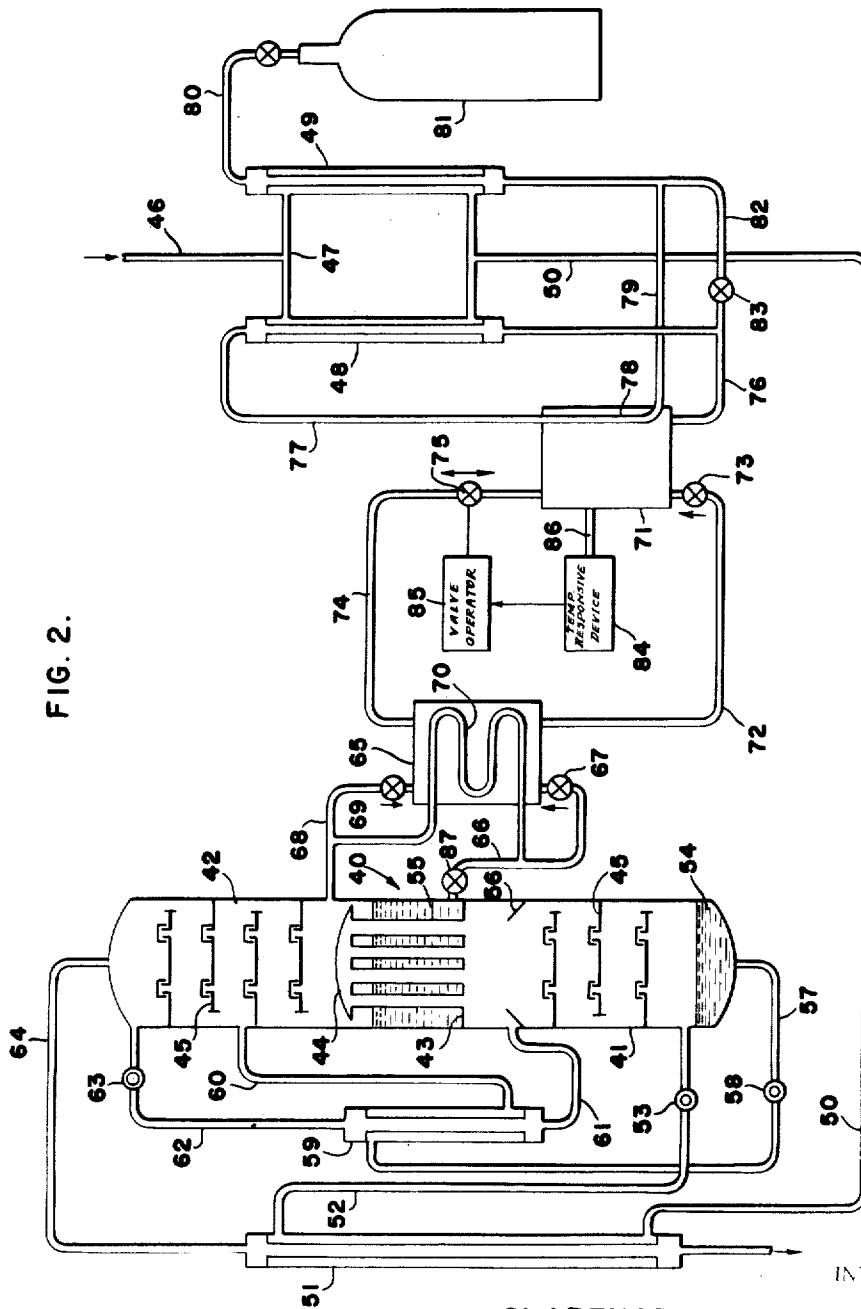
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2 Sheets-Sheet 2

FIG. 2.



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LIQUID PUMPING AND VAPORIZING SYSTEMS

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22 Claims. (Cl. 62—2)

This invention relates to dispensing of volatile liquids and more particularly to methods of and means for transferring a volatile liquid held in a supply vessel at a low pressure to a receiver in gaseous form under a relatively high pressure.

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 pressures. In general, there are two methods for transferring volatile liquids 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 to the desired high pressure. Practice of this method usually 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 pumping gaseous oxygen. In the second method the volatile liquid is pumped in liquid phase to the desired relatively high pressure and thereafter 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. These pumps require special plunger packing and include insulating means to prevent heat infiltration and cold loss as well as an arrangement for cooling the liquid conveying end with a cold fluid to prevent pump stoppages due to vapor lock. While liquid pumps of the foregoing character have proven adequate they are not capable of continuous and uninterrupted performance inasmuch as the moving elements and packing therefor require replacement as is the case of all mechanical machines including moving parts.

It is therefore an object of the present invention to provide a novel method of and means for dispensing a volatile liquid held at a relatively low pressure to a receiver in gaseous phase under a relatively high pressure without the use of mechanical pumps or apparatus requiring packing material.

Still another object is to provide a novel method of and means for transferring the liquid product of a fractionating operation to a receiving means in gaseous phase under a relatively high pressure.

A still further object of the present invention is to provide a fractionating operation in which a gaseous mixture is fractionated into a gaseous fraction and a volatile liquid fraction, including a novel arrangement for delivering the liquid fraction in gaseous phase at a relatively high pressure without the use of mechanical pumping means.

Other objects and features of the present invention will appear more fully hereinafter from the following detailed description considered in connection with the accompanying drawings which disclose two embodiments of the present 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.

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

Fig. 1 is a diagrammatic view illustrating an apparatus embodying the principles of the invention for transferring a volatile liquid under low pressure from a storage vessel to a receiving means in gaseous phase under relatively high pressure, and

Fig. 2 is a diagrammatic view illustrating a fractionating process including a novel arrangement for conducting the low pressure liquid product of the process to a receiving means in gaseous form under relatively high pressure.

According to the present invention a transfer vessel is provided for alternately receiving a low pressure volatile liquid from a supply vessel and for delivering the liquid to the reservoir of a vaporizer under a relatively high pressure. The flow of liquid to and from the transfer vessel is controlled by alternately establishing predetermined pressures in the transfer vessel; one at least as low as the pressure of the supply vessel and the other at least equal to the relatively high pressure of the vaporizer reservoir. These predetermined pressures are established in the transfer vessel according to minimum and maximum states or conditions or vaporization of the liquid or fluid in the vaporizer reservoir. Also, the occurrence of these predetermined pressures is so timed that the transfer vessel is refilled with low pressure liquid before complete vaporization of the liquid previously transferred to the reservoir. Thus, a source of liquid is always available to meet the highest feed demands of the vaporizer. Moreover, the present invention also provides a fractionating apparatus for producing a low pressure volatile liquid as a product, including a novel liquid vaporizer pump of the character described above for delivering the low pressure volatile liquid product in gaseous phase under a relatively high pressure. In both forms of the invention means are provided for substantially preventing the transfer of heat of vaporization to the supply vessel or to the fractionating operation.

With reference more particularly to Fig. 1 of the drawings, a liquid vaporizer pump constructed in accordance with the principles of the present invention is shown for transferring a volatile liquid held under low pressure in a supply vessel 10 to a receiver 11 in gaseous phase under a relatively high pressure. The supply vessel is designed to hold volatile liquids under low pressures with minimum vaporization and may be of conventional construction provided with suitable insulation, not shown, for preventing heat infiltration, while the receiving vessel 11 may comprise a conventional high pressure gas cylinder capable of withstanding pressures up to 2500 pounds gauge for example, or a bank of such cylinders. The liquid vaporizer pump includes a transfer vessel 12 which may be of cylindrical shape and made of metallic material or constructed in any other suitable manner to withstand an internal pressure corresponding to the high pressure developed in the receiving means 11. A low pressure liquid conduit 13 is connected between the bottom of the supply vessel 10 and the bottom of the transfer vessel 12, while a low pressure vapor conduit 14 is provided to establish a vapor connection between the upper portions of these vessels. One-way check valves 15 and 16 are positioned in the conduits 13 and 14, respectively, opening inwardly toward the transfer vessel. The check valve 16 may be of the gravity actuated type, so that when the pressure within the transfer vessel is below the pressure upstream of the valve, it will move to its open position, while the valve 15 may be of the type responsive to a pressure differential to establish its open position. A pressure controlling coil 17 is positioned within the chamber 12^a of the transfer vessel 12. This coil is provided with a liquid feeding conduit 18 connected to the conduit

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13 upstream of the check valve 15, and a vapor conduit 19 connected to the conduit 14 between the check valve 16 and the supply vessel. The transfer vessel 12 is located at an elevation sufficiently below the supply vessel so that liquid material may flow into and fill the transfer vessel under the influence of gravity when the proper pressure conditions exist. A valve 20 may be provided in the conduit 13 for controlling the flow of liquid from the storage vessel 10. Also, the storage vessel 10 is provided with suitable feed means such as an input conduit 21 having a control valve 22.

The vaporizer portion of the liquid vaporizer pump, shown generally by reference numeral 23, includes a reservoir 24. The transfer vessel and the reservoir are provided with a high pressure liquid conduit 25 and a high pressure vapor conduit 26. The liquid conduit is connected between the lowest points of the transfer vessel and the reservoir and includes a one-way check valve 27 opening toward the reservoir. The high pressure vapor conduit forms a vapor path between the upper portions of the transfer vessel and the reservoir. This vapor path is controlled by a valve member 28 and a cooperating valve seat 28^a which may be formed at the end of the conduit 26 in the reservoir. The valve member 28 is adapted to move into and out of engagement with its seat in accordance with the liquid level in the reservoir. For this purpose the valve member 28 is secured to a valve supporting rod 29 which is mounted on spiders 30, 30 for vertical movement in the axially aligned conduits 25 and 26. A float member 31 is slidably mounted on the rod 29 between the valve member 28 and a stop 32 which may be adjustably secured to the lower end of the rod. When the reservoir 24 becomes filled with liquid, the float 31 moves upwardly therewith and forces the valve member 28 into engagement with the seat 28^a to close the vapor connection with the transfer vessel. As the liquid level in the reservoir decreases, the float 31 falls with the liquid eventually contacting the stop 32 and moving the valve member 28 away from the seat upon further reduction of the liquid level. The reservoir 24 is mounted at an elevation below the transfer vessel 12 so that, when the proper pressure conditions exist, liquid may flow, under the influence of gravity, into and fill the reservoir. The reservoir 24 is constructed to hold the high pressure developed in the receiving means, and its volume is preferably no greater than the volume of liquid delivered by the transfer vessel.

The liquid within the reservoir is vaporized by the addition of heat thereto. For this purpose, the reservoir may be constructed of a material having good heat conductivity characteristics and be exposed to the atmosphere. In case the ambient temperature is insufficient to supply the necessary heat to initiate the vaporization process, a jacket may be provided around the reservoir for conducting a warm fluid in heat interchange therewith. Fluid is removed from the vaporizer reservoir 24 by way of a conduit 33, from hence it may be wholly conducted through a heating means 34, or partially through the heating means 34 with the remainder passing through a heating means 35 as controlled by a valve 36 in accordance with the rate of vaporization desired. After passing through the heating means 34, the fluid is conducted by a conduit 37 into heat interchange with the fluid remaining within the reservoir 24, such as by a section of conduit 38 positioned within the reservoir. The fluid is then conducted by way of a conduit 39 through the heating means 35 to the receiving means 11. The heating means 34 and 35 may comprise cylindrical jackets positioned about sections of conduit for circulating warm fluids in heat interchange therewith.

In starting up, with the valve 20 in open position, liquid in the storage vessel 10 flows, under the influence of gravity, through the conduit 13 and the transfer vessel 12 and into the reservoir 24 through the conduit 25. Eventually, the liquid in the reservoir will reach the level at

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which the float 31 moves the valve member 28 against the seat 28^a to close the vapor path to the transfer vessel. Thereafter, the liquid will flow into and fill the transfer vessel. The infiltration of heat into the reservoir raises the temperature of the liquid and produces a pressure increase which closes the check valve 27 and isolates the reservoir from the transfer vessel 12. The reservoir pressure continues to rise as the liquid forfeits its cold, and a stream of fluid is forced from the reservoir by way of the conduit 33. A portion of the fluid stream passes through the heating means 34 wherein its temperature is further increased. The stream of fluid emerges from the heating means 34 in a highly vaporized state and is passed by the conduit 37 through the conduit 38 in heat interchange with the fluid remaining within the reservoir 24. During this heat interchange the stream of partially vaporized liquid forfeits heat to the reservoir fluid to accelerate the vaporization process. After the latter heat interchange the fluid stream is conducted by way of a conduit 39 through the heating means 35 wherein the vaporization is completed and the material in gaseous phase at the desired pressure is delivered to the receiving means. The rate of vaporization is controlled by the valve 36 which determines the quantity of warm fluid passed in heat interchange with the fluid remaining in the reservoir.

As the liquid in the reservoir is vaporized, the float member 31 moves downwardly with the liquid level, while the valve member 28 remains in its closed position due to the high reservoir pressure. When substantially no liquid remains in the reservoir, the float member 31 contacts the stop 32 and moves the valve member 28 away from the seat 28^a to open the conduit 26 and subject the transfer vessel to the high vapor pressure existing in the reservoir. As the pressure in the transfer vessel increases the check valves 15 and 16 move to their closed positions to isolate the transfer and supply vessels, while the pressure equalization allows the liquid in the transfer vessel to flow, under the influence of gravity, through the conduit 25, past the check valve 27 and into the reservoir. Due to the volumetric relationship between the transfer vessel and the reservoir the volume of liquid transferred to the reservoir is sufficient to effect closure of the pressure equalizing conduit 26. Thereafter the vaporization process described above will take place.

The cold liquid material entering the vaporizer reservoir condenses the high pressure vapor therein and creates an abrupt pressure drop. Thus sudden reduction in pressure terminates the flow of high pressure vapor to the transfer vessel, and for a limited period of time may cause a reversal of vapor flow between the transfer vessel and the reservoir. Also, a portion of the high pressure vapor introduced into the transfer vessel will be condensed by the liquid material therein and will pass to the reservoir through the conduit 25. Thus when the transfer of the liquid material is complete, with the valves 27 and 28 closed, the transfer vessel 12 and the conduits 25 and 26 will contain vapor under a pressure greater than the low pressure of the supply vessel but substantially less than the relatively high pressure of the receiving means. Under these conditions substantially the entire volume of liquid material is effectively transferred to the reservoir and the trapped vapor may be condensed to rapidly establish the low pressure condition in the transfer vessel by heat interchange with the cold liquid in the coil 17. When the vapor is condensed to reduce the transfer vessel pressure to correspond to the pressure within the supply vessel, the liquid material will flow into and fill the transfer vessel under the influence of gravity. Inasmuch as the vapor is trapped in the transfer vessel at a reduced pressure a minimum amount of cold is required to effect the pressure reduction. Thus, a minimum amount of heat is added to the liquid material in the storage vessel as a result of the pumping and vaporizing operations.

The system is designed so that vapor trapped in the transfer vessel is liquefied and the transfer vessel again

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becomes filled with liquid from the supply vessel during a time interval less than the time required for vaporization of the liquid in the reservoir. This performance may be realized by proper design of the heat interchange area of the coil 17. With this arrangement substantially continuous operation is possible inasmuch as a supply of material in liquid phase is available for transfer to the reservoir whenever the vaporizer is in a condition to receive additional liquid.

In Fig. 2 of the drawings the present invention is disclosed in connection with an apparatus for fractionating a gaseous mixture into its components, such as the fractionation of air into gaseous nitrogen and liquid oxygen. The fractionating apparatus includes a two-stage fractionating column 40, however it is expressly understood that the present invention may be employed in connection with single stage fractionating columns. The two-stage fractionating column includes a high pressure zone 41 and a low pressure zone 42 separated by a horizontal plate 43 forming the usual refluxing condenser 44. Each of the zones is provided with conventional bubble plates 45. The compressed and cooled air enters the system at conduit 46 and is formed into two sub-streams at junction 47, each of which is conducted through one path of heat interchangers 48 and 49. After leaving the heat interchangers the air stream is combined in a conduit 50 and conducted through a third heat interchanger 51 wherein it passes in heat exchange relation with fractionation products as described hereafter. After passing through the next interchanger 51 the stream is conducted by way of a conduit 52 through an expansion valve 53 and into the high pressure zone 41 near its lower end. The high pressure zone functions to fractionate the air into a liquid rich in oxygen collecting in a pool 54 in the base of the column and gaseous nitrogen flowing upwardly into the condenser 44. The gaseous nitrogen is liquefied by heat interchanger with a pool 55 of boiling liquid oxygen surrounding the condenser. A portion of the liquefied nitrogen collects in a pool formed by a trough 56 while the remainder falls downwardly as reflux for the high pressure zone. A stream of oxygen rich liquid is withdrawn from the pool 54 through a conduit 57 and passed to an expansion valve 58 where it is expanded to the low pressure of the zone 42. The expanded stream is then conducted to a heat interchanger 59 in which it passes in heat exchange relation with liquid nitrogen, preferably in counterflow relation, and is then conducted by way of a conduit 60 to a medial point of the low pressure zone as feed. The high pressure liquid nitrogen is conducted to the heat interchanger 59 by way of a conduit 61, from whence it is passed through a conduit 62 to an expansion valve 63 and then introduced into the top of the low pressure zone as liquid reflux. The low pressure zone completes the fractionation, producing substantially pure liquid oxygen collecting in the pool 55 in the base of the low pressure zone, and gaseous nitrogen which rises to the top of the zone 42 and leaves through a conduit 64. The conduit 64 leads to the heat interchanger 51 in which the cold gaseous nitrogen passes in heat exchange relation with the incoming air stream before leaving the apparatus at substantially atmospheric temperature and pressure.

As mentioned before, one of the objects of the invention is to provide a novel method of and means for transferring the liquid oxygen product collected in the pool 55 to a receiver in gaseous phase under relatively high pressure. The foregoing is accomplished by a liquid vaporizer pump operating in conjunction with the fractionating operation. As shown, the liquid vaporizer pump includes a transfer vessel 65 which may be constructed in a manner similar to the vessel 12 of the Fig. 1 arrangement. Also, the transfer vessel is mounted at an elevation sufficiently below the liquid level of the pool 55 to allow the liquid oxygen to flow, under the influence of gravity into and fill the transfer vessel when the required

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relative pressure conditions are present. The liquid oxygen is transferred to the vessel 65 through a conduit 66 provided with a check valve 67 opening inwardly toward the vessel 65. A vapor connection is provided by a conduit 68 leading from the top of the transfer vessel 65, through a check valve 69, to within the low pressure zone of the column above the level of the pool 55 of liquid oxygen product. The check valve 69 opens inwardly toward the transfer vessel, and may be of the gravity actuated type normally occupying an open position. A condensing coil 70 is positioned within the transfer vessel. One end of the condensing coil is fed from the conduit 66, upstream of the check valve 67, while its other end is connected to the conduit 68 between the check valve and the column.

The vaporizer portion includes a reservoir 71 mounted at an elevation lower than the transfer vessel to allow liquid flow to the reservoir under the influence of gravity. A conduit 72, including a check valve 73 opening toward the reservoir, forms a high pressure liquid connection between the transfer vessel and the reservoir, while a high pressure vapor connection is formed by a conduit 74 controlled by a valve 75. Fluid is discharged from the reservoir 71 through a conduit 76 and is conducted through a heat interchanger 48 in which it passes in heat exchange relation with a portion of the incoming air stream. From the heat exchanger 48 the warmed fluid passes through a conduit 77 into a section of conduit 78 positioned in the reservoir for heat exchange relation with the fluid remaining in the reservoir. Fluid emerging from the conduit 78 is conducted to the heat interchanger 49 by way of a conduit 79, in which it passes in heat exchange relation with another portion of the incoming air stream. The fluid leaves the heat interchanger 49 by way of conduit 80 feeding a high pressure receiver 81 which may comprise a bank of conventional high pressure gas storage cylinders. As in the previous embodiment, the rate of vaporization is governed by a bypass conduit 82 having a control valve 83 which determines the proportion of fluid passed in heat exchange relation with the fluid remaining in the reservoir.

In this form of the invention, the means for controlling the flow of liquid from the transfer vessel 70 to the reservoir 71 operates in response to the temperature within the reservoir. As shown, this means includes a temperature responsive device 84 operating in accordance with predetermined temperature conditions within the reservoir for controlling a valve operator 85 coupled to the valve 75. The device 84 may comprise a pair of temperature responsive devices, such as a pair of thermocouples, one designed to produce an output signal of one characteristic at a high predetermined temperature, with the other calibrated to produce an oppositely or differently characterized signal in response to a predetermined low temperature. The signals may comprise electrical energy signals of opposite polarity. The temperature responsive devices may be positioned within the reservoir, or the reservoir temperature may be conducted to the temperature responsive devices mounted without the reservoir through a suitable transmitting device such as a conduit 86. The valve operator 85 may comprise a solenoid or motor arrangement for opening and closing the valve 75 in response to the differently characterized control signals. With this arrangement, when the liquid within the reservoir is substantially completely vaporized the reservoir temperature will approach its highest value. As this temperature is reached, the device 84 will produce a control signal of the proper character to cause the valve operator 85 to move the valve 75 to its open position. The lowest temperature exists when the reservoir is filled with liquid, and the device 84 produces the second control signal in response to this temperature to effect closure of the valve 75.

After the fractionating process has continued for a sufficient period to produce a substantial pool 55 of liquid

oxygen at the desired purity the pumping and vaporizing operation may be initiated. It may be desirable, especially for use when starting column operations, to provide a valve 87 in the conduit 66. The valve may be closed until the desired conditions for removing the liquid product are attained. When the valve 87 is initially opened, liquid oxygen will flow, under the influence of gravity, into the transfer vessel 65 through the conduit 66 and from the transfer vessel to the reservoir 71 by way of the conduit 72. It may be necessary when starting up to manually move the valve 75 to its open position to allow free flow of liquid to the reservoir. Of course when the reservoir is filled with liquid oxygen the temperature responsive device effects closure of the valve 75. Thereafter the liquid oxygen flows into and fills the transfer vessel.

The liquid oxygen in the reservoir is vaporized in a manner similar to the operation of the Fig. 1 arrangement discussed above with the exception that the oxygen is passed in heat interchange with the incoming air feed so that the cold removed from the oxygen during the vaporization process is returned to the fractionating column. When the oxygen in the reservoir is substantially completely vaporized high pressure and temperature conditions exist within the reservoir. The device 84 responds to the high temperature condition effecting the opening of valve 75 through the valve operator 85. The resulting pressure equalization allows the liquid in the transfer vessel to flow into and fill the vaporizer reservoir under the influence of gravity. The volume of liquid oxygen from the transfer vessel is sufficient to fill the reservoir and effect closure of the valve 75.

When vaporization of the transferred liquid oxygen begins, the valve 73 will close, and oxygen vapor at a pressure substantially less than the high pressure in the receiver but greater than the pressure of the low pressure zone 42 will be trapped in the transfer vessel. As in the arrangement of Fig. 1, the oxygen vapor will be trapped at an intermediate pressure due to momentary flow of oxygen vapor to the transfer vessel following opening of the valve 75, reverse vapor flow to the reservoir and condensation of vapor in the transfer vessel by the liquid flowing from the transfer vessel to the reservoir. Thus only a comparatively slight pressure reduction is required to establish the conditions necessary for the flow of liquid oxygen product to the transfer vessel. Consequently only a small quantity of heat is absorbed by the liquid oxygen in the coil 70 while condensing the oxygen vapor and column operation is not materially affected. Also, as in the previous arrangement, the system is designed so that the transfer vessel may be refilled during a period of time which is short as compared to the interval during which vaporization of the liquid oxygen takes place.

There is thus provided by the present invention a novel method of and apparatus for transferring a volatile liquid material from a storage vessel where it is held at low pressure to a receiving means in gaseous phase at a relatively high pressure. One of the features of the invention resides in the means of accomplishing these phase and pressure changes with a pressure equalizing system and a vaporizing device while preventing material heat transfer to the volatile liquid in the storage vessel. The features of the present invention are readily adaptable for use in connection with fractionating processes for transferring the liquid product without materially varying the column operating temperature and without affecting the fractionating efficiency.

Although only two embodiments of the invention have been disclosed and described herein it is to be expressly understood that various changes may be made therein without departing from the spirit of the invention as well understood by those skilled in the art. For example, the invention may be employed in connection with single stage fractionation operations and with systems for fractionating of gaseous mixtures in addition to air, such as

natural gas. 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 volatile liquid from a storage vessel held at a low pressure to a reservoir of a vaporizer under a relatively high pressure comprising withdrawing a first quantity of liquid from the storage vessel at the low pressure under the influence of gravity, increasing the pressure of the withdrawn first quantity of liquid to equal the relatively high pressure and conducting the first quantity of liquid material at the relatively high pressure to the reservoir under the influence of gravity, vaporizing liquid material in the reservoir, withdrawing a second quantity of liquid material from the storage vessel at the low pressure under the influence of gravity before vaporization of a predetermined portion of the first quantity of liquid material, and increasing the pressure of the second quantity of liquid to equal the relatively high pressure and conducting the second quantity of liquid material at the relatively high pressure to the reservoir under the influence of gravity at a time determined by vaporization of the predetermined portion of the first quantity of liquid material.
2. The method of transferring volatile liquid from a storage vessel held at a low pressure to a reservoir of a vaporizer under a relatively high pressure comprising withdrawing a first quantity of liquid from the storage vessel at the low pressure under the influence of gravity, increasing the pressure of the first quantity of liquid to the relatively high pressure and conducting the first quantity of liquid at the relatively high pressure to the reservoir under the influence of gravity, vaporizing liquid in the reservoir, withdrawing a second quantity of liquid from the storage vessel at the low pressure under the influence of gravity before vaporization of a predetermined portion of the liquid in the reservoir, controlling the rate of vaporization of liquid in the reservoir, and increasing the pressure of the second quantity of liquid to equal the relatively high pressure and conducting the second quantity of liquid at the relatively high pressure to the reservoir under the influence of gravity at a time determined by vaporization of the predetermined portion of the liquid in the reservoir.
3. The method of transferring volatile liquid from a storage vessel held at a low pressure to a reservoir of a vaporizer under a relatively high pressure comprising withdrawing a first quantity of liquid at the low pressure from the storage vessel under the influence of gravity, isolating the first quantity of liquid from the storage vessel and increasing its pressure to correspond to the relatively high pressure and thereafter conducting the first quantity of liquid at the relatively high pressure to the reservoir under the influence of gravity, vaporizing liquid in the reservoir, removing a second quantity of liquid at the low pressure from the storage vessel under the influence of gravity before vaporization of a predetermined portion of the liquid in the vaporizer, and isolating the second quantity of liquid and increasing its pressure to correspond to the relatively high pressure and thereafter conducting the second quantity of liquid to the reservoir under the influence of gravity responsively to vaporization of the predetermined portion of the liquid in the reservoir.
4. The method of transferring liquid from a storage vessel held at a low pressure to a reservoir of a vaporizer under a relatively high pressure comprising withdrawing a first quantity of liquid at the low pressure from the storage vessel under the influence of gravity, increasing the pressure of the withdrawn first quantity of liquid to equal the relatively high pressure and conducting the first quantity of liquid at the relatively high pressure to the reservoir under the influence of gravity, withdrawing a second quantity of liquid at the low pressure from the storage vessel under the influence of gravity, vapor-

izing liquid in the reservoir, and increasing the pressure of the second quantity of liquid to equal the relatively high pressure and conducting the second quantity of liquid at the relatively high pressure to the reservoir under the influence of gravity responsively to a predetermined temperature within the reservoir.

5. The method of transferring volatile liquid from a storage vessel held at a low pressure to a reservoir of a vaporizer under a relatively high pressure comprising withdrawing a first quantity of liquid at the low pressure from the storage vessel under the influence of gravity, isolating the first quantity of liquid from the storage vessel and increasing its pressure to correspond to the relatively high pressure and thereafter conducting the first quantity of liquid at the relatively high pressure to the reservoir under the influence of gravity, removing a second quantity of liquid at the low pressure from the storage vessel under the influence of gravity, vaporizing liquid in the reservoir, and isolating the second quantity of liquid and increasing its pressure to correspond to the relatively high pressure and thereafter conducting the second quantity of liquid to the reservoir under the influence of gravity responsively to a predetermined temperature within the reservoir.

6. The method of transferring in liquid phase volatile liquid material from a storage vessel where it is held at a low pressure to a reservoir of a vaporizer under a relatively high pressure through an intermediate transfer vessel, comprising conducting a first quantity of liquid material at the low pressure from the supply vessel to the transfer vessel under the influence of gravity, establishing a pressure in the transfer vessel corresponding to the relatively high pressure in the reservoir, isolating the transfer vessel from the storage vessel in response to the relatively high pressure and conducting liquid material from the transfer vessel to the reservoir under the influence of gravity, vaporizing liquid material in the reservoir, conducting a second quantity of liquid material from the supply vessel following conduction of liquid material from the transfer vessel to the reservoir, to the transfer vessel and establishing a pressure in the transfer vessel corresponding to the relatively high pressure in the reservoir in accordance with vaporization of a predetermined portion of liquid material in the reservoir.

7. The method of transferring volatile liquid material from a storage vessel where it is held at a low pressure to a reservoir of a vaporizer under a relatively high pressure through an intermediate transfer vessel, the vaporizer being operable to deliver the material in gaseous phase at the relatively high pressure, which method comprises conducting a quantity of liquid material at the low pressure from the supply vessel to the transfer vessel under the influence of gravity, introducing high pressure vapor from the vaporizer to the transfer vessel, conducting liquid material at the relatively high pressure from the transfer vessel to the reservoir under the influence of gravity, vaporizing liquid material in the reservoir, reducing the pressure within the transfer vessel to the low pressure, conducting another quantity of liquid material from the supply vessel to the transfer vessel before vaporization of a predetermined portion of liquid material in the reservoir, and introducing the high pressure vapor to the transfer vessel at a time determined by vaporization of the predetermined portion of liquid material in the reservoir.

8. The method of transferring volatile liquid material from a storage vessel where it is held at a low pressure to a reservoir of a vaporizer under a relatively high pressure through an intermediate transfer vessel, the vaporizer being operable to deliver the material in gaseous phase at the relatively high pressure, which method comprises conducting a quantity of liquid material at the low pressure from the supply vessel to the transfer vessel under the influence of gravity, introducing high pressure vapor from the reservoir to the transfer vessel, conducting liquid

material at the relatively high pressure from the transfer vessel to the reservoir under the influence of gravity, liquefying high pressure vapor in the reservoir by liquid conducted thereto to terminate introduction of high pressure vapor to the transfer vessel, vaporizing liquid material in the reservoir, reducing the pressure within the transfer vessel to the low pressure, conducting another quantity of liquid material from the supply vessel to the transfer vessel before vaporization of a predetermined portion of liquid material in the vaporizer, and introducing high pressure vapor to the transfer vessel at a time determined by vaporization of the predetermined portion of liquid material in the reservoir.

9. The method of transferring volatile liquid material from a storage vessel where it is held at a low pressure to a reservoir of a vaporizer under a relatively high pressure through an intermediate transfer vessel, the vaporizer being operable to deliver the material in gaseous phase at the relatively high pressure, which method comprises conducting a quantity of liquid material at the low pressure from the supply vessel to the transfer vessel under the influence of gravity, introducing high pressure vapor from the reservoir to the transfer vessel, isolating the transfer vessel from the supply vessel and conducting liquid material at the relatively high pressure from the transfer vessel to the reservoir under the influence of gravity in response to introduction of high pressure vapor to the transfer vessel, reducing the pressure within the transfer vessel to the low pressure, conducting another quantity of liquid material from the supply vessel to the transfer vessel, vaporizing liquid material in the reservoir, and introducing high pressure vapor to the transfer vessel at a time determined by the temperature within the reservoir.

10. The method of transferring liquid product of a fractionating operation to a vaporizing process, in which operation a mixture of compressed and cooled gases is fractionated to produce a gaseous lower boiling point fraction and a liquid higher boiling point fraction as liquid product and in which process liquid product is converted to gaseous phase under a relatively high pressure by heat interchange with a warmer fluid, which method comprises withdrawing a first portion of liquid product from the fractionating operation under the influence of gravity, conducting the first portion of liquid product at the relatively high pressure to the vaporizing process under the influence of gravity, withdrawing a second portion of liquid product from the fractionating operation under the influence of gravity before vaporization of a predetermined quantity of the first portion, and conducting the second portion of liquid product at the relatively high pressure to the vaporizing process in accordance with vaporization of the predetermined quantity of the first portion.

11. The method of transferring liquid product of a fractionating operation to a vaporizing process through a transfer vessel, in which operation a mixture of compressed and cooled gases is fractionated to produce a gaseous lower boiling point fraction and a liquid higher boiling point fraction as liquid product, and in which process liquid product is converted to gaseous phase at a relatively high pressure by heat interchange with a warmer fluid, which method comprises withdrawing a first portion of liquid product from the fractionating operation and conducting the portion to the transfer vessel under the influence of gravity, introducing vapor at the relatively high pressure into the transfer vessel upon the material in the vaporizing process attaining a predetermined temperature and conducting liquid product at the relatively high pressure in the transfer vessel to the vaporizer process under the influence of gravity to reduce the temperature of the material in the vaporizing process, and conducting a second portion of liquid product from the fractionating operation to the transfer vessel under the influence of gravity be-

fore the liquid material in the vaporizer process again attains the predetermined temperature.

12. The method of transferring liquid product of a fractionating operation to a vaporizing process through a transfer vessel, in which operation a mixture of compressed and cooled gases is fractionated to produce a gaseous lower boiling point fraction and liquid higher boiling point fraction as liquid product, and in which process liquid product is converted to gaseous phase under a relatively high pressure by heat interchange with a warmer fluid, which method comprises withdrawing a first portion of liquid product from the fractionating operation and conducting the first portion to the transfer vessel under the influence of gravity, introducing vapor at the relatively high pressure to the transfer vessel, conducting liquid product at the relatively high pressure in the transfer vessel to the vaporizing process under the influence of gravity, condensing high pressure vapor remaining in the transfer vessel after the liquid material is conducted to the vaporizing process to reduce the pressure in the transfer vessel to at least equal the pressure of liquid product in the fractionating operation, withdrawing a second portion of liquid product from the fractionating operation and conducting the second portion to the transfer vessel under the influence of gravity before vaporization of a predetermined quantity of the first portion, and subjecting the second portion of liquid product in the transfer vessel to vapor at the relatively high pressure in accordance with vaporization of the predetermined quantity of the first portion.

13. The method of transferring liquid product of a fractionating operation to a vaporizing process through a transfer vessel, in which operation a mixture of compressed and cooled gases is fractionated to produce a gaseous lower boiling point fraction and liquid higher boiling point fraction as liquid product and in which process liquid product is converted to gaseous phase at the relatively high pressure by heat interchange with a warmer fluid, which method comprises withdrawing a first portion of liquid product from the fractionating operation and conducting the first portion to the transfer vessel under the influence of gravity, introducing vapor at the relatively high pressure from the vaporizing process to the transfer vessel upon a predetermined temperature being attained in the vaporizing process and conducting liquid product at the relatively high pressure in the transfer vessel to the vaporizing process under the influence of gravity to reduce the temperature in the vaporizing process, isolating the vaporizing process, condensing vapor at the relatively high pressure remaining in the transfer vessel to reduce the pressure in the transfer vessel to at least equal to the pressure of liquid product in the fractionating operation, withdrawing a second portion of liquid product from the fractionating operation and conducting the second portion to the transfer vessel under the influence of gravity before the predetermined temperature is again attained in the vaporizing process.

14. The method of transferring liquid product of a fractionating operation to a vaporizing process through a transfer vessel, in which operation a mixture of compressed and cooled gases is fractionated to produce a gaseous lower boiling point fraction and liquid higher boiling point fraction as liquid product and in which process liquid product is converted to gaseous phase at relatively high pressure by heat interchange with a warmer fluid, which method comprises withdrawing a first portion of liquid product from the fractionating operation and conducting the first portion to the transfer vessel under the influence of gravity, introducing relatively high pressure gaseous material from the vaporizing process to the transfer vessel, conducting liquid product in the transfer vessel at the relatively high pressure to the vaporizing process under the influence of gravity, terminating introduction of high pressure gaseous ma-

terial to the transfer vessel responsively to introduction of liquid product to the vaporizing process, passing a cold fluid from the fractionating operation in heat interchange with the transfer vessel to condense high pressure gaseous material remaining in the transfer vessel after liquid material is conducted to the vaporizing process to reduce the pressure in the transfer vessel to at least equal the pressure of liquid product in the fractionating operation, withdrawing a second portion of liquid product from the fractionating operation and conducting the second portion to the transfer vessel under the influence of gravity before vaporization of a predetermined quantity of the first portion of liquid product, and introducing high pressure gaseous material from the vaporizing process to the transfer vessel in accordance with vaporization of the predetermined quantity of the first portion of liquid product.

15. Apparatus for transferring volatile liquid from a storage vessel where it is held at a low pressure to a receiving means in gaseous phase under a relatively high pressure comprising a transfer vessel, vaporizing means connected to the receiving means, means for conducting volatile liquid at low pressure from the storage vessel to the transfer vessel under the influence of gravity, and means for conducting liquid at the relatively high pressure from the transfer vessel to the vaporizing means under the influence of gravity, the last named means including pressure equalizing means for increasing the pressure of liquid in the transfer vessel to correspond to the relatively high pressure and means for controlling the pressure equalizing means responsively to vaporization of a predetermined quantity of liquid in the vaporizing means.

16. Apparatus for transferring volatile liquid from a storage vessel where it is held at a low pressure to a receiving means in gaseous phase under a relatively high pressure comprising a transfer vessel, vaporizing means connected to the receiving means, means for conducting volatile liquid at low pressure from the storage vessel to the transfer vessel under the influence of gravity, and means for conducting liquid at the relatively high pressure from the transfer vessel to the vaporizing means under the influence of gravity, the last-named means including a pressure equalizing conduit connected between the transfer vessel and the vaporizing means, valvular means controlling the equalizing conduit and means operative responsively to the temperature within the vaporizing means for controlling the valvular means.

17. Apparatus for transferring volatile liquid from a storage vessel where it is held at a low pressure to a receiving means in gaseous phase under a relatively high pressure, comprising a transfer vessel, means for conducting volatile liquid from the storage vessel to the transfer vessel under the influence of gravity, vaporizing means feeding the receiving means, a reservoir for the vaporizing means, and means for conducting liquid in the transfer vessel to the reservoir at the relatively high pressure under the influence of gravity, the last-named means including pressure equalizing means for increasing the pressure of liquid in the transfer vessel to correspond to the relatively high pressure in the receiving means and means controlling the pressure equalizing means responsively to the level of the liquid in the reservoir.

18. Apparatus for transferring volatile liquid from a storage vessel where it is held at a low pressure to a receiving means in gaseous phase under a relatively high pressure comprising a transfer vessel, means for conducting volatile liquid from the storage vessel to the transfer vessel under the influence of gravity, vaporizing means feeding the receiving means, a reservoir for the vaporizing means, and means for conducting liquid in the transfer vessel to the reservoir at the relatively high pressure under the influence of gravity, the last-named means including a liquid transfer conduit connected between the transfer vessel and the reservoir, a pressure equalizing

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conduit connected between the transfer vessel and the reservoir, valvular means for controlling the pressure equalizing conduit, and means operative responsively to the liquid level in the reservoir for controlling the valvular means.

19. Apparatus for transferring volatile liquid from a storage vessel where it is held at a low pressure to a receiving means in gaseous phase under a relatively high pressure, comprising a transfer vessel, means for conducting volatile liquid at the low pressure to the transfer vessel under the influence of gravity, vaporizing means feeding the receiving means, the vaporizing means including a reservoir, a liquid transfer conduit connected between the transfer vessel and the reservoir, a pressure equalization conduit connected between the reservoir and the transfer vessel for conducting high pressure vapor in the reservoir to the transfer vessel, valvular means for controlling the pressure equalization conduit, means responsive to the level of the liquid in the reservoir for controlling the valvular means, and means for passing a cold fluid in heat exchange with the transfer vessel to liquefy high pressure vapor remaining in the transfer vessel after liquid is transferred to the reservoir.

20. Apparatus for transferring in liquid phase volatile liquid product from a fractionating operation under a relatively high pressure to the reservoir of a vaporizer in which the liquid product forfeits cold and emerges in gaseous phase at the relatively high pressure and in which operation a gaseous mixture is fractionated to produce volatile liquid as a product, comprising a transfer vessel, means for conducting liquid product from the fractionating operation to the transfer vessel, a pressure equalizing conduit between the transfer vessel and the vaporizer for conducting high pressure vapor to the transfer vessel to increase the pressure of liquid product in the transfer vessel to correspond to the relatively high pressure, means for conducting liquid product in the transfer vessel at the relatively high pressure to the reservoir, means for 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 reservoir, valvular means for controlling the equalizing conduit, and means for controlling the valvular means responsively to vaporization of a predetermined portion of the liquid in the reservoir.

21. Apparatus for transferring in liquid phase volatile liquid product from a fractionating operation under a relatively high pressure to the reservoir of a vaporizer in which the liquid product forfeits cold and emerges in

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gaseous phase at the relatively high pressure and in which operation a gaseous mixture is fractionated to produce volatile liquid as a product, comprising a transfer vessel, means for conducting liquid product from the fractionating operation to the transfer vessel, a pressure equalizing conduit between the transfer vessel and the reservoir for conducting high pressure vapor to the transfer vessel to increase the pressure of liquid product in the transfer vessel to correspond to the relatively high pressure, means for conducting liquid product in the transfer vessel at the relatively high pressure to the reservoir, means for 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 reservoir, valvular means for the equalizing conduit, and means for controlling the valvular means responsively to the temperature in the reservoir.

22. The method of transferring liquid from a storage vessel held at a low pressure to a reservoir of a vaporizer under a relatively high pressure comprising withdrawing a first quantity of liquid at the low pressure from the storage vessel under the influence of gravity, increasing the pressure of the withdrawn first quantity of liquid to equal the relatively high pressure and conducting the first quantity of liquid at the relatively high pressure to the reservoir under the influence of gravity, vaporizing liquid in the reservoir, withdrawing a second quantity of liquid material at the low pressure from the storage vessel under the influence of gravity before vaporization of a predetermined portion of liquid in the reservoir, and increasing the pressure of the second quantity of liquid to equal the relatively high pressure and conducting the second quantity of liquid at the relatively high pressure to the reservoir under the influence of gravity responsively to a predetermined level of liquid in the reservoir.

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