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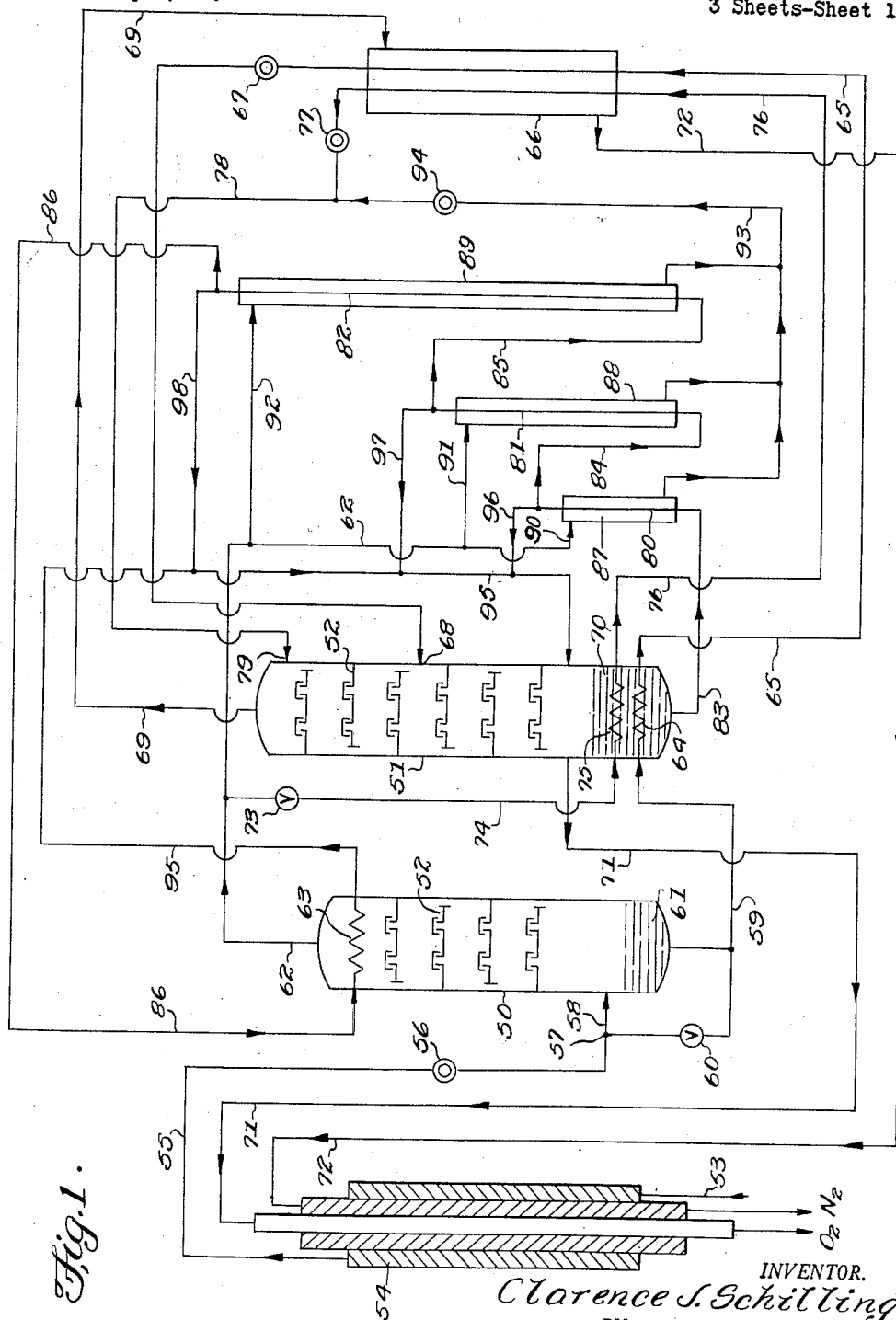
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METHOD AND APPARATUS FOR FRACTIONATING GASEOUS MIXTURES

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3 Sheets-Sheet 1



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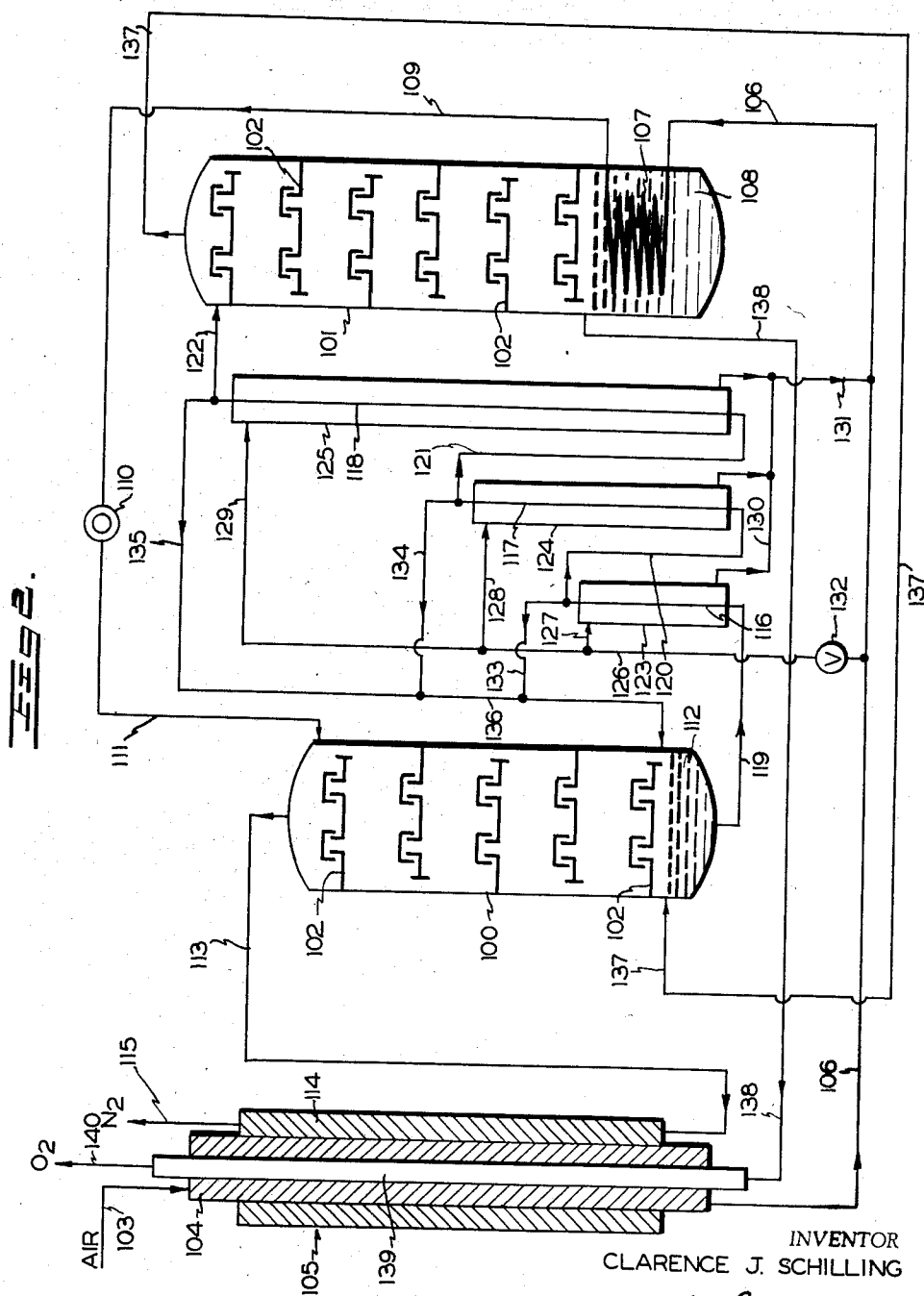
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METHOD AND APPARATUS FOR FRACTIONATING GASEOUS MIXTURES

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3 Sheets-Sheet 2



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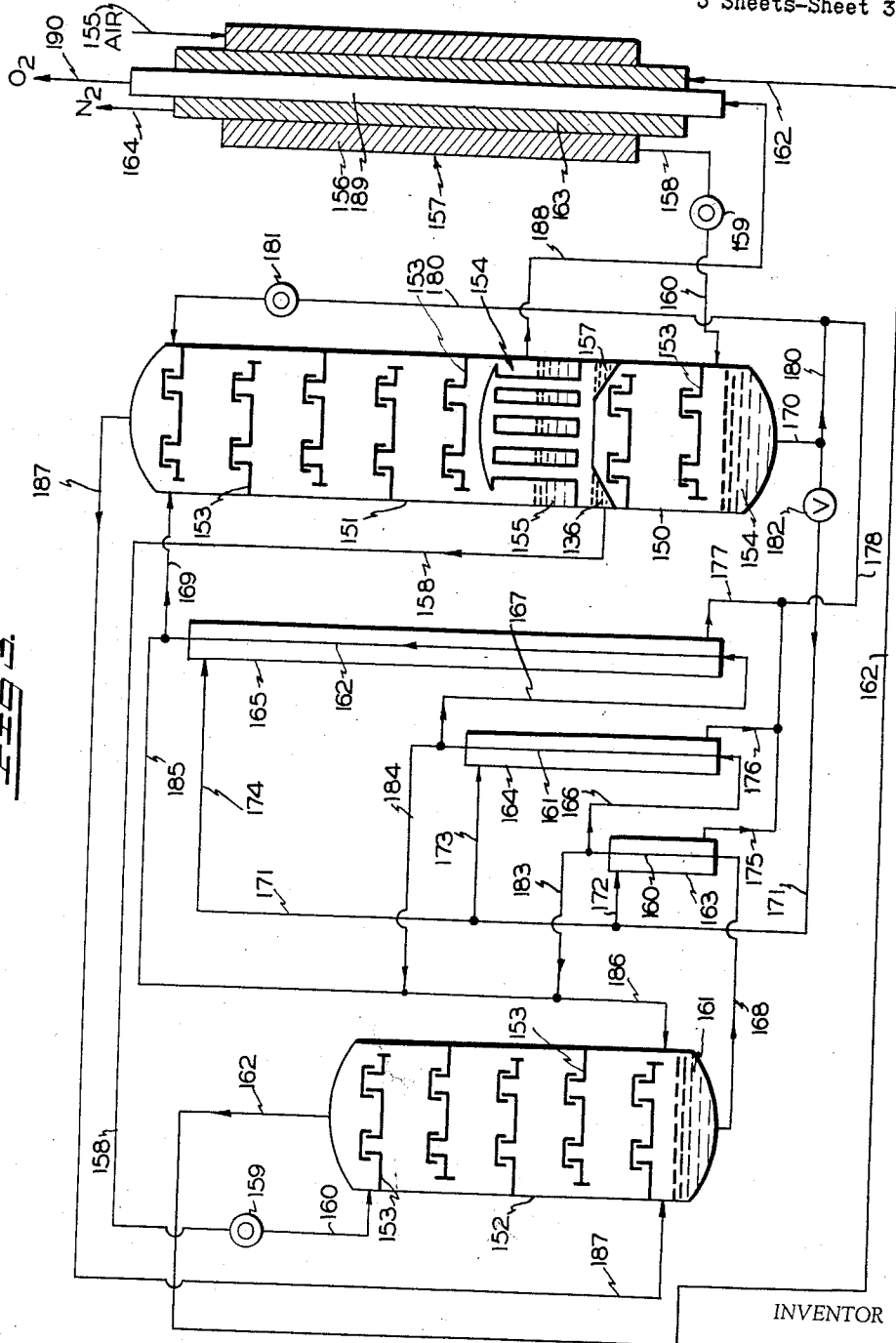
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METHOD AND APPARATUS FOR FRACTIONATING GASEOUS MIXTURES

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3 Sheets-Sheet 3

FIG. 3.



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METHOD AND APPARATUS FOR FRACTIONATING GASEOUS MIXTURES

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Application May 6, 1954, Serial No. 428,079

27 Claims. (Cl. 62—30)

This invention relates to the fractionation of gaseous mixtures and more particularly to methods of and apparatus for fractionating gaseous mixtures by which the overall height of the fractionating equipment is materially reduced and a more compact arrangement is provided without substantially affecting fractionating efficiency.

This application is a continuation-in-part of copending application Serial No. 262,235, filed December 18, 1951, now forfeited, for Fractionating Apparatus.

It is well known that the separation of many gaseous mixtures, such as the separation of oxygen and nitrogen from air, may be performed in a fractionating zone provided by a liquid-vapor contact column in which downwardly flowing liquid and upwardly flowing vapor pass in intimate countercurrent relation. The liquid-vapor contact columns are necessarily of substantial height to provide the liquid-vapor contact required for complete fractionating of gaseous mixtures, and the height of the liquid-vapor columns is relatively high as compared to the other components required for the fractionating operation, such as heat exchangers and gaseous mixture compressors, for example. Heretofore it has not been possible to decrease the height of liquid-vapor contact columns providing fractionating zones for the fractionation of gaseous mixtures, and hence the overall height of the equipment providing the fractionating cycle, without requiring additional components which increases the cost of the equipment and reduces its reliability or without lowering fractionating efficiency.

It is therefore an object of the present invention to provide a novel method of and apparatus for fractionating gaseous mixtures in which the overall height of the fractionating equipment is materially reduced without affecting fractionating efficiency.

Another object is to provide a novel method of and apparatus for fractionating gaseous mixtures in which the fractionation takes place in a zone formed by a plurality of liquid-vapor contact sections adapted to be mounted side by side at a common elevation and in which the sections are interconnected in such a manner as to provide the liquid-vapor contact for effecting the fractionation of the gaseous mixture.

Another object is to provide a novel method of and apparatus for fractionating gaseous mixtures in which the fractionation takes place in a zone formed by a plurality of liquid-vapor contact sections forming sub-fractionating zones interconnected in such a manner so that the liquid-vapor contact sections operate as a unitary fractionating zone.

Another object is to provide a novel method of and apparatus for fractionating gaseous mixtures in which the fractionation takes place in a zone formed by a plurality of liquid-vapor contact sections in which liquid material rich in one component of the gaseous mixture is introduced into one liquid-vapor contact section as wash liquid and liquid material collecting in the base of the one liquid-vapor contact section is lifted to the top elevation of another liquid-vapor contact section and utilized to

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provide wash liquid for the another liquid-vapor contact section.

Another object is to provide a gaseous mixture separation cycle in which liquid at its boiling point is lifted to a higher elevation by the mere addition of heat derived from the separation cycle.

Still another object of the present invention is to provide a single-stage fractionating operation in which the fractionating zone is separated into two liquid-vapor contact sections adapted to be mounted at a common elevation and in which the liquid at its boiling point collecting in the base of one section is lifted to the elevation of the top of the other section for introduction therein by the mere addition of heat to the boiling liquid.

Still another object is to provide a single-stage fractionating operation of the above character in which the heat required for lifting the boiling liquid is derived from the fractionating operation without substantially affecting the fractionating efficiency.

A still further object of the present invention is to provide a novel method of and apparatus for fractionating gaseous mixtures in a two-stage cycle of the type including high and low-pressure fractionating zones.

A still further object is to provide a two-stage fractionating cycle including high and low-pressure fractionating zones which may be mounted side by side at a common elevation connected in a novel manner so as to substantially duplicate the operating characteristics of conventional two-stage fractionating columns.

A still further object is to provide a novel method of and apparatus for fractionating gaseous mixtures which may be carried out in a single-stage or two-stage fractionating cycle in which the fractionating zone is formed in a plurality of sections adapted to be mounted side by side at a common elevation to reduce the overall height of the apparatus, and in which liquid flowing downwardly in one section collects in the base of that section at its boiling temperature and is lifted to the elevation of the top of another section by means of the mere addition of heat to the boiling liquid, which heat is derived from the fractionating cycle without substantially affecting fractionating efficiency.

Other objects and features of the present invention will appear more fully below from the following detailed description considered in connection with the accompanying drawings which disclose several embodiments of the invention. It is to be expressly understood, however, that the drawings are designed for purposes 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:

Fig. 1 is a diagrammatic view of a novel two-stage fractionating cycle incorporating the principles of the present invention;

Fig. 2 is a diagrammatic presentation of a single-stage fractionating cycle incorporating the principles of the present invention; and

Fig. 3 is a diagrammatic view of another form of two-stage fractionating cycle constructed in accordance with the principles of the present invention.

A two-stage air fractionating cycle embodying the principles of the present invention is disclosed in Fig. 1 of the drawings including a high-pressure column 50 and a low-pressure column 51, each having a plurality of bubble plates 52. The columns 50 and 51 may be mounted side-by-side on a common base to reduce the overall height of the apparatus. The columns 50 and 51 comprise fractionating zones and combine to provide the total fractionating zone of the operation, and in one sense may be considered as sub-fractionating zones. A stream of compressed and cooled air, substantially free from

water and carbon dioxide, enters the system by a conduit 53 and is conducted through one passage of a primary interchanger 54 in which it is cooled by heat interchange with fractionation products. The cooled air then passes through a conduit 55 to an expansion valve 56 by which its pressure and temperature are further reduced. The expanded air stream then passes to a point of division 57, and a major portion of the stream flows through a conduit 58 into the base of the high pressure column 50. The remaining portion of the air stream passes through a conduit 59 to the low pressure column 51 through various steps of heat interchange described hereafter. A valve 60 is included in the conduit 59 to control the percentage of the air stream flowing therethrough.

In the high-pressure column, the portion of the total air feed introduced by the conduit 58 is separated by fractionation into an oxygen-rich liquid (crude oxygen) which collects in a pool 61 in the base of the column, and a vapor fraction consisting substantially of nitrogen which passes to the top of the column and is delivered therefrom by way of a conduit 62. A coil 63, through which a stream of liquid oxygen product from the low pressure column is continually circulated by means of an arrangement described hereinafter, is positioned in the top of the high-pressure column for condensing a portion of the nitrogen vapors to provide a liquid reflux for the column.

The oxygen-rich liquid collecting in the base of the high pressure column is mixed with the other portion of the air stream flowing in the conduit 59, and the mixture is carried through the conduit 59 to a coil 64 immersed in boiling liquid oxygen in the base of the low pressure column 51 wherein the mixture is further cooled. The liquefied air stream, rich in oxygen, is then conducted by a conduit 65 through a secondary interchanger 66 in the heat interchange with product gaseous nitrogen wherein its temperature is further reduced. It then passes through an expansion valve 67 from which it is fed in the liquid condition into the low pressure column at an intermediate point 68 thereof.

The low pressure column completes the fractionation of the air, delivering gaseous product nitrogen by way of a conduit 69 leading from the top of the column and collecting commercially pure oxygen (about 99.5%) in a pool 70 in the base of the column. The product oxygen may be removed in liquid form in any conventional manner, or in gaseous form by a conduit 71 connected to the column at a point above the level of the pool 70. The conduit 71 leads to a passage in the primary interchanger 54 through which it passes in heat interchange with the incoming air stream prior to storage and/or utilization. The gaseous product nitrogen is conducted by the conduit 69 to the secondary interchanger 66 and hence through a conduit 72 to another passage in the primary interchanger 54 wherein it forfeits cold to the incoming air and leaves the interchanger at substantially atmospheric temperature and pressure.

A portion of the gaseous nitrogen stream leaving the high-pressure column by way of the conduit 62, the percentage of which is determined by a valve 73, is passed by a conduit 74 through a coil 75 immersed in the boiling liquid oxygen pool 70 wherein the stream is liquefied. The liquefied nitrogen stream then passes through a conduit 76 to the secondary interchanger 66 in heat interchange with the gaseous product nitrogen wherein its temperature is further reduced. The sub-cooled liquid nitrogen stream is then fed to an expansion valve 77 where its pressure and temperature are still further reduced and from which it is fed, by way of a conduit 78, to the top portion of the low-pressure column at point 79 as a liquid reflux therefor.

According to the present invention a liquid lift pump is employed for transferring liquid oxygen product from the pool 70 to the elevation of the coil 63 for heat interchange with the gaseous nitrogen in the high pressure

column. The liquid lift pump disclosed and described herein follows the teachings of copending application Serial No. 386,635, filed September 22, 1953, for Liquid Transfer, which application is a division of the copending application Serial No. 262,235. As shown, the liquid lift pump comprises a plurality of uplift conduits 80, 81 and 82, preferably having their lower ends at a substantially common elevation below the base of the low pressure column and their upper ends terminated at successively higher elevations. Liquid oxygen in the pool 70 is conducted to the uplift column 80 through a conduit 83, so that the liquid oxygen pool comprises the submergence head for the first stage of the pump. Submergence conduits 84 and 85 are connected between the output of the uplift column 80 and the input of the uplift column 81, and between the output of the latter uplift column and the input of the uplift column 82, respectively, to provide submergence heads for the remaining stages. The outlet of the uplift column 82 of the last stage is at an elevation above the coil 63, and a conduit 86 conducts liquid oxygen from the pump output to the coil 63. Heat interchangers 87, 88 and 89, respectively associated with the uplift conduits 80, 81 and 82 are fed with high pressure gaseous nitrogen through conduits 90, 91 and 92 supplied from the conduit 62. The high-pressure nitrogen forfeits heat while partially vaporizing the liquid oxygen product in the uplift conduits and the cooler nitrogen streams emerging from the heat interchangers are combined in a single conduit 93, passed through an expansion valve 94, and introduced into the stream in the conduit 78. The percentage of the high pressure nitrogen stream conducted through the lift pump heat interchangers is selected to produce the necessary oxygen product vaporization for effecting the required lift. The valve 73 is provided for this adjustment. The oxygen product leaving the coil 63, which may be largely vaporized, is returned by a conduit 95 to the lower section of the low-pressure column at a point above the liquid oxygen pool 70. Oxygen vapor emerging from the top of the uplift conduits is returned to the vapor space within the low-pressure column by means of conduits 96, 97 and 98 connected between the conduit 95 and the upper ends of the uplift conduits 80, 81 and 82, respectively.

The foregoing apparatus operates in a manner similar to conventional two-stage fractionating devices wherein the gaseous mixture, such as air, is fractionated in the high pressure column to produce a vapor fraction and a liquid fraction, and wherein the process is completed in the low pressure column to produce a gaseous product such as nitrogen and a liquid product such as oxygen. In particular, the liquid fraction in the high-pressure column is conducted to the low pressure column as feed and the vapor fraction is liquefied by heat interchange with the liquid oxygen product and employed as reflux for the high and low pressure columns. Thus, the fractionating apparatus disclosed in Fig. 1 operates in a manner similar to conventional two stage columns even though the high and low-pressure columns are structurally independent and not interconnected, one on top of the other, by the usually downwardly draining reflux condenser which maintains the high-pressure vapor fraction in heat interchange with the low-pressure liquid product. The function of the downwardly draining condenser is accomplished in the present arrangement by passing a portion of the high-pressure vapor fraction in heat interchange with the liquid oxygen product through a coil 75 immersed in the pool 70 of liquid oxygen product and through the heat interchangers of the liquid lift pump. In order to liquefy a portion of the gaseous fraction within the high-pressure column for reflux, a liquid lift pump, supplied with heat energy from the high-pressure vapor fraction and operating in a manner fully described in the copending application Serial No. 386,635, transfers a stream of the liquid oxygen product through a coil 63

mounted in the top of the high-pressure column. The liquid oxygen product is elevated to the top of the high-pressure column without substantial energy loss, since in operation of the lift pump a portion of the liquid oxygen product is vaporized by heat exchange with the high-pressure fraction, a phenomena which occurs during normal operation of conventional two-stage fractionating cycles.

Another embodiment of the invention is shown in Fig. 2 of the drawings. In this embodiment the principles of the present invention are incorporated in a single-stage fractionating cycle. As shown, the single-stage cycle includes a fractionating zone made up of liquid-vapor contact or column sections 100 and 101, each including vertically spaced bubble plates 102 of conventional construction. The column sections 100 and 101 each comprise a fractionating zone and combine to provide the total fractionating zone of the apparatus and therefore may also be referred to as sub-fractionating zones. The column sections 100 and 101 are structurally independent and may be mounted at a common elevation to materially reduce the overall height of the apparatus. As will appear more fully from the following description, the column sections are equivalent, with respect to fractionating characteristics, to a conventional single-stage fractionating cycle of similar capacity in which the fractionating zone comprises a continuous liquid-vapor contact section.

A stream of cooled and compressed gaseous mixture such as air, substantially free from water and carbon dioxide, enters the cycle by a conduit 103 and is conducted through passageway 104 of heat interchanger 105 in which the air stream is cooled by heat exchange with fractionation products. The cooled air then passes through a conduit 106 to a boiling coil 107 immersed in a pool of liquid oxygen product 108 collected in the base of the column section 101. The air stream is liquefied and cooled to a lower temperature upon passing through the coil 107 in heat exchange relation with the liquid oxygen, and from the coil 107 the liquefied air stream is conducted through a conduit 109 to an expansion valve 110 by which its temperature is further reduced. From the expansion valve the cooled liquefied air stream is introduced, by way of a conduit 111, into the upper end of the column section 100. The liquid air flows downwardly in the column section 100, over the bubble plates 102, in intimate contact with upwardly flowing vapor and collects in a pool 112 of oxygen-rich liquid air, or partially fractionated liquid air. The column section 100 corresponds to an upper portion of a column section in a conventional single-stage fractionating cycle, and the upwardly flowing vapor collecting in the dome of the section 100 comprises a nitrogen product of the fractionating cycle. A stream of gaseous nitrogen product is withdrawn from the section 100 through a conduit 113 and is conducted through a passageway 114 of the heat exchanger 105 where it gives up cold to the incoming air stream and emerges from the cycle by way of a conduit 115 at substantially atmospheric temperature.

A liquid lift pump of the character disclosed in the copending application Serial No. 386,638 is employed for elevating the partially fractionated liquid collecting in the pool 112 of the section 100 to the elevation of the top of the column section 101. The liquid lift pump comprises a plurality of uplift conduits 116, 117 and 118 having their lower ends at a substantially common elevation below the base of the column section 100 and their upper ends terminated at successively higher elevations. A stream of liquid air rich in oxygen in the pool 112 is conducted to the uplift column 116 through a conduit 119 and the liquid in the pool 112 comprises a submergence head for the first stage of the pump. Submergence conduits 120 and 121 are connected between the output of the uplift column 116 and between the in-

put of the uplift column 117 and between the output of the latter uplift column and the input of the uplift column 118, respectively, to provide submergence heads for the remaining stages of the pump. The outlet of the uplift column 118 of the last stage is at an elevation of the top portion of the column section 101, and a conduit 122 conducts the elevated stream of liquid air rich in oxygen to the column section 101 above the uppermost bubble plate. Heat interchangers 123, 124 and 125, respectively associated with the uplift conduits 116, 117 and 118, are fed with a source of vaporizing fluid which passes through the heat interchangers in heat interchange relation with the stream of liquid in respective uplift conduits to partially vaporize the streams of liquid air enriched in oxygen. A source of vaporizing fluid may comprise a stream of air feed mixture. For this purpose a branch conduit 126 is connected to the conduit 106 for withdrawing a side stream of air feed mixture from the main stream of air feed mixture flowing from the heat interchanger 105 to the boiling coil 107. Branch conduits 127, 128 and 129 lead from the conduit 126 to the heat interchangers 123, 124 and 125, respectively. The effluent air feed mixture from the heat interchangers is merged together in a conduit 130 and returned through a conduit 131 to the conduit 106 at a point downstream of the connection of the conduit 126 thereto. The liquid air rich in oxygen in the pool 112 is at its boiling temperature and only a small quantity of heat is required to be added to the streams of liquid air rich in oxygen in the uplift conduits to effect the necessary aeration for operation of the lift pump. A valve 132 is positioned in the conduit 126 upstream of the branch conduit 127 for controlling the quantity of air feed mixture conducted to the heat interchangers and hence the quantity of heat added to the liquid air rich in oxygen in the uplift conduits. Vapor collecting conduits 133, 134 and 135 are connected to the upper ends of the uplift conduits 116, 117 and 118, respectively, at points thereof above the respective liquid outlets. The conduits 133, 134 and 135 collect vaporized liquid air enriched in oxygen produced upon operation of the pump, and are connected to a conduit 136 which returns this vapor to the column section 100 at a point therein above the level of the pool 112 and preferably below the lowermost bubble plate 102.

As mentioned above, the liquid air enriched in oxygen at the output of the lift pump is delivered by way of the conduit 122 into the upper end of the column section 101 above the uppermost bubble plate. This liquid then flows downwardly in the column section 101 in a conventional manner in countercurrent relation with upwardly flowing vapor to complete the fractionation of the gaseous mixture in a manner well understood by those skilled in the art, the source of upwardly flowing vapor comprising the pool 108 of boiling liquid oxygen product. The upwardly flowing vapor in the column section 101 leaves the section at its top through a conduit 137. The conduit 137 leads the withdrawn stream of vapor to the column section 100 and introduces the vapor stream therein at a point above the pool 112 but below the lowermost bubble plate 102. The vapor introduced by the conduits 137 and 136 comprise the source of upwardly flowing vapor for the column section 100.

Liquid oxygen product collecting in the pool 108 in the base of the column section 101 may be withdrawn from the cycle in liquid phase or in gaseous phase, according to conventional practice. For the latter purpose, a conduit 138 may be connected to the column section 101 at a point thereof above the liquid oxygen pool 108. The conduit 138 conducts the withdrawn stream of gaseous oxygen product to another passageway 139 of the heat exchanger 105 in which the stream of gaseous oxygen product gives up cold to the incoming gaseous

mixture and leaves the heat exchanger by a conduit 140 at substantially atmospheric temperature.

The embodiment of the invention shown in Fig. 2 of the drawings thus provides a single-stage fractionating cycle in which the fractionating zone comprises two liquid-vapor contact or column sections adapted to be mounted at a common elevation to reduce the overall height of the apparatus. The fractionating zones provided by each section are combined and constitute the fractionating zone of the apparatus which is equivalent to the fractionating zone of conventional single-stage fractionating cycles of similar capacity in which the fractionating zone comprises a single column section of a height equal to the combined height of the column sections 100 and 101. The provision of the liquid lift pump for elevating a stream of liquid air enriched in oxygen from a pool collecting in the base of the column section 100 to the elevation of the top of the column section 101, and the provision of the conduit 137 for transferring vapor from the top of the column section 101 to the base of the column section 100, allows the column sections to operate in a manner equivalent to their operation if they were stacked one on top of the other in a continuous column as in conventional construction. Since the stream of liquid air enriched in oxygen elevated by the liquid lift pump is at its boiling point, only a relatively small quantity of heat is required to be added thereto to effect operation of the liquid lift pump. The slight make-up refrigeration necessary may be provided by merely increasing the pressure of the incoming air mixture, for example.

In Fig. 3 of the drawings a two-stage fractionating cycle is disclosed in which the low-pressure section is split at the feed point to provide a fractionating zone of substantially reduced height as compared to conventional construction. The high-pressure fractionating zone is formed by a high-pressure column section 150 and the low pressure fractionating zone is formed by liquid-vapor contact on column sections 151 and 152. The high-pressure section and the low-pressure sections are each provided with bubble plates 153 which may be of conventional construction. The high-pressure section 150 and the low-pressure section 151 may be structurally joined together in a conventional manner and separated by a downwardly draining refluxing condenser 154, while the low pressure column sections 151 and 152 are structurally independent, with the section 152 adapted to be mounted at a common elevation with the high pressure section 150. The column sections 150, 151 and 152 each comprise a fractionating zone and the total fractionating zone of the fractionating operation is the combined fractionating zones of the column sections. Thus, with respect to the fractionating operation, the column sections may also be considered as sub-fractionating zones. Moreover, the column sections 151 and 152 provide the total low pressure fractionating zone of the fractionating operations, and with respect to the latter zone, may also be considered as sub-fractionating zones.

A stream of compressed and cooled gaseous mixture such as air substantially free from water and carbon dioxide enters the system by a conduit 155 and is conducted through a passage 156 of heat interchanger 157 where it is cooled by heat interchange with relatively cold products of the fractionating operation. The stream of cooled air from the heat interchanger then passes through a conduit 158 to an expansion valve 159 by which its pressure and temperature are further reduced. The expanded air stream then passes by way of conduit 160 into the base of the high-pressure section 150. The air feed mixture undergoes a preliminary fractionation in the high-pressure section 150, producing a crude oxygen liquid fraction collecting in a pool 154 in the base of the column section and a gaseous nitrogen fraction which flows upwardly and into the passageways of the refluxing condenser 154 and is liquefied by heat exchange

with liquid oxygen product collecting in a pool 155 in the base of the low-pressure column section 151 and surrounding the refluxing condenser. A portion of the liquefied nitrogen fraction falls downwardly in the high-pressure column section as liquid reflux therefor, while another portion collects in a pool 156 formed by a trough 157. A stream of liquid high-pressure nitrogen is withdrawn from the pool 156 by way of a conduit 158, and the withdrawn stream is passed through an expansion valve 159 whereby its pressure is reduced to the pressure existing in the low-pressure column sections 152 and 153 with an accompanying decrease in temperature and then the expanded stream is introduced into the low-pressure section 152 above the uppermost bubble plate 153 as reflux liquid for the latter section. The liquid nitrogen reflux flows downwardly in the column section 152 over the bubble plates in intimate countercurrent contact with upwardly flowing vapor and collects in a pool 161 at the base of the column section, the liquid in the pool 161 being predominantly liquid nitrogen but including some oxygen. The upwardly flowing vapor in the column section 152 collects at the top of the section as gaseous nitrogen product of the fractionating cycle and is withdrawn from the column section through a conduit 162. The conduit 162 conducts the withdrawn stream of nitrogen product to another passageway 163 of the heat interchanger 157, wherein the stream passes in heat exchange relation with the incoming air stream and emerges from the heat interchanger by way of a conduit 164 at substantially atmospheric temperature.

The liquid rich in nitrogen collecting in the pool 161 at the base of the column section 152 is lifted to the elevation of the top of the column section 151 and is introduced into the latter column as reflux liquid. The nitrogen-rich liquid is lifted or pumped in the foregoing manner by means of a heat-type liquid lift pump constructed in accordance with the teachings of the copending application Serial No. 386,635. The liquid lift pump includes a plurality of uplift conduits 160, 161 and 162, each provided with a heat interchanger 163, 164 and 165, respectively, and submergence conduits 166 and 167, respectively, connected between the output of the uplift conduit 160 and the input of the uplift conduit 161 and between the output of the latter uplift conduit and the input of the uplift conduit 162. The input of the uplift conduit 160 is supplied with a stream of liquid from the pool 161 through a conduit 168 and the output of the uplift conduit 162 of the last stage of the pump is conducted by way of a conduit 169 to within the section 151 above the uppermost bubble plate. The inputs of the uplift conduits may be located at a substantially common elevation, preferably below the base of the column section 152 so that the pool of liquid 161 comprises the submergence head for the first stage of the pump. Also, the output of the last stage of the pump is at an elevation above the elevation of the uppermost bubble plate of the section 151. The heat necessary for operation of the liquid lift pump may be derived from the liquid crude oxygen collecting in the pool 154 in the base of the high-pressure section 150. As shown, a stream of liquid crude oxygen is withdrawn from the pool 154 through a conduit 170, a conduit 171 is connected to the conduit 170 to conduct a substream of liquid crude oxygen to the heat interchangers 163, 164 and 165 of the liquid lift pump; branch conduits 172, 173 and 174 being connected to the conduit 171 and leading to respective heat interchangers. A valve 182 is included in the conduit 181 for controlling the quantity of heat added to the heat exchangers of the liquid lift pump. The effluent liquid crude oxygen streams leave the heat interchangers through conduits 175, 176 and 177, respectively, and these conduits are connected to a common conduit 178. The conduit 178 is joined to a conduit 180 leading from the conduit 170, which conducts the main stream of liquid crude oxygen from the

pool 154 to a point of the column section 151 above the uppermost bubble plate as liquid feed for this portion of the fractionating zone. An expansion valve 181 is included in the conduit 180 to reduce the pressure of the stream of crude oxygen to the pressure in the section 151 with an accompanying reduction in its temperature. Also, vapor collecting conduits 183, 184 and 185 are connected to the uplift conduits for collecting crude oxygen vapor formed upon operation of the pump. These conduits conduct the collected crude oxygen vapor through a common conduit 186 to the column section 152 at a point thereof above the level of the liquid pool 161 and below the lowermost bubble plate.

Vapor flowing upwardly in the column section 151 collects in the dome of this column section and is withdrawn as a stream through a conduit 187 and introduced into the column section 152 at a point thereof above the level of the liquid in the pool 161 and below the lowermost bubble plate. The vapor supplied to the contact section 152 by way of the conduit 187 and the vapor generated upon operation of the lift pump returned to the contact section by the conduit 186 comprise the vapor source for the contact section 152.

It is to be expressly understood that the provision of the conduit 187 and the liquid lift pump allows the column sections 151 and 152 to operate in a manner similar to operation of conventional column structure in which the section 152 would be mounted above the section 151 in a continuous column construction. Thus, the liquid reflux supplied to the column section 151 through the conduit 169 and the liquid feed fed thereto supplied by the conduit 180, flow downwardly in this column section in countercurrent relation with upwardly flowing vapor produced from the pool of boiling oxygen 155, with the liquid collecting in the pool 155 as liquid oxygen product. The oxygen product may be withdrawn from the fractionating cycle in liquid phase or in gaseous phase. For the latter purpose a conduit 188 may be connected to the liquid oxygen collecting space of the column section 151 above the level of the pool 155. The conduit 188 withdraws a stream of gaseous oxygen product and conducts the withdrawn stream to a passageway 189 of the heat exchanger 157 where the oxygen product stream passes in heat exchange relation with the incoming stream of air feed mixture. The gaseous oxygen product stream leaves the interchanger through a conduit 190 at substantially atmospheric pressure.

Fig. 3 of the drawings thus discloses a two-stage fractionating operation in which the total fractionating zone of the operation comprises the fractionating zones of the column sections 150, 151 and 152; the fractionating zone of the column section 150 comprising the high-pressure zone of the operation and the column sections 151 and 152 comprising the low-pressure zone. The low-pressure fractionating zone is split, such as at its feed point, to reduce the overall height of the column structure by the height of its portion above the feed point. The latter portion comprises the section 152 which may be mounted at an elevation common with the high-pressure section 150. The low-pressure sub-fractionating zones provided by the column sections 151 and 152 are interconnected to operate as a single low-pressure total fractionating zone, that is, as if the column sections 151 and 152 were mounted one on top of the other as a single column section in accordance with conventional practice. This is accomplished by lifting liquid material collecting in the base of the column section 152 to the elevation of the top of the column section 151 and for utilizing such liquid material to provide reflux for the column section 151, and by conducting vapor material collecting in the dome of the column section 151 to the base of the column section 152 above the path of liquid material collecting therein. The liquid material collecting in the base of the column section 152 is at its boiling temperature and may be lifted to the elevation of the top of the column sec-

tion by utilizing a heat type of liquid lift pump operated by heat derived from the fractionating operation without materially affecting its efficiency.

The source of heating fluid for operation of the heat pump is not limited to the fluids illustrated in the various embodiments disclosed and described above, but may comprise any fluid from the fractionating operation, including the gaseous feed mixture, which is relatively warm with respect to the liquid to be elevated by the pump. Also, external heat sources including ambient heat may be employed. If desired, the heat exchangers for the stages of the lift pump may be placed in heat exchange relation with the horizontally disposed conduits connecting the submergence head to the uplift conduit of each of the stages instead of in heat exchange relation with the uplift conduits as disclosed in each of the embodiments. Moreover, although a liquid lift pump including three stages is disclosed in each of the embodiments, it is to be expressly understood that in some installations a liquid lift pump including one or two stages may be adequate, while in other installations a liquid lift pump including three or more stages may be employed.

Although the various embodiments of the present invention have been disclosed and described in the environment of the fractionation of air into oxygen and nitrogen, it is to be expressly understood that the principles of the present invention may be employed in the fractionation of other gaseous mixtures including different boiling point components.

There is thus provided by the present invention novel methods of and apparatus for the fractionation of gaseous mixtures, including different boiling point components, such as the fractionation of air into oxygen and nitrogen, in which the fractionating operation is accomplished by compact equipment of substantially reduced height without substantial sacrifice of fractionating efficiency. The foregoing is accomplished according to the present invention by providing a total fractionating zone made up of a plurality of structurally independent liquid-vapor contact sections or columns, forming isolated sub-fractionating zones, adapted to be mounted side-by-side at a common elevation, and connected together in such a manner as to provide the liquid-vapor contact for effecting complete or the desired fractionation of the gaseous mixture. A liquid lift pump is provided for lifting liquid at its boiling temperature collecting in the base of one column section to the top of another section for the continuous downward flow of liquid reflux through the sections as if they were mounted one on top of the other as is conventional practice. The total fractionating zone of a single stage or a two-stage fractionating cycle may be divided into a plurality of liquid-vapor contact sections forming sub-fractionating zones, and the sections may be serially interconnected to duplicate the fractionating operation of an equivalent total fractionating zone constructed in accordance with conventional practice.

Although several embodiments of the invention have been disclosed and described herein, it is to be expressly understood that various changes and substitutions may be made therein without departing from the spirit of the invention as well understood by those skilled in the art. For example, the manner of splitting the total fractionating zone is not limited to the arrangements disclosed in the various embodiments. In a single stage fractionating cycle the total fractionating zone may be split at any desired level to provide a plurality of liquid-vapor contact sections of the desired total height. Also, in two-stage fractionating cycles the low pressure fractionating zone may be divided at levels other than at the level of the feed point as disclosed in Fig. 3. Moreover, combination of the embodiments shown in Figs. 1 and 3 may be employed. Reference therefore will be had to the appended claims for a definition of the limits of the invention.

I claim:

1. The method of fractionating a gaseous mixture to produce different boiling point components of the mixture by a fractionating operation including a plurality of fractionating zones in which liquid material containing a greater percentage of one boiling point component is provided in the top of the zones as wash liquid and in which liquid material containing a percentage of the one boiling component smaller than the percentage of the one boiling component in the wash liquid provided in corresponding zones collects in a pool in the liquid material collecting space in the base of the zones, the top of one of the fractionating zones being at an elevation above of the liquid product collecting space of another of the fractionating zones, comprising the steps of withdrawing liquid material from the pool of liquid material collecting in the liquid material collecting space of the another zone, elevating withdrawn liquid material to the elevation of the top of the one zone, utilizing elevated liquid material to provide wash liquid for the one zone, the mass of the withdrawn stream of liquid material being sufficient to provide the quantity of wash liquid required for the one zone, producing a source of liquid independently of the elevated stream, the liquid of the source containing a greater percentage of one boiling point component than the percentage of the one boiling point component in liquid material withdrawn from the another zone, and introducing liquid from the source into the another zone as wash liquid.

2. The method of fractionating a gaseous mixture to produce different boiling point components of the mixture by a fractionating operation including a plurality of fractionating zones in which liquid material containing a greater percentage of one boiling point component is provided in the zones as wash liquid and in which liquid material containing a percentage of the one boiling component smaller than the percentage of the one boiling component in the wash liquid provided in corresponding zones collects in a pool in the liquid material collecting space in the base of the zones, the top of one of the fractionating zones being at an elevation above the liquid product collecting space of another of the fractionating zones, comprising the steps of withdrawing liquid material from the pool of liquid material collecting in the liquid material collecting space of the another zone, elevating withdrawn liquid material to at least the elevation of the top of the one zone including the step of adding heat to withdrawn liquid material to aerate withdrawn liquid material by partial vaporization of liquid material, utilizing elevated liquid material to provide wash liquid for the one zone, producing a source of liquid independently of the elevated stream, the liquid of the source containing a greater percentage of one boiling point component than the percentage of the one boiling point component in liquid material withdrawn from the another zone, and introducing liquid from the source into the another zone as wash liquid.

3. The method of fractionating a gaseous mixture to produce different boiling point components of the mixture by a fractionating operation including a plurality of fractionating zones in which liquid material containing a greater percentage of one boiling point component is provided in the zones as wash liquid and in which liquid material containing a percentage of the one boiling component smaller than the percentage of the one boiling component in the wash liquid provided in corresponding zones collects in a pool in the liquid material collecting space in the base of the zones, the top of one of the fractionating zones being at an elevation above the liquid product collecting space of another of the fractionating zones, comprising the steps of withdrawing a stream of liquid material from the liquid material collecting space in the another zone and forming the stream into a submergence head, passing the stream through a confined path including a section extending upwardly to a point

above the liquid level of the submergence head, the confined path being so characterized that the liquid in the section will be supported by the submergence head, passing a warm fluid from the fractionating operation in heat interchange with liquid in the confined path to partially vaporize liquid therein and decrease the overall density of liquid in the section sufficiently to raise the level of liquid in the section to at least the elevation of the top of the one zone, utilizing elevated liquid material to provide wash liquid for the one zone, producing a source of liquid independently of the elevated stream, the liquid of the source containing a greater percentage of one boiling point component than the percentage of the one boiling point component in liquid material withdrawn from the another zone, and introducing liquid from the source into the another zone as wash liquid.

4. The method of fractionating a gaseous mixture to produce different boiling point components of the mixture by a fractionating operation including a plurality of fractionating zones in which liquid material containing a greater percentage of one boiling point component is provided in the zones as wash liquid and in which liquid material containing a percentage of the one boiling component smaller than the percentage of the one boiling component in the wash liquid provided in corresponding zones collects in a pool in the liquid material collecting space in the base of the zones, the top of one of the fractionating zones being at an elevation above the liquid product collecting space of another of the fractionating zones, comprising the steps of withdrawing a stream of liquid material from the liquid material collecting space in the another zone, periodically conducting the withdrawn stream of liquid material through a confined path alternately in serially interconnected downwardly and upwardly flowing streams with liquid in each of the downwardly flowing streams forming a submergence head for liquid in the next upwardly flowing stream in the series, passing warm fluid from the fractionating operation in heat interchange with liquid in the confined path to partially vaporize liquid therein and decrease the overall density of the liquid sufficiently to raise the level of liquid in the confined path to at least the elevation of the top of the one zone, utilizing elevated liquid material to provide wash liquid for the one zone, producing a source of liquid independently of the elevated stream, the liquid of the source containing a greater percentage of one boiling point component than the percentage of the one boiling point component in liquid material withdrawn from the another zone, and introducing liquid from the source into the another zone as wash liquid.

5. The method of fractionating a gaseous mixture to produce different boiling point components of the mixture by a fractionating operation including a plurality of fractionating zones in which liquid material containing a greater percentage of one boiling point component is provided in the zones as wash liquid and in which liquid material containing a percentage of the one boiling component smaller than the percentage of the one boiling component in the wash liquid provided in corresponding zones collects in a pool in the liquid material collecting space in the base of the zones, the top of one of the fractionating zones being at an elevation above the liquid product collecting space of another of the fractionating zones, comprising the steps of withdrawing a stream of liquid material from the liquid material collecting space in the another zone, periodically conducting the withdrawn stream of liquid material through a confined path alternately in serially interconnected downwardly and upwardly flowing streams with liquid in each of the downwardly flowing streams forming a submergence head for liquid in the next upwardly flowing stream in the series, the downwardly flowing streams being conducted to successively lower levels relative to respective liquid levels, passing warm fluid from the fractionating operation in heat interchange with liquid in the confined path

to partially vaporize liquid therein and decrease the overall density of the liquid sufficiently to raise the level of liquid in the confined path to at least the elevation of the top of the one zone, utilizing elevated liquid material to provide wash liquid for the one zone, producing a source of liquid independently of the elevated stream, the liquid of the source containing a greater percentage of one boiling point component than the percentage of the one boiling point component in liquid material withdrawn from the another zone, and introducing liquid from the source into the another zone as wash liquid.

6. The method of fractionating gaseous mixtures by a fractionating operation including a high-pressure zone and a low-pressure zone, which comprises feeding gaseous mixture to the high-pressure zone wherein the gaseous mixture undergoes a preliminary fractionation to produce gaseous fraction collecting in the gaseous fraction collecting space in the high-pressure zone and liquid fraction, withdrawing liquid fraction from the high-pressure zone and conducting withdrawn liquid fraction to the low pressure zone as feed wherein the operation is completed producing gaseous product and liquid product, withdrawing liquid product from the low-pressure zone at an elevation below the gaseous fraction collecting space of the high pressure zone, pumping withdrawn liquid product to at least the elevation of the gaseous fraction collecting space of the high-pressure zone, passing elevated liquid product in heat exchange relation with gaseous fraction in the high-pressure zone to liquefy a portion of the gaseous fraction as reflux for the high-pressure zone, returning elevated liquid product following the heat exchange step to the low-pressure zone, withdrawing gaseous fraction from the high-pressure zone, and liquefying withdrawn gaseous fraction as reflux for the low-pressure zone.

7. The method of fractionating gaseous mixtures by a two-stage fractionating operation, in which operation gaseous mixture is fed to a high-pressure column where the mixture undergoes preliminary fraction producing a liquid fraction and a gaseous fraction collecting in a gaseous fraction collecting space at the top of the high-pressure column and in which liquid fraction is fed to a low-pressure column where the operation is completed producing gaseous product and liquid product, which method comprises withdrawing a stream of liquid product from the fractionating operation at an elevation below the gaseous product collecting space of the high-pressure column and forming the stream into a submergence head, passing the stream through a confined path including a section extending upwardly to a point above the liquid level of the submergence head, the confined path being so characterized that the liquid in the section will be supported by the submergence head, passing a warm fluid from the fractionating operation in heat interchange with liquid in the confined path to partially vaporize liquid therein and decrease the density of liquid in the section sufficiently to raise the level of the partially vaporized liquid to at least the elevation of the gaseous fraction collecting space at the top of the high-pressure column, passing raised liquid in heat interchange with gaseous fraction in the gaseous fraction collecting space of the high-pressure column to liquefy a portion of the gaseous fraction as reflux for the high-pressure column, returning raised liquid following the heat interchange step to the low-pressure column, withdrawing gaseous fraction from the high-pressure column, and liquefying withdrawn gaseous fraction as liquid reflux for the low-pressure column.

8. The method of fractionating gaseous mixtures by a two-stage fractionating operation, in which operation gaseous mixture is fed to a high-pressure column where the mixture undergoes preliminary fractionation, producing a liquid fraction and a gaseous fraction collecting in the gaseous fraction collecting space at the top of the high pressure column and in which liquid fraction is fed to a low-pressure column where the operation is

completed producing gaseous product and liquid product, which method comprises withdrawing a stream of liquid product from the fractionating operation at an elevation below the elevation of the gaseous product collecting space of the high-pressure column, periodically conducting the withdrawn stream of liquid product through a confined path alternately in serially interconnected downwardly and upwardly flowing streams with liquid in each of the downwardly flowing streams forming a submergence head for liquid in the next upwardly flowing stream in the series, passing a warm fluid from the fractionating operation in heat interchange with liquid in the confined path to partially vaporize liquid therein and removing vapor from the downwardly flowing streams to reduce the density of liquid in the upwardly flowing streams relative to the density of liquid in the downwardly flowing streams so that liquid in the upwardly flowing streams is raised to a higher level than the level of the preceding downwardly flowing stream with liquid in the last upwardly flowing stream of the series being raised to a level at least corresponding to the elevation of the gaseous fraction collecting space at the top of the high-pressure column, passing raised liquid in heat interchange with gaseous fraction in the high-pressure column to liquefy a portion of the gaseous fraction, returning raised liquid following the heat interchange step to the low-pressure column, withdrawing gaseous fraction from the high-pressure column, and liquefying withdrawn gaseous fraction as liquid reflux for the low-pressure column.

9. The method of fractionating gaseous mixtures by a two-stage fractionating operation, in which operation a gaseous mixture is fed to a high-pressure column where the mixture undergoes preliminary fractionation producing liquid fraction and gaseous fraction collecting in a gaseous fraction collecting space at the top of the high-pressure column where the operation is completed producing gaseous product and liquid product, which method comprises withdrawing a stream of liquid product from the fractionating operation at an elevation below the gaseous fraction collecting space of the high-pressure column, periodically conducting the withdrawn stream of liquid product through a confined path alternately in serially interconnected downwardly and upwardly flowing streams with liquid in each of the downwardly flowing streams forming a submergence head for liquid in the next upwardly flowing stream in the series, passing a warm fluid from the fractionating operation in heat interchange with liquid in the confined path to partially vaporize liquid therein and removing the vapor from the downwardly flowing streams to reduce the density of liquid in the upwardly flowing stream relative to the density of liquid in the downwardly flowing streams so that liquid in the upwardly flowing streams is raised to a higher level than liquid of the preceding downwardly flowing stream with liquid in the last upwardly flowing stream of the series being raised to a level at least as high as the gaseous fraction collecting space at the top of the high-pressure column, the downwardly flowing streams being conducted to successively lower levels relative to respective liquid levels to establish progressively increased submergence heads in the series, passing raised liquid in heat interchange with gaseous fraction in the gaseous fraction collecting space of the high-pressure column to liquefy a portion of the high-pressure gaseous fraction as liquid reflux for the high-pressure column, liquefying the remaining portion of the high-pressure gaseous fraction as liquid reflux for the low-pressure column, and returning raised liquid following the heat interchange step to the low-pressure column.

10. The method of lifting liquid product of a fractionating operation, in which operation a mixture of gases is fractionated to produce a body of liquid material as product, which method comprises withdrawing a stream

of liquid material from the fractionating operation at a point below the liquid level of the body to thereby form a submergence head, passing the stream through a confined path including a section extending upwardly to a point above the liquid level of the body, the confined path being so characterized that liquid material in the section will rest on and be supported by the submergence head, passing a warm fluid from the fractionating operation in heat interchange with liquid material in the confined path to partially vaporize liquid therein and decrease the over-all density of liquid in the section sufficiently to raise the material in the section to a higher level, separating raised material into a vapor portion and a liquid portion, returning the vapor portion to the fractionating operating and utilizing the liquid portion to perform a cooling function in the fractionating operation.

11. The method of lifting liquid product to a fractionating operation in which a mixture of gases is fractionated to produce a body of liquid material as product, which method comprises withdrawing liquid material from the body and periodically conducting withdrawn liquid material through a confined path alternately in serially interconnected downwardly and upwardly flowing streams with liquid in each of the downwardly flowing streams forming a submergence head for liquid in the next upwardly flowing stream in the series and with the submergence heads progressively increasing along the series, passing a warm fluid from the fractionating operation in heat interchange with liquid in the confined path to partially vaporize liquid material therein and removing vapor from the downwardly flowing streams to decrease the over-all density of liquid in the upwardly flowing streams relative to the density of liquid in the downwardly flowing streams so that material in the upwardly flowing streams is raised to a level higher than the level of the preceding downwardly flowing stream, separating material raised in the last upwardly flowing stream of the series into a vapor portion and a liquid portion, returning the vapor portion to the fractionating operation, and utilizing the liquid portion to perform a cooling function in the fractionating operation.

12. The method of lifting liquid product of a fractionating operation, in which operation a mixture of gases is fractionated to produce a body of liquid fraction as product, which method comprises withdrawing liquid product from the body and periodically conducting withdrawn liquid product through a confined path alternately in serially interconnected downwardly and upwardly flowing streams with liquid in the downwardly flowing streams forming a submergence head for liquid in the next upwardly flowing stream in series, passing warm fluid from the fractionating operation in heat interchange with liquid in the confined path to partially vaporize liquid therein and removing resulting vapor to decrease the over-all density of liquid in the upwardly flowing streams relatively to the density of liquid in the upwardly flowing streams so that liquid on the upwardly flowing streams is raised to a higher level than the level of the preceding downwardly flowing stream, the downwardly flowing streams being conducted to successively lower points with respect to the highest liquid level of respective streams to establish progressively increasing submergence heads in the series.

13. A system for fractionating gaseous mixtures into different boiling components including a plurality of columns providing fractionating zones, each of the columns being provided with a liquid material collecting space at its base and a vapor collecting space at its top and the columns being adapted to be mounted with the liquid collecting space of one column at an elevation below the vapor collecting space of another column, means for withdrawing liquid material from the liquid material collecting space in the one column, means for elevating withdrawn liquid material to at least the elevation of the

vapor collecting space of the another column, means for utilizing elevated liquid material to provide wash liquid for the another column, means producing a source of liquid independently of elevated liquid material, liquid of the source containing a larger percentage of one boiling component than the percentage of the one boiling point component in the withdrawn liquid, and means introducing liquid from the source to the one column as reflux.

14. A fractionating system as defined in claim 13 in which the means for elevating withdrawn liquid material comprises a liquid lifting pump including interconnected uplift conduit means and submergence conduit means and means for aerating liquid in the pump including means passing a relatively warm fluid from the fractionating system in heat interchange with liquid in the pump.

15. A two-stage fractionating system having a high-pressure column for fractionating a gaseous mixture into liquid fraction and gaseous fraction and a low-pressure column for completing the fractionation and producing liquid product and gaseous product, comprising means for elevating liquid product from the low-pressure column to at least the elevation of the gaseous fraction collecting space at the top of the high-pressure column, means for passing elevated liquid product in heat interchange with gaseous fraction to liquefy a portion of the gaseous fraction as reflux for the high pressure column, means for returning elevated liquid product stream after the heat interchange with the gaseous fraction to the low-pressure column, means for withdrawing gaseous fraction from the high-pressure column, and means for liquefying withdrawn gaseous fraction as a reflux for the low-pressure column.

16. An apparatus for fractionating compressed and refrigerated gaseous mixtures comprising a high-pressure fractionating column, a low-pressure fractionating column, the columns being mounted so that the base of the low-pressure column is at an elevation below the top of the high-pressure column, conduit means for conducting compressed and refrigerated gaseous mixture to the high-pressure column as a feed wherein gaseous mixture is fractionated producing liquid fraction and vapor fraction, conduit means for conducting liquid fraction from the high-pressure column to the low-pressure column as feed wherein liquid fraction is fractionated producing liquid product and gaseous product, means for withdrawing vapor fraction from the high-pressure column, means for liquefying withdrawn vapor fraction and conducting liquefied withdrawn vapor fraction to the low-pressure column as reflux, and means for liquefying vapor fraction in the high-pressure column as liquid reflux for the high-pressure column, the last-named means comprising a liquid lift pump including aerating means energized by a warm fluid from the fractionating operation for raising a stream of liquid product from the low-pressure column to at least the elevation of the top of the high-pressure column and means for passing elevated liquid product in heat interchange with the vapor fraction within the high-pressure column.

17. Apparatus for fractionating compressed and refrigerated gaseous mixtures comprising a high-pressure fractionating column, a low-pressure fractionating column, the base of the low-pressure column being at an elevation below the top of the high-pressure column, conduit means for conducting compressed and refrigerated gaseous mixture to the high-pressure column as a feed wherein gaseous mixture is fractionated producing liquid fraction and vapor fraction, conduit means for conducting liquid fraction from the high-pressure column to the low-pressure column as feed wherein liquid fraction is fractionated producing liquid product and gaseous product, means for withdrawing vapor fraction from the high-pressure column, means for liquefying withdrawn vapor fraction and for conducting liquefied withdrawn vapor

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fraction to the low-pressure column as reflux, and means for liquefying vapor fraction in the high-pressure column as reflux for the high-pressure column, the last-named means including a cascade liquid lift pump including aerating means for raising liquid product of the low-pressure column to at least the elevation of the top of the high-pressure column for heat interchange with vapor fraction in the high-pressure column, the aerating means comprising means for passing warm fluid from the fractionating apparatus in heat interchange with the liquid product withdrawn from the low-pressure column.

18. An apparatus as set forth in claim 17 wherein the cascade lift pump comprises a plurality of lift stages each including an uplift section and a submergence section with the uplift sections of the stages extending from a substantially common elevation below the level of the liquid product in the low-pressure column and terminated at successive higher elevations.

19. A device for transferring liquid product of a fractionating apparatus, in which apparatus a mixture of gases is subjected to a fractionating operation to produce a body of liquid fraction as product, comprising a succession of substantially vertical columns, the lower ends of the columns being at an elevation below the level of the body of liquid product, the upper ends of the columns being terminated at successively higher elevations above the level of the body of liquid product, means including conduit means connecting the upper end of the columns to the lower end of the next column in the succession and means for conducting liquid product from the liquid product collecting space of fractionating apparatus to the lower end of the first column in the succession defining a confined path between the liquid product collecting space of the fractionating operation and the upper end of the last conduit of the succession, and means for passing a warm product from the fractionating apparatus in heat interchange with liquid in the confined path.

20. The method of separating gaseous mixtures in a fractionating operation including a plurality of fractionating zones each having a liquid collecting space and a vapor collecting space with liquid-gas contact means therebetween, the liquid collecting space of one zone being at an elevation below the vapor collecting space of the another zone, which method comprises feeding a stream of liquid material to the top of one of the fractionating zones, withdrawing a stream of liquid material collected in the liquid collecting space of the one zone, pumping the withdrawn stream of liquid material to the elevation of the top of another zone, introducing the elevated stream of liquid material into top of the another zone, and withdrawing a stream of vapor from the vapor collecting space of the another zone and conducting the withdrawn stream of vapor to the bottom of the one zone.

21. The method of fractionating a gaseous mixture as defined in claim 20 in which the stream of liquid material withdrawn from the one zone is pumped to the elevation of the top of the another zone by adding heat to the withdrawn stream of liquid material to aerate the withdrawn stream of liquid material by partial vaporization of the liquid material.

22. A fractionating system for producing different boiling point components of a gaseous mixture in a fractionating operation, comprising a plurality of liquid-vapor contact columns forming the fractionating zone of the operation, the columns having liquid collecting space at their bottoms and a vapor collecting space at their tops with the liquid collecting space of one column being at an elevation below the vapor collecting space of another column, means for feeding a stream of the liquid material into the top of the one column, means for withdrawing a stream of liquid material from the liquid material collecting space in the one column, means for pumping the withdrawn stream of liquid material to the elevation of the

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top of the another column, means for introducing the elevation stream of liquid material into the vapor collecting space of the another column, and means for withdrawing a stream of vapor from the vapor collecting space of the another column and conducting the withdrawn stream of vapor into the bottom of the one column above the liquid collecting space thereof.

23. A fractionating system as defined in claim 22 in which the means for elevating the withdrawn stream comprises a liquid lifting pump including interconnected uplift conduit means and submergence conduit means and means for aerating the liquid in the pump including means passing a warm fluid from the fractionating system in heat interchange with the liquid in the pump.

24. The method of fractionating a gaseous mixture in a two-stage fractionating operation comprising a single high-pressure fractionating zone and a low-pressure fractionating zone including a plurality of low-pressure sub-fractionating zones, each of the fractionating zones having a liquid collecting space and a vapor collecting space with liquid-vapor contact means therebetween, the liquid collecting space of one of the low-pressure sub-fractionating zones being in heat exchange relation with the vapor collecting space of the high-pressure fractionating zone, in which operation a stream of gaseous mixture is fed to the high-pressure zone wherein the gaseous mixture undergoes a preliminary fractionation producing a gaseous fraction and a liquid fraction and in which a stream of liquid fraction is withdrawn from the high-pressure fractionating zone and introduced into the low-pressure fractionating zone wherein the fractionation is completed producing a gaseous product and a liquid product, which method comprises withdrawing a stream of liquefied gaseous fraction from the high-pressure zone and introducing the withdrawn stream into the another of the sub-fractionating zones, withdrawing a stream of liquid material collected in the liquid collecting space of the another sub-fractionating zone, pumping the withdrawn stream of liquid to the elevation of the vapor collecting space of the one sub-fractionating zone, introducing the elevated stream into the top of the one sub-fractionating zone, and withdrawing a stream of vapor collected in the vapor collecting space of the one sub-fractionating zone and introducing the withdrawn vapor stream into the bottom of the another sub-fractionating zone.

25. The method of fractionating a gaseous mixture as defined in claim 24 in which the stream of liquid material withdrawn from the another sub-fractionating zone is pumped to the elevation of the top of the one sub-fractionating zone by adding heat to the withdrawn stream of liquid material to aerate the withdrawn stream of liquid material by partial vaporization of the liquid material.

26. A fractionating system for producing different boiling point components of a gaseous mixture in a two-stage fractionating operation including a high-pressure fractionating zone and a low-pressure fractionating zone, in which operation a stream of gaseous mixture is fed to the high-pressure zone where the gaseous mixture undergoes a preliminary fractionation producing a gaseous fraction and a liquid fraction and in which a stream of liquid fraction is withdrawn from the high-pressure fractionating zone and introduced into the low-pressure fractionating zone where the fractionation is completed producing a gaseous product and a liquid product, comprising a liquid-vapor contact section forming the high-pressure zone, a plurality of liquid-vapor contact sections forming the low-pressure zone, the liquid-vapor contact sections having a vapor collecting space and a liquid collecting space, means for withdrawing a stream of liquefied fraction from the high-pressure zone and introducing the withdrawn stream into one contact section of the plurality of contact sections, means for withdrawing a stream of liquid material collected in the liquid collecting space of the one contact section, means for pumping

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the withdrawn stream of liquid to the elevation of the vapor collecting space of another contact section of the plurality of contact sections, means for introducing the elevated stream of liquid into the top of the another contact section and means for withdrawing a stream of vapor collected in the vapor collecting space of the another contact section and introducing the withdrawn vapor stream into the bottom of the one contact section above the liquid collecting space thereof.

27. A fractionating system as defined in claim 26 in which the means for elevating the withdrawn stream comprises a liquid lifting pump including interconnected uplift conduit means and submergence conduit means and means for aerating the liquid in the pump including

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means passing a warm fluid from the fractionating system in heat interchange with the liquid in the pump.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,913,882

November 24, 1959

Clarence J. Schilling

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 7, line 70, for "fractionization" read -- fractionation --; column 11, line 14, strike out "of", first occurrence; column 13, line 39, for "fraction" read -- fractionation --; column 15, line 15, for "operating" read -- operation --; line 58, for "on the" read -- in the --; column 16, line 32, strike out "a"; column 17, line 51, after "into" insert -- the --; line 66, after "having" insert -- a --; column 18, line 2, for "elevation" read -- elevated --.

Signed and sealed this 14th day of June 1960.

(SEAL)

Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

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