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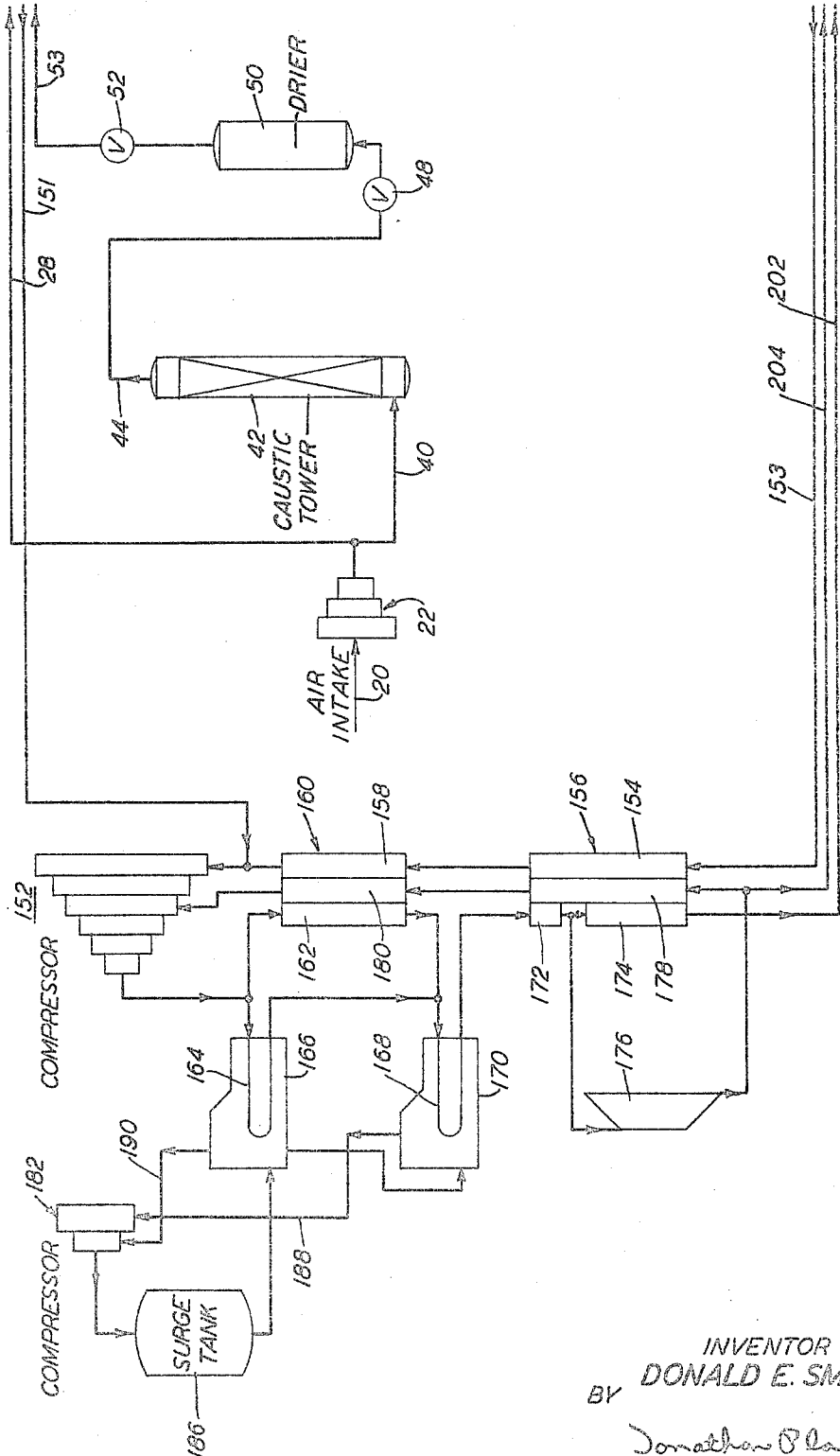
3,264,830

SEPARATION OF THE ELEMENTS OF AIR

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2 Sheets-Sheet 1

FIG. 1A



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2 Sheets-Sheet 2

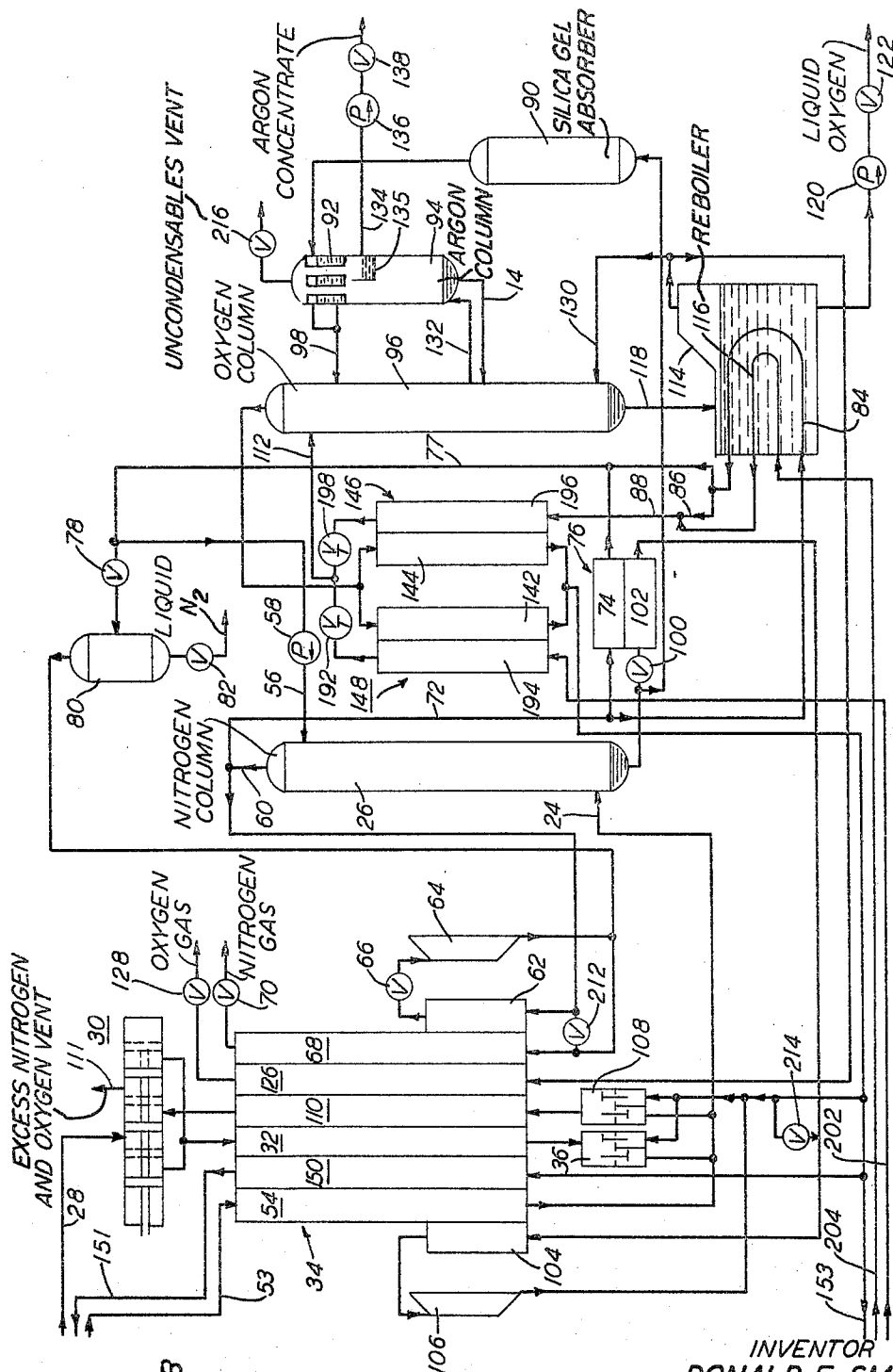


FIG. 1B

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3,264,830

SEPARATION OF THE ELEMENTS OF AIR

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2 Claims. (Cl. 62—39)

My invention relates to the separation of the elements of air by liquefaction and rectification into a plurality of products including liquid nitrogen, gaseous nitrogen, liquid oxygen, gaseous oxygen, all of high purity, together with a crude argon concentrate representing a high recovery of all the argon contained in the process air stream.

It is an object of my invention to make an air separation plant highly flexible as to proportioning the nitrogen product between liquid and gas, to proportioning the oxygen product between liquid and gas, and to varying the relative amounts of nitrogen and oxygen produced within the bounds of the normal constituency of the atmospheric air.

Another object is to maintain a high degree of recovery of the available argon in the air without sacrificing flexibility of nitrogen and oxygen output as between proportions of liquid and gas or between proportions of nitrogen and oxygen.

Another object is to improve the refrigeration of an air separation plant.

Another object is to increase the argon recovery in an air separation system, utilizing nitrogen gas already utilized in the system.

A feature of the invention is the evaporation and venting of a portion of rich liquid when it is desired to dispose of unwanted oxygen product instead of expending energy on rectifying all of the oxygen product and then throwing away some of the purified oxygen product. In this connection, not only is refrigeration conserved by heat exchange within the plant but pressure energy is conserved by utilizing the departing gas to operate a turbine or work expansion engine.

A further feature is improved independence between high argon recovery and efficient production of nitrogen and oxygen, both gaseous and liquefied.

A further feature is the increasing of the percentage recovery of argon.

Other objects, features and advantages will appear from the following more detailed description of illustrative embodiments of the invention, which will now be given in conjunction with the accompanying drawings.

In the drawings,

FIGS. 1A and 1B when placed end to end, FIG. 1A to the left of FIG. 1B, constitute a flow sheet of an illustrative embodiment of the invention.

Referring to the drawings, the air intake is shown at 20 connected to the suction side of an air compressor 22 and delivered over parallel paths to the feed inlet 24 of a nitrogen (high pressure) column 26. One path is by way of a conduit 28 and a slide valve 30 which in the full line position thereof leads to a reversing passage 32 of a multiple passage heat exchanger 34, and thence through a check-valve pair 36 to the feed inlet 24. Another path is by way of the inlet 40 of a caustic tower 42, the outlet 44 thereof, a valve 48, a drier 50, a valve 52, a conduit 53, a nonreversing cooling passage 54 in the heat exchanger 34, and thence joining the first path to the feed inlet 24. It will be assumed that water coolers (not shown) are included whenever required according to conventional practice.

Reflux liquid input to the column 26 is pumped in under pressure at an inlet 56 near the top of the column

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by means of a pump 58 fed by a source to be described below.

Effluent gaseous nitrogen of high purity is evolved in the usual manner at the top of the column 26 at an outlet 60. Gas from the outlet 60 divides between two paths, one of which is directed to the cold end of a relatively short warming passage 62 in the heat exchanger 34 from whence the gas is directed through a valve 66 to the input side of a turbine or work expansion engine 64. From the output side of the turbine 64 the expanded gas is directed to a warming passage 68 in the heat exchanger 34 and thence to a valve 70 from which product gaseous nitrogen of high purity may be taken from the system. The second path for gaseous nitrogen of high purity from the outlet 60 is by way of a conduit 72 from which the stream divides two ways. One way is through the condenser portion 74 of a condenser-evaporator 76 and thence through a conduit 77 and a valve 78 to a nitrogen flash drum 80. Liquid nitrogen of high purity condensed in the condenser 74 may be taken off from the system as product by means of a valve 82 connected to the bottom of the flash drum 80. Residual nitrogen gas from the top of the flash drum 80 is directed to join the gaseous nitrogen from the outlet of the turbine 64. The second portion of gaseous nitrogen from the conduit 72 is directed to a reboiler coil 84, in which it is more or less completely liquified and then divides, part mingling in conduit 77 with the material from the output side of the condenser 74. A portion of liquid and gas at the input side of the valve 78 goes to the suction side of the pump 58 to serve as the above-mentioned source of reflux liquid for the column 26.

The flash drum 80 serves to cool the liquid nitrogen product by permitting some evaporation thereof and so takes the place of the conventional product subcooler, effecting a saving in capital expenditure as compared to a subcooler.

The rich liquid which is collected in the bottom of the column 26 is divided into two portions, one of which is fed to a silica gel adsorber 90 for removing acetylene or other potentially explosive substances from the rich liquid. The rich liquid thus freed from such unwanted contaminants is passed through the evaporator portion of a condenser-evaporator combination 92 at the top of an argon column 94, and a resultant combination of liquid and vapor is fed into an oxygen (low pressure) column 96 at a feed inlet 98 in the upper portion of the column.

Another portion of the rich liquid is directed through a valve 100 into the evaporator portion 102 of the condenser-evaporator 76. The gas developed in the evaporator is directed to a relatively short warming passage 104 in the heat exchanger 34 and thence through a turbine or work expansion engine 106, wherein pressure energy is recovered from the evaporated rich liquid, and thence to a check valve pair 108 and the previously mentioned check valve pair 36 whereby the expanded gas is admitted either to the reversing passage 32 or to a reversing passage 110 of the heat exchanger 34 according to which of the check valve pairs can be opened by the stream from the turbine 106. If the stream enters the passage 110, it leaves that passage through the middle chamber of the slide valve 30 in the full line position thereof to exhaust to the atmosphere through an outlet 111.

The oxygen column 96, which is fed with rich liquid and evaporated rich liquid at the feed inlet 98 is supplied with reflux liquid at an inlet 112 near the top of the column, from a source to be described below. Liquid oxygen of high purity collects in the bottom of the column 96 and is reboiled in a separate reboiler 114 containing the reboiler coil 84 and a second reboiler coil 116, the liquid from the column being fed preferably by gravity

through a conduit 118 to the reboiler. Liquid may be withdrawn from the bottom of the reboiler 114 by means of a pump 120 and a valve 122 as product liquid oxygen of high purity. Gaseous oxygen is collected at the top of the reboiler 114 and may be passed through a warming passage 126 in the heat exchanger 34 and taken off through a valve 128 as product gaseous oxygen of high purity. The gaseous oxygen not so removed from the system as product is returned to a level of the column 96 just above the liquid pool in the column through a conduit 130.

The slide valve 30 operates at intervals between the full line position and the dotted line position shown, in known manner in conjunction with timing devices (not shown) and the check valve pairs 36 and 108 to reverse periodically the stream flows in the passages 32 and 110 in order to keep these passages free from condensed substances. With the slide valve 30 in the full line position, the air stream under high pressure passes through the passage 32 into the check valve pair 36 opening the left hand check valve of the pair and closing the right hand check valve, overpowering the relatively low pressure developed against the right hand check valve by expanded gas from the turbine 106 or elsewhere. That expanded gas is, however, able to open the right hand check valve of the pair 108 against atmospheric pressure and pass through the passage 110 and thence through the slide valve 30 to be vented to the atmosphere at outlet 111.

With the slide valve 30 in the dotted line position, the incoming high pressure air stream is directed through the passage 110 into the check valve pair 108 where it opens the left hand check valve and closes the right hand check valve. In this case, expanded gas is able to open the right hand check valve of the pair 36, pass upward through the passage 32 and be vented to the atmosphere through the slide valve 30 at outlet 111.

Gaseous material of optimum available argon content is taken from the column 96 at an appropriate intermediate level at an outlet 132 and fed into the bottom of the argon column 94. Rising vapor in the column 94 is condensed at the top of the column by the top condenser-evaporator combination 92 to form liquid reflux which washes down in contact with the rising vapor to rectify the rising vapor and produce a liquid product high in argon content, some of which is collected by means such as a trough 135, taken off through an outlet conduit 134 by a pump 136, and supplied to a valve 138 as an argon concentrate or crude argon product. Residual liquid in the bottom of the argon column 94 is drained back into the oxygen column 96 through a conduit 140 which enters the oxygen column just below the outlet conduit 132. A vent valve 216 may be provided at the top of the argon column 94 to vent noncondensable vapor should the need arise.

The portion of the liquid nitrogen that is fed to the suction side of the pump 58 and pumped into the top of the nitrogen column at inlet 56 as reflux liquid at column pressure takes part in a high purity nitrogen cycle for providing an ordinarily constant flow of high purity liquid reflux to the nitrogen column 26. In this cycle, an equivalent amount of nitrogen gas leaving the top of the column enters the conduit 72, undergoes condensation in condenser 74 and in reboiler coil 84, and returns through conduit 77 to the pump 58, completing the cycle.

Nitrogen may, however, be withdrawn when desired from various parts of this cycle. One way of withdrawal is through the valve 78 to the nitrogen flash drum 80 from the bottom of which product nitrogen may be supplied through the valve 82, as previously mentioned.

A second manner of withdrawing nitrogen from the high purity cycle is by a conduit 86 which takes off a portion of the stream from reboiler coil 84 and mingles this portion with a stream of lower purity nitrogen from the reboiler coil 116 in a conduit 88 leading to a sub-cooling passage 196 and a throttle valve 198. This com-

bined stream forms a portion of the reflux for the oxygen column 96, as will be described more fully below.

A third means for withdrawing nitrogen from the high purity cycle is the above-described withdrawal of high purity nitrogen effluent from the top of the nitrogen column through the heating passage 62 and valve 66 into the turbine 64 where it is work expanded, then warmed against the incoming process air streams and made available as product nitrogen gas at valve 70.

Effluent nitrogen gas of lesser purity collects at the top of the oxygen column 96 and is led in parallel through warming passages 142 and 144 in subcoolers 146 and 148 respectively, to aid in lowering the temperature of the stream approaching the inlet 112. The streams from passages 142 and 144 are recombined and thereupon again divided into three parallel streams. One stream mingles with evaporated rich liquid from the turbine 106 to enter one or the other of the check valve pairs 36, 108 and thence to waste through passage 32 or passage 110 to aid in cooling the incoming air streams. A second stream is directed through a warming passage 150 in the heat exchanger 34 to further aid in cooling the incoming air streams and thence through a conduit 151 to the input side of a multi-stage cycle-nitrogen compressor 152. The third stream is also directed to the input side of the compressor 152, by way of a conduit 153, a warming passage 154 of a heat exchanger 156, and a warming passage 158 of another heat exchanger 160 thereupon, mingling with the stream from passage 150 in conduit 151.

The effluent nitrogen gas passing through the compressor 152 is condensed as described below to provide the liquid reflux for the oxygen column 96 which is delivered to the column at the inlet 112 as hereinabove mentioned. This liquid reflux is refrigerated in a cycle as hereinbelow described to provide a major portion of the refrigeration needed in the over-all process. The point of delivery of the refrigerated liquid to the system is at the inlet 112, located near the top of the oxygen column, a location where the application of refrigeration is most effective for high argon recovery.

In this refrigeration cycle, compressed nitrogen gas at, for example 2500 p.s.i.a. from the outlet of the compressor 152 divides into two parallel streams, one of which is cooled in the cooling passage 162 of the heat exchanger 160. The other stream is cooled in the coil 164 of a Freon evaporator 166. These two streams recombine and are cooled as a single stream in the coil 168 of a second Freon evaporator 170. The stream so cooled is further cooled in a relatively short cooling passage 172 in the heat exchanger 156 and then divides again into two parallel streams, one of which is further cooled in the cooling passage 174 of the heat exchanger 156. The other stream is work expanded in a turbine or work expansion engine 176 to a pressure of, for example 100 p.s.i.a. The latter stream after expansion is divided, part being warmed successively in passage 178 of heat exchanger 156 and passage 180 of heat exchanger 160 and returned to an intermediate stage of the compressor 152 for recompression to the higher pressure.

Before further tracing the high pressure stream and the low pressure stream of cycle nitrogen gas, it will be noted that the Freon for the Freon evaporators 166 and 170 may be provided in conventional manner. As shown, there is a multistage Freon compressor 182 the output of which is fed through a water cooler (not shown) to a Freon surge tank 186 from which liquid Freon circulates into the evaporators 166 and 170 in series. The evaporated Freon gas from the evaporator 170 is fed through a conduit 188 to the first stage of the compressor 182 while the evaporated Freon gas from the evaporator 166 is fed through a conduit 190 to a later stage of the compressor 182.

The high pressure stream of nitrogen gas of lesser purity from the compressor 152 after emerging from the passage 174 of the heat exchanger 156 is directed through

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a conduit 202 in to the warm end of the passage 194 of the subcooler 148 where it is cooled against effluent gas in passage 142, some of which gas is on the way to the compressor 152. Upon leaving the cold end of the passage 194 the material is expanded in a throttle valve 192 and delivered to the top of the oxygen column 96 through the inlet 112, mainly as liquid but usually with some accompanying gas.

A portion of the low pressure stream of nitrogen gas of lesser purity, utilizing some of the pressure energy of the nitrogen compressor 152 and emerging from the turbine 176, is sent by way of a conduit 204 to the reboiler coil 116. In this coil the cycle nitrogen is at least partially condensed while boiling up liquid oxygen surrounding the coil 116 in the oxygen reboiler 114. From the reboiler coil 116, the liquefied nitrogen and accompanying vapor passes through the conduit 88 where it mingles with liquid nitrogen and accompanying vapor from the reboiler 84 coming in by way of the conduit 86. The combined stream is then directed into the passage 196 of the subcooler 146 where it is further cooled against effluent gas in passage 144, and then expanded in the throttle valve 198. The very cold liquid nitrogen, usually with some residual vapor, is poured into the upper portion of the oxygen column 96 at the inlet 112. Effluent gas from the top of the oxygen column returns through the heat exchangers 146 and 148 and by paths hereinabove described to the nitrogen compressor 152.

In the lower purity nitrogen reflux cycle, a substantial balance may be maintained between liquid oxygen boiled off in the oxygen reboiler 114 and nitrogen rectified in the oxygen column. In the reboiler 114, liquid oxygen continually enters from the bottom of the oxygen column by way of conduit 18 and gaseous oxygen returns to the oxygen column through conduit 130. At the same time liquid nitrogen continually enters the oxygen column at inlet 112 while gaseous nitrogen leaves the column as effluent. Heat carried by the nitrogen passing through the reboiler coils 84 and 116 serves to evaporate a certain amount of oxygen while condensing the equivalent amount of nitrogen. The evaporated oxygen returns to the oxygen column carrying the heat received from the nitrogen in the reboiler coils. This heat then serves to evaporate a certain amount of nitrogen in the oxygen column while condensing the equivalent amount of oxygen. With respect to the oxygen column, then, the only energy required to be supplied by the compressor 152 is that required to make up for unavoidable irreversible heat exchanges incident to the cycle and to perform the liquefaction of the material that is to be drawn from the plant as liquid products. Additional available energy supplied by the compressor 152 is used for the general purposes of refrigeration in the system as a whole, particularly for cooling the incoming air streams.

The cycle-nitrogen refrigeration system will now be summarized as an entity auxiliary to the air separation process. The coldest point in the cycle-nitrogen refrigeration system is at the inlet 112 to the oxygen column 96 where liquid nitrogen with some accompanying vapor is poured into the column near the top thereof, thereby rendering the top of the oxygen column the coldest part of the entire air separation plant. The cycle-nitrogen imparts some of its refrigeration to the liquids and vapors in the oxygen column to provide the necessary refrigeration for operating that column and for performing the liquefaction required to produce liquid products by heat exchange in the reboiler 14. The remaining refrigeration passes out from the top of the column in the effluent gas. This gas gives up more refrigeration in the subcoolers 146 and 148 by cooling incoming gases and liquids presently to be converted into reflux liquid for the column. One portion of the effluent gas which remains in the refrigeration cycle after leaving the subcoolers gives up substantially all its remain-

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ing refrigeration to the incoming air streams in the heat exchanger 34. Another portion of the effluent gas which remains in the refrigeration cycle transfers substantially all its remaining refrigeration to the heat exchangers 156 and 160. These portions of effluent gas are combined and compressed in the cycle-nitrogen compressor 152. Essentially, from this point on, the compressed gas is lowered in temperature by giving up heat to the Freon evaporators 166 and 170, the heat exchangers 160 and 156, the liquid oxygen reboiler 114, and the subcoolers 146 and 148, arriving at the inlets of the throttle valves 192 and 198 with temperatures somewhat above that of the effluent gas leaving the top of the oxygen column 96. In the throttle valves the liquid is expanded and thus lower in temperature. The refrigeration system thus effected is a simple, substantially unitary cycle that is highly efficient and that delivers the coldest refrigerant to the portion of the air separation plant where it can be most effective in promoting high recovery of argon.

The flow of liquid nitrogen delivered to the inlet 112 from the reboiler coils 84 and 116 may be adjusted to compensate more or less exactly for the flow of product nitrogen removed from the system in order to maintain the quantity and purity of the liquid nitrogen reflux supplied to the top of the oxygen column 96 through the inlet 112.

The invention can be utilized in obtaining, over a wide range, any desired proportioning between nitrogen output and oxygen output and any desired proportioning as between product liquid nitrogen and product gaseous nitrogen as well as between product liquid oxygen and product gaseous oxygen, all with substantially no interference with a high recovery of argon.

If while maintaining a constant rate of input of air it is desired to increase the rate of liquid nitrogen production while decreasing the rate of gaseous nitrogen production, valve 78 may be opened wider to produce the desired increase in the rate of liquid nitrogen production. To compensate for this increase, the valve 66 may be closed down to such an extent that the rate of gaseous nitrogen production is decreased until the sum of the nitrogen product, liquid and gaseous, is the same as before the change. Due to the closing down of the valve 66, more of the total effluent from the top of the nitrogen column is condensed in the condenser 74 and in the reboiler coil 84 thereby providing enough liquid nitrogen to maintain substantially constant the stream of reflux liquid supplied to the top of the nitrogen column and to provide the increased amount of liquid nitrogen being withdrawn through the valve 78 and taken out of the system as liquid nitrogen product. In this change, there is substantially no reaction upon the operation of the oxygen column, nor upon the operation of the argon column. The resulting increase in the amount of refrigeration carried away from the system by the increased amount of liquid nitrogen withdrawn may be made up by increasing the input of mechanical or electrical energy into the cycle-nitrogen compressor 152 to maintain constant the purity and rate of flow of the liquid reflux supplied to the top of the oxygen column. As a result of all these compensating changes, there is no material reaction upon the operation of either the oxygen column or the argon column.

In similar manner, the rate of gaseous nitrogen production may be increased while decreasing the rate of liquid nitrogen production, by opening valve 66 wider and closing down on valve 78, again while maintaining a constant rate of input of air and without material effect upon the operation of either the oxygen column or the argon column, and in this case with an accompanying decrease in the energy input to the cycle-nitrogen refrigeration system.

If while maintaining a constant rate of input of air it is desired to increase the rate of liquid oxygen pro-

duction while decreasing the rate of gaseous oxygen production, valve 122 may be opened wider and valve 128 may be closed down correspondingly. At the same time, the refrigeration in the cycle-nitrogen system may be increased to compensate for the increased amount of refrigeration carried off by the increased liquid product.

Similarly, the rate of gaseous oxygen production may be increased while decreasing the rate of liquid oxygen production, by opening valve 128 wider and closing down on valve 122, again while maintaining a constant rate of input of air and without material effect upon the operation of either the oxygen column or the argon column, and in this case with an accompanying decrease in the energy input to the cycle-nitrogen refrigeration system.

It is known in the art that for a given rate of input of air into an air separation system, substantially the full 20 percent of the process stream that is oxygen can be recovered as oxygen product, while of the 80 percent that is nitrogen, the maximum available as product if taken from the nitrogen column for the sake of high purity is only about 40 percent of the process stream. If it is desired to produce nitrogen at a faster rate, the rate of input of air may be increased within the limits of the plant facilities. This means a concomitant increase in the rate of oxygen production. If there is no demand for the increased oxygen product, it has been customary to run the unwanted oxygen to waste, possibly recovering some refrigeration therefrom to help cool the incoming air stream. In accordance with the present invention, the excess oxygen is removed from the system indirectly, by removing some of the rich liquid instead of feeding all of the rich liquid into the oxygen column. This is done by opening the valve 100 to any desired extent. The rich liquid passed through the valve 100 is heat exchanged in the evaporator 102 against effluent gas from the nitrogen column passing through the condenser 74, the rich liquid being evaporated as the effluent gas is condensed. The evaporated rich liquid is then passed through a preheating passage 104 in heat exchange with the incoming air stream and is work expanded in the turbine 106 to recover pressure energy imparted to the material by the air compressor before the expanded gas is passed through the heat exchanger passage 32 or 110 along with waste nitrogen from the top of the oxygen column. Thus not only is refrigeration conserved that would otherwise be carried to waste by the oxygen to be thrown away but part of the mechanical energy previously expended upon the process air stream to develop pressure energy therein is recovered from the evaporated rich liquid in the turbine 106.

If it is desired to produce oxygen at an increased rate when there is no accompanying demand for increased nitrogen production, the rate of input of air may be increased to the desired degree within the limits of the plant facilities. This will result of course in the desired increase in oxygen production with concomitant increase in the rate of nitrogen production. In accordance with the present invention, pressure energy may be recovered from the unwanted excess nitrogen by closing down the valve 78 and opening valves 66 and 70 until the flow of liquid nitrogen product is reduced to the desired value. Closing down the valve 78 and opening valves 66 and 70 forces a greater proportion of the effluent gas from the top of the nitrogen column 26 to be taken into the turbine 64 wherein pressure energy is converted into mechanical or electrical energy which may be utilized in any desired manner, thus salvaging some of the power being supplied to the plant. As much product gaseous nitrogen may be taken from the valve 70 as is needed to supply the demand and the remainder may be vented to waste, having already given up not only refrigeration but also pressure energy.

A combination of the features disclosed makes argon recovery substantially independent of the removal of nitrogen and oxygen products from the air separation system. The cycle-nitrogen refrigeration system may be equipped with conduits of sufficient flow capacity and the nitrogen compressor may be operated with sufficient power input to insure any desired quantity of flow of reflux liquid into the oxygen column as required to permit a high proportionate recovery of the argon content of the process air stream. The purity of the nitrogen reflux may be maintained at a high level by adding some high purity nitrogen effluent from the nitrogen column to the nitrogen in the refrigeration cycle. Once charged with gas, the cycle maintains its volume of gas circulating around and around the cyclic path, requiring only slight addition from time to time to make up unavoidable losses. The amount and purity of the reflux for the oxygen column is assured due to the fact that the nitrogen stream comprising the reflux enters the column near the top, where quantity and purity have the maximum effect upon the argon recovery process.

For peak loads of demand for argon concentrate, the rate of air intake may be increased above normal while at the same time the power expended for refrigeration is increased, with the result that not only is argon intake and output increased but also the percentage of recovery of the argon present in the process air stream is increased. The recovery is increased by increasing the flow of nitrogen gas through conduit 204 to reboiler coil 116. This gas is condensed at this point, increasing the amount of oxygen vapor reboiled and caused to rise up through the oxygen column. The condensed gas from coil 116 then goes to oxygen column inlet 112 via heat exchanger 146, thus increasing the liquid nitrogen flow down through the oxygen column. In this way both the vapor and liquid flow rates in the oxygen column are increased, producing a better separation at a cost of increased power equivalent to compressing the increased flow in conduit 204 from the pressure at the top of the oxygen column to the pressure in coil 116. There is no appreciable effect upon the production of nitrogen and oxygen due to the increased argon recovery as long as enough cold gas is available to cool and clean the reversing passages of the heat exchanger 34 and there is make-up gas available to maintain the high purity and lower purity reflux cycles. It will be understood, of course, that increased percentage recovery of argon involves increased cost of operation, due mainly to the necessary increase in the refrigeration requirements.

If for any reason it becomes necessary or desirable to shut down the nitrogen compressor 152, as for example due to clogging of the heat exchanger passages 162, 172, or 174 with oil from the compressor, and, as a consequence there is insufficient refrigeration available to permit full liquid production, the plant can be operated as a gas plant. In this case, sufficient refrigeration can be made available by utilizing pressure energy developed in the air compressor 22 in conjunction with the work expansion capacity of the turbine 64, the turbine 106, or both. Cold product nitrogen gas is expanded in turbine 64 and delivers refrigeration in passage 62 and passage 68 of heat exchanger 34 to the incoming air streams. Evaporated rich liquid is expanded in turbine 106 and delivers refrigeration in passage 104 and passage 32 or passage 110 of heat exchanger 34 to the incoming air streams.

Bypass valves 212 and 214 may be provided as shown for bypassing the turbines 64 and 106, respectively, for use in case of repairs of other emergencies involving either or both of the turbines.

The various novel features disclosed herein may be used together or, if desired, one or more of the features may be used alone or in various combinations, depending upon the amount of flexibility desired in the operation of the air separation plant. For example, one or both of the

turbines 64 and 106 may be omitted or bypassed, although each turbine is important for obtaining the most flexibility and maximum efficiency. The subcoolers 146 and 148 may or may not be provided, although these are important to the efficiency of the refrigeration system. The silica gel adsorber 90 may or may not be provided, as desired.

While illustrative forms of apparatus, methods and processes in accordance with the invention have been described and shown herein, it will be understood that numerous changes may be made without departing from the general principles and scope of the invention.

I claim as my invention:

1. In an air separation system designed for proportioning its product output as between nitrogen and oxygen according to varying demand from time to time, in combination, a relatively high pressure nitrogen column for producing relatively high purity nitrogen and an oxygen-rich liquid, a relatively low pressure oxygen column for producing high purity oxygen from said oxygen-rich liquid; means to economically dispose of excess oxygen during intervals of relatively high demand for nitrogen product output, said means comprising, means to divert and evaporate a part of the said oxygen-rich liquid by heat exchange with a warmer process stream that is on its way from said high pressure nitrogen column to serve as reflux in said nitrogen column, thereby salvaging refrigeration from said oxygen-rich liquid, work expansion means for salvaging pressure energy from said evaporated portion of oxygen-rich liquid, means to vent to the atmosphere the work-expanded oxygen-rich material from said work expansion means, whereby the venting of partially processed oxygen-rich material to the atmosphere is substituted for the venting of more fully processed high purity oxygen, means to derive an argon concentrate from said oxygen column, nitrogen cycle means for refluxing said oxygen column and for furnishing refrigeration for both said columns, means determining a path in said cycle means whereby there is continual recirculation of material in said path, and means for heat exchanging the said recirculating material in said path with incoming air that is on its way to said nitrogen column for processing into component gases, thereby aiding in refrigerating said incoming air, the said recirculating material serving to provide reflux for said oxygen column in desired quantity and quality substantially irrespective of material withdrawal of nitrogen product from the system to maintain a desired condition for producing said argon concentrate.

2. In an air separation system which produces a relatively high purity nitrogen effluent from a high pressure nitrogen column and nitrogen effluent of lesser purity from a low pressure oxygen column, and which derives an argon concentrate from said oxygen column, the method of refluxing and refrigerating said system, which method comprises the following steps: in a first nitrogen cycle, taking nitrogen effluent from said nitrogen column, dividing said effluent into first and second streams, using heat from said first stream in heat exchange to evaporate a liquid process stream, using heat from said second

stream to evaporate liquid oxygen derived from the bottom of said oxygen column, recombining said first and second streams and pumping at least a portion of the combined streams into the nitrogen column as reflux therefor; in a second nitrogen cycle, taking nitrogen effluent from said oxygen column, using refrigeration contained in said effluent to cool reflux material that is on its way to the upper portion of the oxygen column, dividing said thus cooled effluent into first and second streams, using refrigeration contained in the first said stream to cool incoming air that is on its way to being separated into component gases, using refrigeration contained in the second said stream to cool material of said second nitrogen cycle as it is coming out of a compressor, recombining said last-mentioned two streams, compressing the combined streams in said compressor, cooling the compressed material, diverting and work-expanding a portion of the compressed material, further cooling the expanded material by using heat thereof to aid in evaporating said liquid oxygen derived from the bottom of the oxygen column, and by heat exchange with the effluent leaving the oxygen column, and by throttle expansion; cooling the remainder of the compressed material by heat exchange with the effluent leaving the oxygen column and by throttle expansion, combining said throttle expanded streams and delivering the combined streams to the upper portion of the oxygen column as reflux therein; withdrawing at least some nitrogen product from said first nitrogen cycle, and transferring a selected amount of high purity nitrogen from said first nitrogen cycle to said second nitrogen cycle to maintain the quality and quantity of the reflux material in said second nitrogen cycle as required to promote desired argon production irrespective of material withdrawal of nitrogen product from the system.

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