

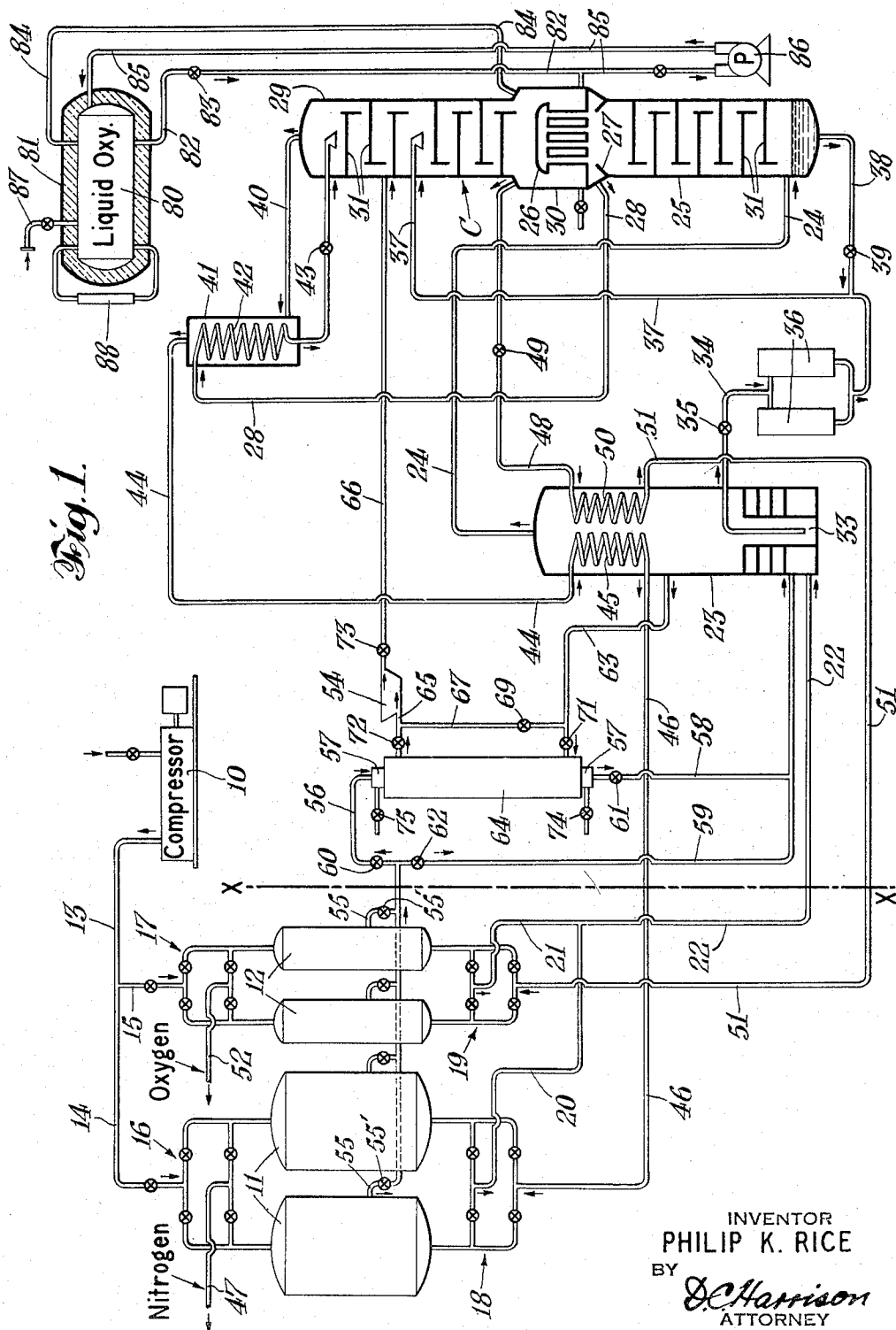
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PROCESS OF AND APPARATUS FOR LOW-TEMPERATURE
SEPARATION OF AIR

2,664,718

Filed Oct. 11, 1949

3 Sheets-Sheet 1



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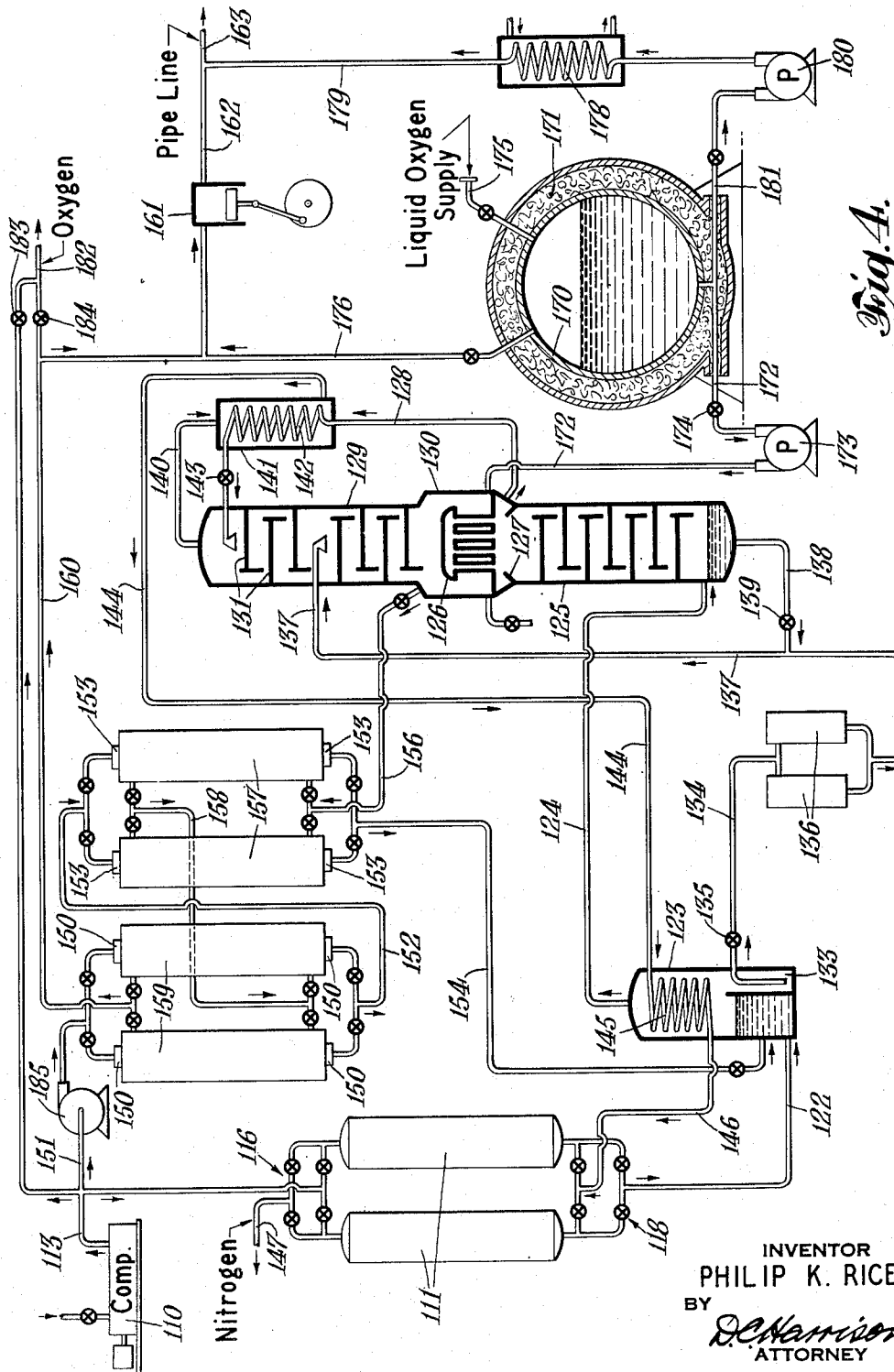
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UNITED STATES PATENT OFFICE

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PROCESS OF AND APPARATUS FOR LOW-TEMPERATURE SEPARATION OF AIR

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19 Claims. (Cl. 62—122)

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This invention relates to an improved process and apparatus for the low-temperature separation of air to produce oxygen and nitrogen products, and more particularly to improvements of such process and apparatus resulting in the simplification of, or elimination of, refrigeration-producing equipment, and a reduction of the time and cost of starting an air separation system.

In systems for the low-temperature rectification of air, especially those for producing large amounts of oxygen, removal of the water vapor and carbon dioxide is more economically effected by refrigeration than by mechanical means, but removal of the impurities, and particularly carbon dioxide, by refrigeration, has necessitated the use of expensive heat exchangers provided in duplicate or regenerative heat exchangers with low initial pressures. If periodically reversed regenerators, as proposed by M. Franklin, for example, United States Patent No. 1,970,299, are employed, refrigeration requirements of the process necessitate an expansion with the production of external work and the gas which is expanded is most conveniently a portion of the air. Since partly-cooled air would contain carbon dioxide and thus interfere with the expansion process, it has been proposed to employ air that has been cooled to condensation temperature, freed of carbon dioxide, and reheated to the desired temperature, for the efficient expansion with external work. Such reheating employs large heat exchangers that are provided in duplicate because the air employed for the reheating contains carbon dioxide which is deposited on heat exchanger surfaces. The duplication permits thawing of a clogged heat exchanger without interruption of the operation. An example of such a system is shown and described in United States Patent No. 2,619,810, issued December 2, 1952, to Philip K. Rice and Edward F. Yendall. Since such heat exchangers are a large item of equipment, the elimination of at least one of them is an important advantage.

Usually in such systems it is more economical to provide equipment for producing refrigeration (e. g., expansion engine or turbine and heat exchanger) of a size and refrigeration-producing capacity large enough only for the desired steady rate of oxygen production. Therefore the starting of such a system after a shut-down period requires a long initial period of nonproductive operation. The practice of installing extra refrigeration-producing capacity to shorten the starting period adds expensive nonproductive equipment.

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Among the objects of the present invention are to provide improved process of and apparatus for the low-temperature separation of air which permits operation to continue during a period when part of the heat exchange and refrigeration-producing devices are shut down for elimination of accumulated carbon dioxide; and which supplements the refrigeration produced by the operating refrigeration-producing devices so that quick starting of the entire apparatus after a long period of shut down can be effected without the use of extra mechanical refrigeration capacity.

Customary air separation plants are efficiently operated only at a substantially constant and continuous production rate, but there are occasions where the complete oxygen output of a plant could economically supply a single large consumer, such as a steel mill, which however usually has a demand for oxygen that varies considerably at different times of the day. To provide such a plant, which is large enough to supply the peak demand, involves not only high investment costs, but great inefficiencies, if it is attempted to operate the plant at sub-normal rates; or if operated at a continuous full rate, there is a serious problem of disposal of excess oxygen. By the principles of this invention such problems are efficiently solved by providing a plant including a low temperature air separation apparatus which is large enough to supply only the normal constant oxygen demand, and also a store of liquid oxygen with means to vaporize portions thereof according to a variable demand in excess of the normal. The stored oxygen consumed during peak demand periods can be replenished during periods of sub-normal demand. Further according to the invention, the stored liquid oxygen can be economically shipped to the plant from a large central plant because it is then practical to entirely eliminate the expense of providing mechanical refrigeration-producing devices.

Further objects of the present invention are: to provide a process of and apparatus for low-temperature separation of air by which a normal steady oxygen demand is supplied by separation of air by low-temperature rectification and the excess demand peaks are supplied by vaporization of stored liquid oxygen; to provide an air-separating plant in which mechanical means to produce refrigeration may be eliminated, the refrigeration requirement being supplied by liquid oxygen; and to provide a simple apparatus by which the refrigeration of liquid oxygen which is vaporized to supply part of a demand for gase-

ous oxygen is usefully employed for the refrigeration requirement of low-temperature separation of enough air to provide the balance of the demand for gaseous oxygen.

These and other objects and advantages of the invention will become apparent from the following description and the accompanying drawings showing exemplary embodiments of apparatus for separating gas mixtures such as air, and including improvements according to the invention. In the drawing:

Figs. 1, 2, and 3 are schematic views of an exemplary air separating apparatus including mechanical refrigeration-producing means and, according to the invention, three embodiments of means to supply refrigeration from a stored body of liquid which in Fig. 1 is liquid oxygen, in Fig. 2 is liquid air, and in Fig. 3 is liquid nitrogen; and

Fig. 4 is a schematic view of an air separation plant without mechanical refrigeration-producing devices and, according to the invention, including means for supplying the refrigeration from a stored body of liquefied gas such as liquid oxygen.

In the drawings, similar items of apparatus in the several figures are designated by the same reference characters.

Referring now to the drawings, and particularly to Fig. 1, a means for preparing air for rectification which is intended to be representative of means customarily employed for such purposes, includes at 10 a compressor which preferably compresses the air to be separated to a pressure below 125 p. s. i. (pounds per square inch). Such air is cooled to substantially its condensation temperature by passage through alternately reversed pairs of regenerators 11 and 12, the pair of regenerators 11 being cooled by outflowing nitrogen product and the regenerators 12 being cooled by outflowing oxygen product. The air is conducted to the warm ends of the regenerators by a conduit 13 with branches 14 and 15. The branches 14 and 15 connect respectively to reversing valves 16 and 17 at the warm ends respectively of regenerators 11 and 12. Sets of automatic valves 18 and 19 at the cold ends of the regenerators 11 and 12 discharge the cooled air, which has been freed of moisture and carbon dioxide in the regenerators, to branch conduits 20 and 21 connecting to conduit 22 that discharges the air into the lower part of a scrubber separator 23. The scrubber separator 23 is a device for washing the incoming air with liquid air to scrub out residual hydrocarbon impurities and any particles of residual carbon dioxide. The upper portion of the scrubber separator 23 eliminates entrained liquid particles and provides a clean vapor that is conducted by conduit 24 to the lower end of an air-separating rectifying column C.

The rectifying column C may be of customary construction, having a high pressure chamber 25 closed at its upper end by a condenser 26. The condenser 26 operates in the customary manner to condense vapors rising in the chamber 25, producing reflux for the chamber, and also producing liquid nitrogen that is collected on a shelf 27 directly under part of the condenser 26. The liquid nitrogen from the shelf 27 is conducted by a conduit 28 to the upper end of a low-pressure rectifying chamber 29 which is mounted above the chamber 25 and has at its lower end a liquid oxygen collecting space 30 that surrounds the condenser 26. The rectifying chambers may be

provided with customary gas and liquid contact rectifying trays 31.

In the scrubber 23 the scrubber liquid that collects impurities flows into a cup 32 from which it is discharged through a conduit 34 provided with an expansion valve 35. The conduit 34 conducts the liquid to a set of filters 36 and the cleaned scrubber liquid is conducted from the filters through a conduit 37 to an intermediate portion of the low-pressure rectifying chamber 29. Liquid that collects in the lower part of the high-pressure rectifying chamber 25 is conducted by a conduit 38 controlled by expansion valve 39 to the conduit 37 for delivery to the intermediate part of the low-pressure chamber 29. The nitrogen product of rectification leaves the chamber 29 through a conduit 40 which preferably delivers the cold gaseous effluent to a heat exchanger 41 surrounding a heat exchange coil 42 which is interposed in the conduit 28 for sub-cooling the nitrogen reflux so as to avoid excessive vaporization when the reflux is expanded through an expansion valve 43 also interposed in the conduit 28. From heat exchanger 41 a conduit 44 conducts the effluent nitrogen to a heat exchange coil 45 located in the upper part of the scrubber separator 23, the purpose of the heat exchange coil 45 being to liquefy some of the scrubbed air to provide scrubber liquid. From coil 45 a conduit 46 conducts the effluent nitrogen to the reversing valve system 18 at the cold end of the regenerators 11. The warmed nitrogen leaves the reversing valve system 18 at the warm end of the regenerators through a conduit 47.

The oxygen product of rectification which boils in the space 30 produces cold gaseous oxygen that is conducted by a conduit 48 controlled by a valve 49 to a second heat exchange coil 50 also in the upper part of the scrubber chamber 23 and from coil 50, a conduit 51 conducts the product oxygen to the reversing valve system 19 at the cold end of the regenerators 12. The oxygen product is delivered from the warm end of the regenerators 12 through a conduit 52 controlled by the reversing valves 17.

The portions of the system described thus far do not provide enough low-temperature refrigeration for operating the system, and therefore a means for producing the necessary refrigeration must be employed. Exemplary means is provided by an expansion turbine 54 which expands a portion of air from substantially the compression pressure to the pressure of the column 29. For such expansion, air free of carbon dioxide is preferred to avoid difficulty, so that a portion of the scrubbed air from the chamber 23 is employed. Such air, however, is already at condensation temperature, and it must be warmed to provide efficient production of refrigeration by expansion with external work.

Such warming is preferably effected by a portion of the incoming air in order to avoid loss of refrigeration. To this end there is drawn from an intermediate part of the regenerators through connections 55 controlled by valves 55' an equivalent portion of air which is conducted by a conduit 56 to the warm end of a heat exchanger passage 57. From the cold end of the passage 57 a conduit 58 conducts the cooled withdrawn portion of air to the lower part of the scrubber chamber 23. For use as explained hereinafter, a by-pass 59 from conduit 56 to conduit 58 is provided and valves 60, 61, and 62 are interposed respectively in conduits 56, 58, and 59. The air to be expanded is taken from chamber 23 through

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a conduit 63 that conducts it to the cold end of a heat exchange passage 64 around the passage 57, and from the warm end of the heat exchange passage 64 a conduit 65 conducts the air to the inlet of the expansion turbine 54. A conduit 66 conducts the expanded air to an intermediate part of the chamber 29.

There is preferably provided a by-pass 67 between conduit 63 and conduit 65 controlled by a valve 69. The connections of conduits 63 and 65 with the heat exchange passage 64 are controlled by valves 71 and 72 respectively, and a valve 73 is interposed in the conduit 66. Valved connections 74 and 75 are disposed at the ends of the heat exchange passage 57 for use when thawing the passage of accumulated carbon dioxide.

Since only one heat exchanger 57 is provided, the turbine 54 is shut down when the heat exchanger 57 is taken out of service for thawing. Refrigeration for continuing the operation is provided, according to Fig. 1, by supplying liquid oxygen to the oxygen boiler space 30. Such liquid oxygen may be stored in a well-insulated storage tank 80 which is surrounded by an insulating jacket 81 providing one of the best insulations for the purpose, for example, a space filled with powder and highly evacuated of gas. The tank 80 may be large enough to supply liquid for a period necessary to thaw out the heat exchanger 57. Alternatively, the tank 80 may be much larger for purposes to be described hereinafter.

The oxygen is fed from tank 80 through a conduit 82 controlled by a valve 83 and connecting to the oxygen boiler space 30. A pipe 84 may also be provided connecting the upper parts of the space 30 and the tank 80 for equalizing of pressures and transmission of vapors from the tank to the space 30. During normal operation the tank 80 may be gradually filled by drawing liquid oxygen from the space 30 through a conduit 85 connecting with the tank 80. If the tank 80 is mounted at the same level as the space 30, gravity flow could be relied upon for moving the liquid into the tank. If the tank 80 is positioned at a higher level, as indicated in Fig. 1, a liquid oxygen pump 86 may be interposed in the conduit 85. Since it may be desirable to add liquid oxygen to the tank 80 from an outside source, a supply connection 87 may also be provided. The tank 80 may also be provided with a suitable liquid level indicating device 88. All cold conduits and apparatus are protected by heat insulation according to the usual practice.

The apparatus of Figs. 2 and 3 is similar to that of Fig. 1 in respect to the elements designated by the same reference characters, but differ in the provisions for producing the refrigeration requirement from portions of stored liquid. Thus in Fig. 2 a tank 90 is provided for holding an accumulated body of liquid air, the liquid air being produced by a condenser 92 disposed within an auxiliary oxygen boiler chamber 93. The condenser 92 is interposed in the scrubbed air conduit 24 and the liquid produced by the condenser 92 is conducted in part through a conduit 94 to a conduit 95 connected between the lower ends of the scrubber 23 and the rectifying chamber 25. A branch 96 of conduit 94 controlled by a valve 97 feeds liquid air made by the condenser 92 at a very slow rate into the tank 90 and when the refrigeration-producing device is shut down, liquid air is drained from the tank 90 at a controlled rate through a conduit 98 to the conduit 95, the rate being controlled

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by a valve 99 in conduit 98. The boiler chamber 93 is interposed in the gaseous product oxygen conduit 48, and for feeding liquid oxygen from the space 30 to the boiler 93 there is provided a conduit 100 controlled by a valve 100'. A gas phase connection 101 between chambers 39 and 93 may also be provided.

In Fig. 3, a storage tank 102 is positioned to receive liquid nitrogen through a conduit 103 from the lower part of a condenser 104, the conduit 103 being controlled by a valve 105. The condenser 104 is disposed in the auxiliary oxygen boiler 93 similar to that of Fig. 2. The condenser 104 receives nitrogen from the upper part of the main condenser 26 through a connecting conduit 107. Liquid nitrogen produced by condenser 104 in excess of the rate required for filling the tank 102 during a period of operation is conducted through a branch conduit 108 leading from conduit 103 to the transfer conduit 28, and for feeding liquid nitrogen into the rectification device when the expansion turbine is shut down a conduit 109 is connected from the bottom of the tank 102 and the transfer conduit 28. Conduits 108 and 109 have control valves 108' and 109' interposed therein.

The normal operation of the system of Figs. 1, 2, and 3 is believed clear from the above description. It is pointed out, however, that during normal operation, with the expansion turbine 54 in operation, the amount of refrigeration produced by the turbine is to be slightly in excess of that required for operating a plant to produce the desired amount of oxygen product. The slight excess of refrigeration is provided so that the liquid which is to be accumulated in the storage tanks 80, 90, or 102 can be withdrawn from the system at a slow rate. Thus in the case of Fig. 1 the pump 86 operates to draw liquid oxygen at a very slow rate from the oxygen boiler space 30 and deposits it in the tank 80. Then when the heat exchanger 57 is to be cut out of service and the turbine 54 is to be shut down, operation of the plant and withdrawal from the system may continue by closing valves 60, 61, 71, and 72 and opening valve 62 to by-pass the withdrawn air directly to the scrubber 23. Substantially all the scrubbed air then enters the lower column 25 through conduit 24. When it is desired to maintain the turbine at operating temperature, a small flow of scrubbed air may be passed from conduit 63 by conduit 67 through the turbine to the upper column, by cracking valves 69 and 73. The heat exchange passage 57 is thawed by passing warm dry gas through it by use of the valved connections 74 and 75.

To prevent the lowering of the liquid levels in the rectifying column due to loss of refrigeration, liquid oxygen is drawn from the stored body in tank 80 as needed. Such liquid oxygen may be fed to the liquid oxygen collecting space 39 at the needed rate regulated by the valve 83. As soon as heat exchanger 57 has been cleaned, it may be returned to service by opening valves 60, 61, 71, 72, 73 and closing valves 62 and 69. When the turbine 54 is operating properly, the feeding of liquid oxygen to the chamber 30 can be stopped by closing valve 83 and replenishment of liquefied oxygen begun by operation of pump 86.

If the complete plant is shut down for a period, the starting of the plant can be facilitated by passing liquid oxygen from tank 80 to the oxygen boiler 30 to supplement the refrigeration produced by the turbine 54. After steady operation is attained the liquid oxygen store can be replen-

ished. Also, if desired, liquid oxygen can be shipped to the plant and filled into tank 80 through the connection 87.

In the embodiment of Fig. 2 the liquid air tank 90 is gradually filled during normal operation with valve 97 slightly opened, and when the refrigeration turbine is shut down, valve 97 may be closed and liquid fed to the system from the tank 90 by opening control valve 99 sufficiently to regulate the feed at the required rate. Obviously the liquid air from tank 90 could be fed to the scrubber, or preferably, to the lower part of the high pressure chamber 25, from which it would be transferred with liquid from said chamber through conduit 38 to the low-pressure rectifying chamber 29.

The embodiment of Fig. 3 may be operated similarly, except that it is liquid nitrogen that is condensed and accumulated at a desired slow rate and then during periods of turbine shut down, is gradually fed to the upper part of the low-pressure rectifying column.

Referring now to the embodiment illustrated in Fig. 4, it will be seen that the system lacks a specific mechanical refrigeration-producing device, and the low-temperature refrigeration needed for operation is obtained by the evaporation of liquid oxygen which may be shipped to the plant. Air is compressed in the compressor 110 and passed to nitrogen regenerators 111 through a conduit 113 in cooperation with reversing valves 116 and the cooled air is conducted from the regenerators through the medium of reversing valves 118 and a conduit 122 conducting it to the lower part of the scrubber chamber 123. From the top of the scrubber chamber 123 the air is conducted by conduit 124 to the lower part of the high-pressure rectifying chamber 125. The chamber 125 communicates with main condenser 126 in the lower part 130 of the low-pressure rectifying chamber 129 and from a shelf 127 at the upper part of chamber 125 the transfer conduit 128 conducts liquid nitrogen to the top of the column 129. The scrubber liquid from the overflow cup 133 in chamber 123 is conducted by conduit 134 and control valve 135 through filters 136 and through a conduit 137 to an intermediate part of the low-pressure column 129. A transfer conduit connection 133 conducts liquid from the bottom of chamber 125 to the transfer conduit 137 after throttling through a valve 139. Effluent nitrogen flows from the top of the rectifying column through conduit 140 to a heat exchanger 141 in which is heat exchange coil 142 of the transfer conduit 128, and from heat exchanger 141 a conduit 144 conducts the nitrogen to a heat exchange coil 145 in the upper part of the chamber 123, the nitrogen being then conducted from coil 145 through a conduit 143 to the regenerators 111 through the reversing valves 113. The effluent nitrogen leaves the system through a conduit 147.

If it is desired to produce an oxygen product of, for example, not over 98% purity, a pair of oxygen regenerators could be used to recover the refrigeration of the product oxygen as, for example, shown in Figs. 1 to 3. However, if at least part of the oxygen demand is for high-purity oxygen such as 99.5% purity, the warming of the oxygen product is effected by indirect heat exchange, and to this end there is provided a series of heat exchangers comprising heat exchanger passages 150 provided in duplicate for receiving a portion of compressed air from conduit 113 through a conduit 151. From the cold end of the

heat exchange passages 150 a conduit 152 conducts the partly-cooled air to another pair of heat exchange passages 153 in which the air may be partially liquefied. The thus cooled and partially-liquefied air is conducted from the heat exchange passages 153 through a conduit 154 to a lower part of the scrubber chamber 123. The heat exchangers 150-153 are installed in duplicate so that one of a pair can be thawed out while the other is on stream so as not to interrupt operation. The product oxygen to be warmed is led by a conduit 156 to the cold end of heat exchange passages 157 around passages 153 and from the warm end of passages 157 through a conduit 158 to the cold end of heat exchange passages 159 around passages 150. The warmed oxygen is then conducted by a conduit 160 to the inlet of an oxygen compressor 161 which delivers it through a conduit 162 to a pipe line 163 leading to oxygen-consuming devices such as various operations in a large steel mill requiring high-purity oxygen.

The refrigeration necessary for continuing operation of the plant thus far described is provided by liquid oxygen which is fed from a storage tank 170 disposed within highly efficient heat insulation 171. If this tank is situated at a proper elevation with respect to the rectifying column, the force of gravity may be relied upon for draining liquid at a desired rate from the bottom of the storage tank 170 through a conduit 172 to the oxygen boiling chamber 130. Alternatively the liquid oxygen in the tank 170 may be stored therein under a pressure slightly higher than the pressure existing in the low-pressure rectifying chamber 129, in which case the oxygen feed may be forced by pressure difference to flow from the tank 170 to the chamber 130. As another alternative, illustrated herein, a liquid oxygen pump 173 may be interposed in the conduit 172 so that the tank 170 may be at a low level and operated under atmospheric pressure, the liquid feed being forced by the pump from the tank 170 into the chamber 130. In any event, a control valve 174 is interposed in the conduit 172. The tank 170 may be filled from time to time through a filling connection 175, and vapors produced by heat leak to the stored liquid may be transferred from the upper part of the tank 170 through a conduit 176 to the suction side of the oxygen compressor 161.

When the pipe line demand is variable, the plant is economically constructed and operated to produce oxygen corresponding to the low constant demand rate, and for supplying the excess peaks of demand there is conveniently provided a vaporizer 178 interposed in a conduit 179 connected between the discharge side of a pump 180 and the pipe line 163. The suction side of the pump 180 is connected by a valved conduit 181 with the bottom of the storage tank 170. If a quantity of lower-purity (for example, 95%) oxygen is also required, such purity oxygen can conveniently be provided and supplied to a pipe line 182 by admixing a portion of compressed air with a portion of the high-purity oxygen delivered through the conduit 160, the connections for such purpose being controlled by valves 183 and 184 respectively.

In the operation of the plant it may be desirable to have the air supplied through the heat exchangers 150 and 153 at a slightly higher pressure than that which is supplied through the regenerators 111 and therefore there may be interposed in the conduit 151 a booster compressor 185.

In the operation of the embodiment of Fig. 4, all the oxygen shipped to the plant in liquid form and periodically filled into the tank 170 is used to furnish gaseous oxygen to the consumer pipelines. A larger amount of oxygen, however, can be produced by operation of the air separation plant than the amount of oxygen produced by vaporizing the liquid oxygen fed to the chamber 130 from tank 170. At the same time the refrigeration of the liquid oxygen fed to the chamber 130 is usefully employed. It is seen therefore that the system economically supplies a large amount of gaseous oxygen at or close to the place of consumption while requiring the shipment of only moderate amounts of liquid oxygen from a distant liquid oxygen plant. The investment expense as well as the maintenance expense of a refrigeration turbine and large heat exchanger are likewise saved. The system is capable of supplying a variable demand with a low investment and operating expense.

It will be understood that changes in the details of the systems disclosed herein may be made without departing from the principles of the invention. A continuation-in-part of this application is application Serial No. 344,431, filed March 24, 1953.

What is claimed is:

1. In a process for the low-temperature separation of air by rectification in which air freed of moisture and carbon dioxide is at least partly liquefied and the gaseous and liquefied portions are rectified to separate oxygen and nitrogen products, which products are used to cool further portions of air, supplying the entire low-temperature refrigeration requirement for such process which exceeds that regained from the warming of said oxygen and nitrogen rich products during at least a substantial period of continuous operation by providing a body of liquid having a composition similar to one of the liquids involved in the air separation process; holding such body of liquid at low temperature and separate from the liquids present in the separation process; and, during said period of continuous operation, continuously feeding portions of said body of liquid to the rectification where the liquid composition is similar to that of the body of liquid, and at a rate sufficient to supply said entire low-temperature refrigeration requirement, the gas products resulting from the liquid fed to the rectification from said body supplementing said oxygen and nitrogen rich products in cooling the further portions of air.

2. A process according to claim 1 in which said liquid comprises mainly liquid air.

3. A process according to claim 1 in which said liquid comprises mainly liquid oxygen.

4. A process according to claim 1 in which said liquid comprises mainly liquid nitrogen.

5. In a process for the low-temperature separation of air by rectification in which air freed of moisture and carbon dioxide is at least partly liquefied and the gaseous and liquefied portions are rectified to separate oxygen and nitrogen products, which products are used to cool further portions of air, the steps of providing a body of liquid made from air; holding said body of liquid at low temperature and separate from the liquids involved in the rectification; stopping the inflow of air and the rectifying operation for a desired shut-down period while conserving said body of liquid; and concurrently with the resumption of said operation after such shut-down period, utilizing the re-

frigeration of said stored liquid to facilitate the starting.

6. A process according to claim 5 in which said liquid comprises liquid air.

7. A process according to claim 5 in which said liquid comprises liquid oxygen.

8. A process according to claim 5 in which said liquid comprises liquid nitrogen.

9. In a process for the low-temperature separation of air by rectification in which air freed of moisture and carbon dioxide is at least partly liquefied and the gaseous and liquefied portions are rectified to separate oxygen and nitrogen products, which products are used to cool further portions of air, the steps of producing refrigeration required for the normal operation of the process by expansion with production of external work of a portion of the air; accumulating gradually a store of a liquid produced from air during such normal operation; stopping for a desired period the production of refrigeration by external work; and during said stoppage, continuing the operation of air separation by utilizing the refrigeration of said stored liquid in lieu of that normally produced by the work expansion.

10. A process according to claim 9 in which said liquid comprises liquid air.

11. A process according to claim 9 in which said liquid comprises liquid oxygen.

12. A process according to claim 9 in which said liquid comprises liquid nitrogen.

13. In a process for separation of air by low-temperature rectification in which a main stream of air under pressure is freed of moisture and carbon dioxide, cooled to condensation temperature, subjected to at least partial liquefaction and then rectified to produce oxygen and nitrogen-rich products, and in which a second stream of air freed of moisture and cooled to a higher temperature such that it contains carbon dioxide, is further cooled by heat exchange with a portion of the main stream whereby carbon dioxide is deposited during such heat exchange and in which said portion of the main stream after being warmed by the heat exchange is expanded with production of external work to produce refrigeration for the normal operation of the process, the steps of providing a body of liquid made from air and having a composition equivalent to one of the liquids present in the rectification; discontinuing the said work expansion and the said heat exchange for a period of time sufficient to remove deposited carbon dioxide by thawing while by-passing said portion of the main stream to the rectification; and during such period of time, supplying liquid from the body of liquid to the rectification at a zone of equivalent composition at a rate to compensate the lack of refrigeration during the suspension of work expansion.

14. In a process for the low-temperature separation of air by rectification in which air freed of moisture and carbon dioxide is at least partly liquefied and the gaseous and liquefied portions are rectified to separate oxygen and nitrogen products, which products are used to cool further portions of air, the steps of providing a storage body of liquid oxygen; holding said body of liquid oxygen separate from the liquids involved in the rectification; during continuous rectifying operation, utilizing portions of said body of liquid oxygen to produce refrigeration for the rectification at a rate sufficient to provide the refrigeration requirements of the air separation in excess of

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that regained by the cooling of the air by the products; and delivering the oxygen product of the air separation and the oxygen product corresponding to the liquid fed from said body to consuming means.

15. Apparatus for the low-temperature separation of air by rectification in a rectifying column having an oxygen-rich liquid reboiler, which apparatus includes means for partly liquefying the air fed to the column, means for expanding a portion of air with the production of external work, a heat exchanger for regulating the temperature of the portion of air to be expanded, and means for by-passing said heat exchanger and said expansion means; an insulated container for holding a liquid made from air; means for feeding liquid from said container to said column; and means for regulating said feed during a period when said heat exchanger and expansion means are by-passed.

16. Apparatus according to claim 15 in which said liquid is liquid air and said feeding means connects with an intermediate part of the rectifying column.

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17. Apparatus according to claim 15 in which said liquid is oxygen and said feeding means connects with the oxygen-rich liquid reboiler.

18. Apparatus according to claim 15 in which said liquid is nitrogen and said feeding means connects with the upper end of said rectifying column.

19. Apparatus according to claim 15, which includes means for feeding a liquid made from the air in the system slowly into said container during operation of said expansion means.

PHILIP K. RICE.

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