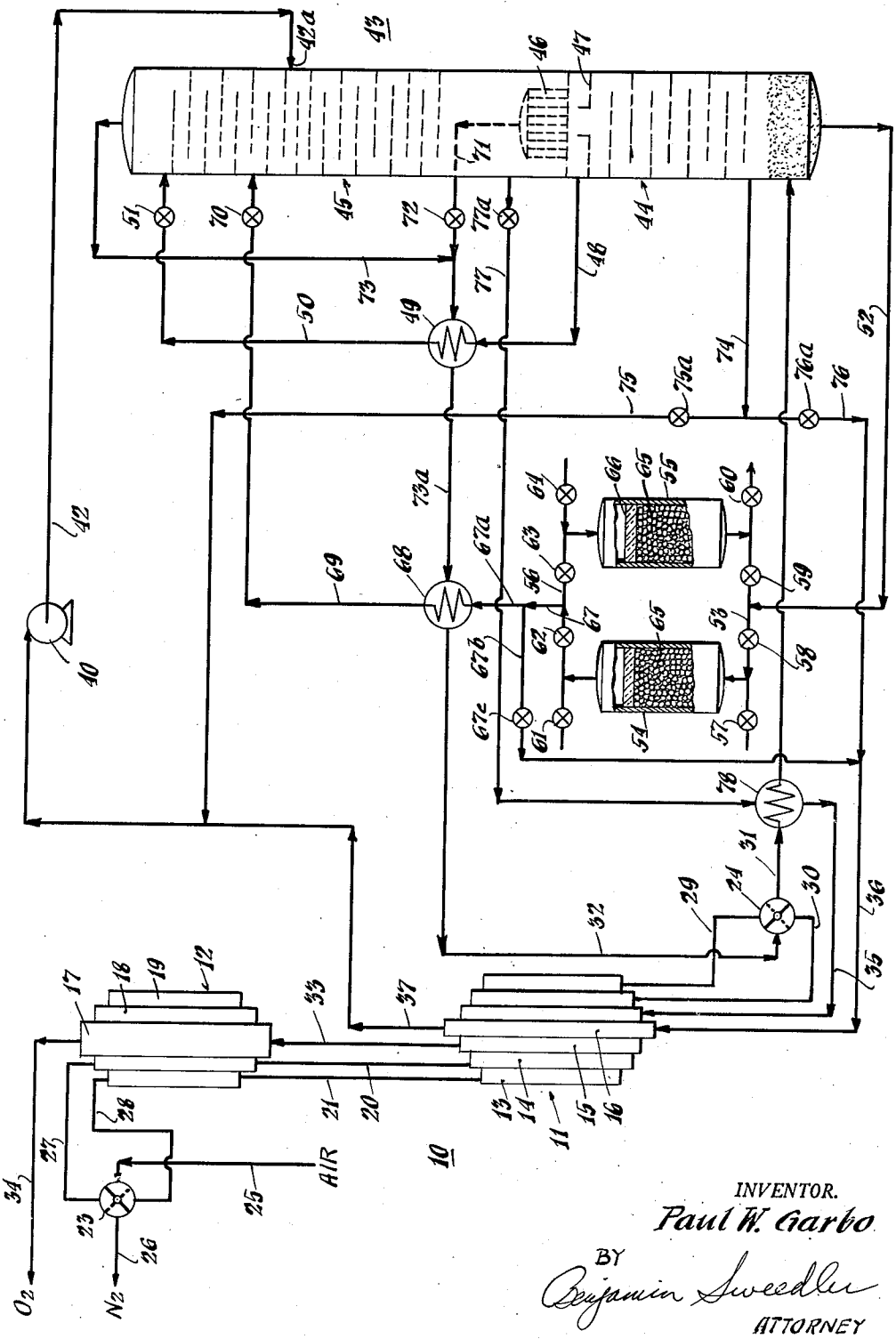
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PROCESS FOR PRODUCING OXYGEN BY THE LIQUEFACTION AND RECTIFICATION OF AIR

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PROCESS FOR PRODUCING OXYGEN BY THE LIQUEFACTION AND RECTIFICATION OF AIR

Paul W. Garbo, Freeport, N. Y., assignor to Hydrocarbon Research, Inc., New York, N. Y., a corporation of New Jersey

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This invention relates to the production of oxygen by the liquefaction and rectification of air in a rectification system comprising low and high pressure stages.

All temperatures herein are in degrees F., pressures in pounds per square inch gauge, and percentages are by volume.

Oxygen processes are known which involve the flow of air under pressure through reversing exchangers in which the air recovers the cold content of the outgoing products of rectification and the thus cooled air is introduced into the high pressure stage of the rectification system. In such processes the air is thus cooled in the exchanger to a temperature close to its condensation point at the pressure existing in the reversing exchanger. The carbon dioxide present in the air is thereby substantially completely removed therefrom and deposited in the flow path in the exchanger through which the air flows. Periodically the flows of the rectification product and the air through the reversing exchanger are reversed through their respective flow paths. The rectification product stream then removes by sublimation the carbon dioxide deposited in the exchanger, thus purging same.

It is an object of this invention to provide a process for producing oxygen in which improved purging of the exchanger takes place.

Another object is to provide such process in which disturbance of the fractionating conditions within the rectification system is minimized.

Other objects and advantages of this invention will be apparent from the following detailed description thereof.

In accordance with this invention liquid from the high pressure stage of the rectification system is passed through at least the cold end of the reversing exchanger in indirect heat exchange relation with the air and/or rectification product passing therethrough. This liquid is caused to boil by the heat extracted from the gas stream or streams flowing in indirect heat exchange relation therewith and the resultant vapors are expanded to produce refrigeration which is employed to compensate for enthalpy losses and for heat leaks into the system.

A specific embodiment of this invention involves the passage of air compressed to a pressure of 60 to 150, preferably 75 to 125, pounds per square inch and at a temperature of 50° to 110° F., preferably 60° to 80° F., through a reversing exchanger in indirect heat exchange relation with a stream of rectification product, e. g., nitrogen, the air being thus cooled to a temperature

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close to its condensation point. The reversing exchanger may be of either the regenerative or of the recuperative type. The thus cooled air is then passed to the high pressure stage of the rectification system and preferably brought into intimate contact with the crude liquid oxygen maintained in the lower portion of the high pressure column. The crude liquid oxygen, desirably after passage through a purification system which effects removal of residual carbon dioxide and any acetylene which may be present, is divided into two streams. One, the major stream consisting of from 90% to 95% of the liquid collected at the bottom of the high pressure column, is expanded and introduced as reflux into the low pressure stage. The other stream consisting of from 5% to 10% of the crude liquid oxygen collected at the bottom of the high pressure column is warmed by flow through at least the cold end of the exchanger where the liquid is vaporized by heat exchange with the air and/or rectification product passing therethrough. Preferably, a stream of vapor of substantially the same composition as that of air and herein referred to as of essentially air composition, preferably withdrawn from the bottom portion of the high pressure stage, is employed as a carrier to effect introduction of the liquid into the exchanger. In this way droplets of the liquid are introduced into and caused to flow through a substantial portion of the flow path for the liquid through the exchanger before complete vaporization of the liquid is effected.

The resultant vapors admixed with a stream of essentially air composition are introduced into an expander. Of the total stream fed to the expander 10% to 25% by volume is derived from the liquid withdrawn from the bottom of the high pressure column. The remainder is a stream of essentially air composition, preferably, also derived from the high pressure column. The stream which is introduced into the expander and expanded to produce the refrigeration necessary to compensate for enthalpy losses and heat leaks into the system corresponds to from 15% to 35%, preferably 15% to 25%, of the amount of air fed to the process. The stream passing through the expander and thence introduced into the low pressure column is usually at least 10% richer in oxygen than ordinary air, since, as pointed out above, from 10% to 25% of this stream is derived from the crude liquid oxygen (generally about 35% to 40% oxygen purity) withdrawn from the bottom of the high pressure column. As compared with prior procedures in

which a portion of cooled air is expanded and the expanded air introduced into the low pressure column, the process of this invention, involving as it does the introduction of a vapor stream enriched in oxygen into the low pressure column, results in less disturbance in the fractionating conditions within the low pressure column.

In the accompanying drawing forming a part of this specification the single figure illustrates diagrammatically a preferred layout of apparatus for practicing the process of this invention. It will be understood, however, this invention may be carried out in other apparatus than that shown in the drawing. For example, any desired number of reversing exchangers may be used instead of the reversing exchanger shown in the drawing, each pair of reversing exchangers arranged in series may be replaced by one long exchanger, reversing exchangers of the regenerative type may be used in lieu of the reversing exchangers of the recuperative type illustrated diagrammatically in the drawing and other rectification systems may be used in lieu of that shown in the drawing including, for example, rectification systems in which separate columns are used for the low and high pressure stages.

Referring to the single figure of the drawing 10 is a recuperative heat exchanger which may be of any well-known type. In the embodiment shown in the drawing it consists of two sections 11 and 12. Section 11 is provided with four flow paths 13, 14, 15 and 16 disposed in concentric relationship in heat exchange relation with each other. Section 12 is provided with interior flow path 17 and concentric paths 18 and 19 disposed in heat exchange relation with each other. The heat exchanger 10 has in each of the paths suitable fins of heat conducting material, e. g., copper or aluminum, permitting rapid and efficient heat exchange between the gaseous media flowing therethrough.

For purposes of illustration and in the interests of simplicity, each flow path is shown on the drawing as consisting of a single tube, the several paths being disposed concentrically. Actually, however, each path in each exchanger may comprise a multiplicity of tubes for flow therethrough. As the construction of the heat exchanger per se does not form a part of this invention and as it may be of any well known type, it is believed further description thereof is unnecessary.

Path 18 is connected with path 14 by line 20 and path 19 with path 13 by line 21. These paths 18, 14 and 19, 13 are the paths through which air and nitrogen flow, the flow of these two media through their respective paths being periodically reversed so that during one step of the process air flows through paths 19 and 13 and nitrogen through paths 18 and 14 and upon reversal during the succeeding step air flows through paths 18 and 14 and nitrogen through paths 19 and 13. Reversal of flow is accomplished by suitably positioning the reversing valves 23, 24 which may be of any well known type. Valve 23 is disposed in the pipe line system consisting of air inlet pipe 25 leading into valve 23, nitrogen exit line 26 leading to any suitable point of nitrogen disposal and pipe lines 27, 28 leading to one end of paths 18 and 19. Lines 29 and 30 lead from the flow paths 13 and 14 of section 11 to valve 24. A line 31 leads from valve 24 through a non-reversing exchanger 78 to the high pressure stage 44 of the rectification system 43 hereinafter described and nitrogen line 32 leads into valve 24.

Flow paths 15 and 17 are the flow paths through which oxygen flows. These paths are interconnected by line 33. Flow path 17 is provided with an exit line 34 leading to a suitable point of oxygen storage or utilization and the flow path 15 is provided with an inlet line 35. Flow of oxygen through flow paths 15 and 17 continues unidirectionally, i. e., flow through these flow paths is not reversed.

Flow path 16 is the flow path into which a portion of the crude liquid oxygen from the base of the high pressure column is introduced, preferably admixed with a gaseous carrier stream of essentially air composition. The liquid thus introduced is vaporized and the resultant oxygen-enriched air stream is warmed by flow through path 16 in indirect heat exchange relation with the air, nitrogen and oxygen flowing through their respective paths in section 11. In this way the temperature approach between the temperature of the air leaving flow path 13 or 14, as the case may be, and the temperature of the nitrogen entering one or the other of these flow paths is brought within the range of 5° to 10° F., preferably 6° to 8° F., resulting in more efficient purging of these flow paths. Flow path 16 is provided with an inlet line 36 and an exit line 37 passing to an expander 40, which may be a centrifugal expander or turbine of any well known type. A line 42 connects the expander 40 with the low pressure stage of the rectification system 43.

Rectification system 43 comprises a two-stage rectification column, the lower section 44 of which is operated at a pressure of about 60 to 150 pounds, preferably about 75 to 125 pounds, and the upper section 45 of which is operated at a pressure of about 4 to 12 pounds, preferably at about 5 to 8 pounds. This column, as is customary, is provided with rectification plates of the bubble cap or other desired type. The lower section 44 communicates with a condenser 46 which acts as a reboiler for the low pressure stage 45. Condenser 46 has a liquid collecting shelf 47 disposed immediately below the condenser for collecting liquid nitrogen. Pipe line 48 leads from this shelf 47 to a non-reversing heat exchanger 49. A line 50 provided with a pressure reducing valve 51 leads from the non-reversing exchanger 49 to the top of low pressure stage 45.

From the base portion of the high pressure stage 44 a line 52 leads to a line 53 communicating with a pair of liquid purifiers 54, 55. A line 56 is communicably connected with the opposite ends of the purifiers 54, 55. Line 53 is provided with a pair of valves 57 and 58 associated with purifier 54 and with a second pair of valves 59, 60 associated with purifier 55. Line 56 is provided with a pair of valves 61, 62 associated with purifier 54 and a second pair of valves 63, 64 associated with purifier 55. Only one of the purifiers 54, 55 is placed on stream during operation. For example, valves 57, 59, 61 and 63 may be closed and valves 58 and 62 opened so that flow of crude liquid oxygen from line 52 takes place through purifier 54 and line 56. Simultaneously, purifier 55 may be purged by passing a suitable purge medium, e. g., nitrogen or air, through the open valve 64 into and through the purifier 55 and through open valve 60. When purifier 54 requires purging, valves 58, 60, 62 and 64 are closed and 59, 63 opened, thereby placing purifier 55 on stream. Purifier 54 may then be purged by opening valves 61 and 57 and passing a suitable purge medium therethrough, as herein-

above described in connection with the purging of purifier 55.

Preferably each of the purifiers 54 and 55 consists of a bed 65 of granular silica gel adsorbent having superimposed thereon a filter plate 66 for effecting removal of carbon dioxide particles from the crude liquid oxygen. This filter may be porous silicon carbide or porous metal. The silica gel acts to adsorb the acetylene dissolved in the crude liquid oxygen and the filter medium 66 to separate out the solid carbon dioxide. The silica gel adsorbent and the filter disposed in each of the purifiers 54 and 55 are preferably so proportioned that the filter and adsorber both require purging at about the same time. Instead of having the silica gel in one and the same unit with the filter 66, as shown in the drawing, separate units, one functioning to effect removal of acetylene and the other carbon dioxide from the liquid oxygen may be employed and these units may be designed to permit purging of each independently of the other.

A line 67 leads from line 56 and is provided with two branches 67*a* and 67*b*. Branch 67*a* leads to a non-reversing exchanger 68. From exchanger 68 a line 69 having an expansion valve 70 therein leads to the low pressure stage 45 for introducing thereinto, as reflux, crude oxygen freed of acetylene and carbon dioxide. Branch 67*b* is provided with a valve 67*c* for controlling flow therethrough and communicates with line 36 leading into flow path 16. Thus from 10% to 15% of the crude liquid oxygen collected at the bottom of column 44 and freed of acetylene and carbon dioxide is introduced through lines 67*b* and 36 into flow path 16.

From the top of condenser 46 a line 71 provided with an expansion valve 72 leads into nitrogen line 73 leading from the top of low pressure stage 45. Nitrogen line 73 leads into the non-reversing exchanger 49 which is connected by a nitrogen line 73*a* with non-reversing exchanger 68. Nitrogen line 32 leads from the exchanger 68 into reversing valve 24.

A line 74 leads from the base of the high pressure column 44 just above the body of crude liquid oxygen therein and communicates with a pair of lines 75 and 76. Line 75 is provided with a valve 75*a* and communicates with line 37 leading into expander 40. Line 76 is provided with a valve 76*a* for controlling flow therethrough and communicates with line 36.

The base portion of low pressure column 45 is provided with an oxygen line 77 having a valve 77*a* therein for controlling flow therethrough. Line 77 leads into a non-reversing exchanger 78 from which line 35 leads into the oxygen flow path 15.

In the operation of the equipment shown in the drawing, air is admitted through line 25, and, as indicated by the full line valve settings, flows through line 28, flow path 19, line 21, flow path 13 in indirect heat exchange relation with nitrogen flowing through flow paths 14 and 18 and oxygen flowing through flow paths 15 and 17. The air leaving flow path 13 through line 29 is thus cooled to a temperature close to its condensation point, at which temperature it enters valve 24 and flows from this valve through line 31 and non-reversing heat exchanger 78, and passes up through the body of crude liquid oxygen maintained at the base of the high pressure stage 44. The air bubbles through this crude liquid oxygen which effects removal of entrained carbon dioxide and acetylene from the air.

A minor portion of the liquid scrubbed air stream is withdrawn from the high pressure column 44 just above the body of crude liquid oxygen maintained therein through line 74 and is divided into two streams one of which passes through line 75 and the other through line 76. Crude liquid oxygen is continuously withdrawn through line 52, passed through one or the other of the purifiers 54, 55 which effect removal of the carbon dioxide and acetylene contained therein and then flows through line 56 into line 67 where the thus purified liquid is divided into two streams. One the minor stream, consisting of from 5% to 10% of the liquid withdrawn from the high pressure column, flows through line 67*b* into line 36 where it mixes with the air stream flowing through line 76 which functions as a gaseous carrier for the liquid in its flow through flow path 16 introducing the liquid into this flow path in the form of mist or fine droplets. The remainder of the crude liquid oxygen passes through line 67*a*, exchanger 68 and line 69 and is flashed as it flows through expansion valve 70 into the low pressure stage 45.

The oxygen-enriched air flowing through path 16 is warmed by the air flowing in a countercurrent direction through flow path 13. The thus warmed oxygen-enriched air flows through line 37 where it mixes with the stream of essentially air composition flowing through line 75. The resultant oxygen-enriched air stream enters expander 40 at a temperature such that liquefaction of the air in the expander does not take place. The expanded air flows through line 42 into the low pressure stage 45 of the rectification system at an intermediate point 42*a* therein.

Liquid nitrogen flows from shelf 47 through line 48 into exchanger 49 where it is cooled by the nitrogen gas flowing through this exchanger. From this exchanger the cooled nitrogen flows through line 50 and expansion valve 51 where it is flashed and thus further cooled and enters the top of low pressure stage 45 where it serves as reflux liquid.

Gaseous nitrogen flows through line 73 into exchanger 49, thence through line 73*a* into exchanger 68, thence through line 32 through reversing valve 24, line 30, flow paths 14 and 18, exiting through line 27, valve 23 and line 26. If desired, some nitrogen may be withdrawn from the high pressure stage 44 through line 71, flashed as it flows through valve 72 and mixed with the nitrogen stream flowing through line 73. In this way incondensible gases tending to collect in the high pressure stage 44 may be purged therefrom.

Product oxygen flows continuously from the low pressure stage 45 through line 77, exchanger 78 into line 35, flow paths 15 and 17, exiting through line 34.

Upon reversal, which may take place every 3 to 15 minutes, as indicated by the dotted line valve settings, air flows from line 25 through valve 23 into and through line 27, flow paths 18 and 14, while the nitrogen flows through flow paths 13 and 19 and the oxygen flows through flow paths 15 and 17. No reversal of flow of the oxygen or of the oxygen-enriched air stream passing through flow path 16 takes place. The flow of the various streams from the reversing valve 24 to the rectification system 43, as well as the flow of the various streams hereinabove described, within the rectification system and from the rectification system to the reversing valve 24 remains the same. On each reversal, the nitrogen effects removal by sublimation and evaporation of car-

bon dioxide and other condensible impurities of air, e. g., moisture, deposited in exchanger 16 during the preceding step of the process.

Instead of passing crude liquid oxygen in a carrier gas of essentially air composition through flow path 16 and admixing additional such gas from line 75 with the vapor stream flowing through line 37 and expanding this mixture in expander 40, only the crude liquid oxygen, preferably after removal of acetylene and carbon dioxide therefrom, may be passed through branch 67b into line 36 and through flow path 16 where the liquid is vaporized. The resultant vapors are expanded in expander 40 and the expanded vapors introduced into the low pressure column 45 at a point substantially below point 42a where line 42 leads into the low pressure column. Usually the expanded vapor thus produced will provide only a portion of the refrigeration necessary to compensate for enthalpy losses and for heat leaks into the system. The remainder of the refrigeration necessary for this purpose, desirably, is provided by expanding the gas stream of essentially air composition withdrawn through line 74 in a separate expander and introducing the expanded air into the low pressure column 45 at a point somewhat above point 42a. Operating in this manner 10% to 25% of the total stream expanded in both expanders is derived from the crude liquid oxygen collected in the bottom of the high pressure column and the remainder from the air withdrawn through line 74.

One example of the operation of the process of this invention in apparatus of the type shown in the drawing is described below. It will be understood this example is given for purposes of exemplification only and the invention is not limited thereto.

This example refers to an oxygen plant operated in a locality where the atmospheric pressure is 14.7 pounds per square inch absolute. All pressures given in the example are in pounds per square inch gauge.

Air under pressure of about 85 pounds and at a temperature of 60° F. is supplied to line 25 and flows through valve 23, line 28, flow path 19, line 21, flow path 13; the air is thus cooled to a temperature of —274° F. The air then flows through reversing valve 24, exchanger 78 into the high pressure stage 44, the air entering this high pressure stage at a pressure of about 83 pounds and at a temperature of —275° F. The air bubbles through the body of crude liquid oxygen (containing approximately 40% oxygen) maintained in the base of the high pressure stage 44 under pressure of about 83 pounds and at a temperature of —276° F.

Crude liquid oxygen is withdrawn continuously through line 52 and passes through one or the other of the purifiers 54, 55 which effects the removal of entrained carbon dioxide and acetylene. Of this crude liquid oxygen 7.3% flows through line 67b at a temperature of —276° F. into line 36, and thence through flow path 16 of exchanger section 11 issuing therefrom into line 37 at a temperature of about —13° F. A stream of essentially air composition is withdrawn through line 74 at a temperature of —276° F. and a pressure of about 82.5 pounds and flows through line 75 into line 37 where it mixes with the oxygen-enriched stream flowing through this line and thus produces a mixed stream at a pressure of about 82 pounds and a temperature of —242° F. This mixed stream is expanded in expander 40 producing an oxygen-enriched air stream (23.3% oxygen content) at a temperature of —304° F. and a pressure of about 9.4 pounds which is introduced into the low pressure stage 45 through line 42 at 42a. Of the total stream fed to expander 40, 14.6% is derived from the crude liquid oxygen collecting at the bottom of high pressure column 44 and the remainder is the stream of essentially air composition withdrawn through line 74. Of the total air introduced into the process, 21.6% is expanded in expander 40 to produce the refrigeration necessary to compensate for enthalpy losses and heat leaks into the system.

The remainder (92.7%) of the crude liquid oxygen flows through line 67a, exchanger 68, line 69 and through expansion valve 70 where it is flashed to enter the low pressure stage 45 as a vapor-liquid mixture at a temperature of about —305° F. and a pressure of about 9 pounds.

Nitrogen is drawn from shelf 47 of high pressure stage 44 at a temperature of —283° F. through line 48, exchanger 49 and line 50 and passed through expansion valve 51 into the top of low pressure stage 45 at a temperature of about —313° F. and a pressure of about 7.3 pounds.

Nitrogen at a temperature of —313° F. and a pressure of about 7.3 pounds flows through line 73, is warmed in exchangers 49 and 68 to a temperature of —282° F. at which temperature and a pressure of about 6.5 pounds it flows through valve 24, enters line 30 flowing through paths 14 and 18, exiting through line 27, valve 23 and exit line 26 at a temperature of 50° F. and at substantially atmospheric pressure.

Oxygen at a temperature of —288° F. and a pressure of about 10 pounds flows through line 77 and exchanger 78 and enters flow path 15 at a temperature of —282° F. In its flow through flow paths 15 and 17, the oxygen is warmed to a temperature of 50° F. at which temperature and a pressure of about 1 pound it exits through line 34.

Upon reversal, which may take place every five minutes, the air flows through paths 18 and 14 of exchanger sections 12 and 11, respectively, and the nitrogen through paths 13 and 19. The flow of the various streams is otherwise the same as hereinabove described and the temperature and pressure conditions remain the same. The nitrogen in its flow through paths 13 and 19 removes by sublimation and evaporation the carbon dioxide and frost, if any, deposited in these paths by the air during the preceding step of the process. Thus in the continued operation, the nitrogen rectification product effects removal of the carbon dioxide and frost, if any, deposited in the path through which the air has passed in the preceding step of the process.

In the operation of the process of this invention, it is preferred to effect removal of both moisture and carbon dioxide in the reversing exchanger through which the air is passed. It will be understood, however, that, if desired, the moisture may be removed from the air by any conventional means and dry air containing carbon dioxide passed through the exchanger or exchangers as hereinabove disclosed. In the event dry air is supplied to the process, reversing valve 23 may advantageously be moved to a position between exchanger sections 12 and 11 so that reversal of the flow of air and nitrogen takes place only in exchanger section 11 wherein the carbon dioxide is deposited by the air stream. Operation of such an arrangement is carried out so that the temperature at the warm end of ex-

changer section 11 is at least slightly higher than the temperature at which carbon dioxide begins to deposit from the air stream. In general, the warm end of this exchanger should be at a temperature above about −180° F.

The expressions "reversing the flow of air and nitrogen" and "reversal" are used herein in the sense commonly employed in this art, namely, to mean the switching of the flow of two streams, for example, the air and the nitrogen or oxygen streams, so that upon each "reversal" the air flows through the path through which had previously flowed the nitrogen or oxygen and the nitrogen or oxygen flows through the path through which had previously flowed the air.

It will be noted that in the process of this invention liquid from the high pressure stage is passed through flow path 16 and is vaporized by heat removed from the air stream flowing through path 13 or 14 as the case may be thus bringing the temperature approach between the exiting air stream and the incoming nitrogen stream within the range of 5° to 10° F., preferably 6° to 8° F., with consequent improvement in the purging of the flow path 13 or 14 by the nitrogen stream passing therethrough. The introduction of liquid from the high pressure stage into flow path 16 reduces the cross-sectional area of the feed line to this flow path and of the flow path itself, i. e., the tubes or passages in the exchanger through which the liquid flows. Furthermore, the use of such liquid results in better heat transfer conditions in the cold end of the exchanger. Moreover, the expanded stream introduced into the low pressure stage at 42*a* is enriched in oxygen and hence causes less disturbance of the fractionating conditions within this stage than would the introduction of a stream of expanded air.

Since certain changes may be made in carrying out the above processes without departing from the scope of the invention, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A process for producing oxygen by the liquefaction and rectification of air in a rectification column, which comprises, passing a stream of air under pressure through a path in a reversing exchanger to recover the cold content of an outgoing product of rectification and thus cool the air to a temperature close to its condensation point, periodically reversing the flow of air and rectification product through their respective paths in the reversing exchanger so that upon each of said reversals the rectification product substantially completely removes the carbon dioxide deposited in the reversing exchanger during the preceding step of the process, introducing the thus cooled air into the rectification column, passing liquid from said rectification column into and through at least the cold end of said reversing exchanger in indirect heat exchange relation with the air and rectification product passing therethrough thus vaporizing said liquid, and expanding the resultant vapors to produce refrigeration to compensate for enthalpy losses and heat leaks into the process.

2. A process for producing oxygen by the liquefaction and rectification of air in a rectification system involving high and low pressure stages, which comprises, passing a stream of air under pressure through a path in a reversing exchanger to recover the cold content of an outgoing product of rectification and thus cool the air to a temperature close to its condensation point, periodically reversing the flow of air and rectification product through their respective paths in the reversing exchanger so that upon each of said reversals the rectification product substantially completely removes the carbon dioxide deposited in the reversing exchanger during the preceding step of the process, passing the thus cooled air through a body of crude liquid oxygen in the high pressure stage of the rectification system, continuously passing a portion of the crude liquid oxygen into and through at least the cold end of said reversing exchanger in indirect heat exchange relation with the air and rectification product passing therethrough thus vaporizing said crude liquid oxygen, expanding the resultant vapors to produce refrigeration to compensate for enthalpy losses and heat leaks into the process, and introducing the expanded vapors into the low pressure stage of the rectification system.

3. A process for producing oxygen by the liquefaction and rectification of air in a rectification system involving high and low pressure stages, which comprises, passing a stream of air under pressure through a path in a reversing exchanger to recover the cold content of the outgoing nitrogen product of rectification and thus cool the air to a temperature close to its condensation point, periodically reversing the flow of air and nitrogen rectification product through their respective paths in the reversing exchanger so that upon each of said reversa's the nitrogen substantially completely removes the carbon dioxide deposited in the reversing exchanger during the preceding step of the process, passing the thus cooled air through a body of crude liquid oxygen in the high pressure stage of the rectification system, continuously passing a portion of the crude liquid oxygen into and through at least the cold end of said reversing exchanger in indirect heat exchange relation with the air and nitrogen rectification product passing therethrough thus vaporizing said crude liquid oxygen, expanding the resultant vapors to produce refrigeration to compensate for enthalpy losses and heat leaks into the process, and introducing the expanded vapors into the low pressure stage of the rectification system.

4. A process for producing oxygen by the liquefaction and rectification of air in a rectification system involving low and high pressure stages, which comprises, passing a stream of air under pressure through a path in a reversing exchanger to recover the cold content of the outgoing stream of nitrogen rectification product and thus cool the air to a temperature close to its condensation point, periodically reversing the flow of air and nitrogen rectification product through their respective paths in the reversing exchanger so that upon each of said reversals the nitrogen substantially completely removes the carbon dioxide deposited in the reversing exchanger during the preceding step of the process, passing the thus cooled air through a body of crude liquid oxygen in the high pressure stage of the rectification system thus scrubbing said thus cooled air with said crude liquid oxygen, withdrawing a minor portion of the crude liquid oxygen-scrubbed air, passing a minor portion of said crude liquid oxygen together with said minor portion of the crude liquid oxygen-scrubbed air through at least the cold end of said reversing exchanger in indirect heat exchange relation with the air and nitrogen rectification product passing therethrough thus vaporizing the crude

liquid oxygen and producing a vapor stream enriched in oxygen, expanding the oxygen-enriched vapor, and introducing the expanded vapor into the low pressure stage of the rectification system.

5. A process of producing oxygen as defined in claim 4, in which the vapor stream enriched in oxygen is at least 10% richer in oxygen than ordinary air.

6. A process for producing oxygen by the liquefaction and rectification of air in a rectification system involving low and high pressure stages, which comprises, passing a stream of air under pressure through a path in a reversing exchanger to recover the cold content of outgoing streams of oxygen and nitrogen rectification products and thus cool the air to a temperature close to its condensation point, periodically reversing the flow of air and nitrogen rectification product through their respective paths in the reversing exchanger so that upon each of said reversals the nitrogen substantially completely removes the carbon dioxide deposited in the reversing exchanger during the preceding step of the process, passing the thus cooled air through a body of crude liquid oxygen in the high pressure stage of the rectification system thus scrubbing said thus cooled air with said crude liquid oxygen, withdrawing a minor portion of the crude liquid oxygen-scrubbed air, dividing said minor portion into two streams, continuously passing crude liquid oxygen from said body through a purification system which effects removal of carbon dioxide from said crude liquid oxygen, dividing the purified crude liquid oxygen into two streams, expanding one of said streams and introducing the expanded stream as reflux into said low pressure stage, mixing the other liquid stream with one of the said two streams of crude liquid oxygen-scrubbed air, passing the resultant mixture through at least the cold end of said reversing exchanger in indirect heat exchange relation with the air and nitrogen rectification product passing therethrough thus vaporizing the crude liquid oxygen and producing a vapor stream enriched in oxygen, mixing the other of said two streams of crude liquid oxygen-scrubbed air with the oxygen-enriched vapor stream, expanding the resultant mixture, and introducing the expanded mixture into the low pressure stage of the rectification system.

7. A process of producing oxygen by the liquefaction and rectification of air in a rectification system involving a low pressure stage and a high pressure stage, which comprises, passing a stream of air under a pressure of from 60 to 150 pounds per square inch gauge and at a temperature of from 50° to 110° F. through a path in a reversing exchanger to recover the cold content of an outgoing stream of nitrogen product of rectification and thus cool the air to a temperature close to its condensation point, periodically reversing the flow of air and nitrogen rectification product through their respective paths in the reversing exchanger so that upon each of said reversals the nitrogen substantially completely removes the carbon dioxide deposited in the reversing exchanger during the preceding step in the process, passing the thus cooled air through a body of crude liquid oxygen in the high pressure stage of the rectification system thus scrubbing said thus cooled air with said crude liquid oxygen, withdrawing a minor portion of the crude liquid oxygen-scrubbed air, dividing said minor portion into two streams, continuously passing the crude liquid oxygen from the high pressure stage through a purification system which effects removal of carbon dioxide from said crude liquid oxygen, dividing the thus purified crude liquid oxygen into two streams, one consisting of approximately 90% to 95% of the crude liquid oxygen and the other consisting of from 5% to 10%, expanding the stream consisting of from 90% to 95% of the crude liquid oxygen to a pressure of from 4 to 12 pounds per square inch gauge, introducing the expanded stream as reflux into said low pressure stage, mixing the stream consisting of from 5% to 10% of the crude liquid oxygen with one of the said two streams of crude liquid oxygen-scrubbed air, passing the resultant mixture through at least the cold end of said reversing exchanger in indirect heat exchange relation with the air and nitrogen rectification product passing therethrough thus vaporizing the crude liquid oxygen and producing a vapor stream enriched in oxygen, mixing the other of said two streams of crude liquid oxygen-scrubbed air with the oxygen-enriched vapor stream, expanding the resultant mixture to a pressure of from 4 to 12 pounds per square inch gauge, and introducing the expanded mixture into the low pressure stage of the rectification system.

8. A process for producing oxygen as defined in claim 7, in which from 15% to 35% of the air introduced into the process is expanded to produce the refrigeration necessary to compensate for enthalpy losses and heat leaks into the process and of the total stream fed to the expander from 10% to 25% is derived from the crude liquid oxygen collected in the high pressure stage.

PAUL W. GARBO.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,460,859	Trumpler	Feb. 8, 1949

OTHER REFERENCES

Air Purification in the Revising Exchanger, by Lobo and Skaperdas, Transactions American Institute Chem. Engrs., Feb. 1947, page 69.

Low Pressure Liquefaction of Air, by Rushton, Refrigerating Engineering, Jan. 1947, page 24.