

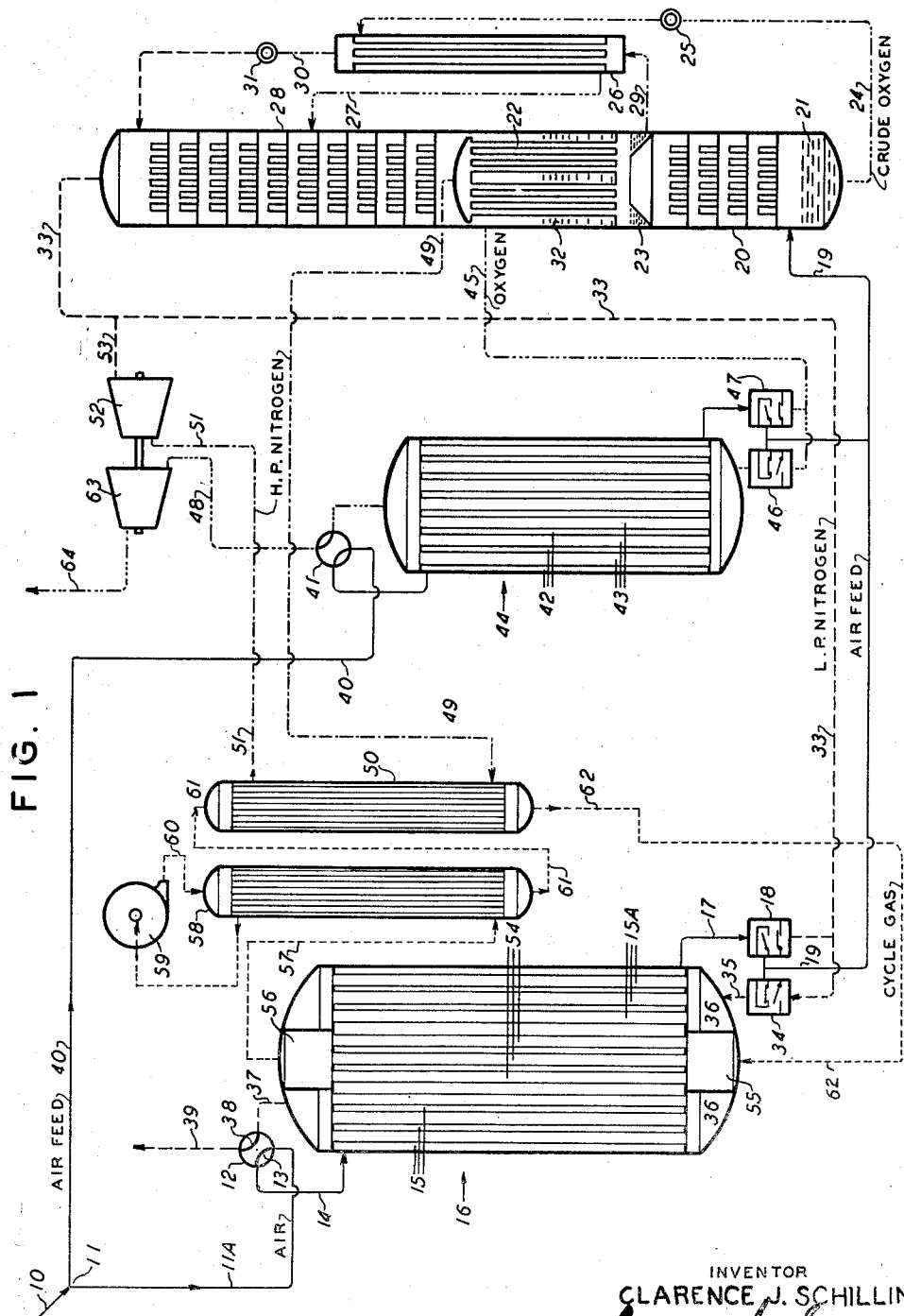
Dec. 28, 1954

C. J. SCHILLING
FRACTIONATION OF AIR

2,697,922

Filed June 14, 1951

3 Sheets-Sheet 1



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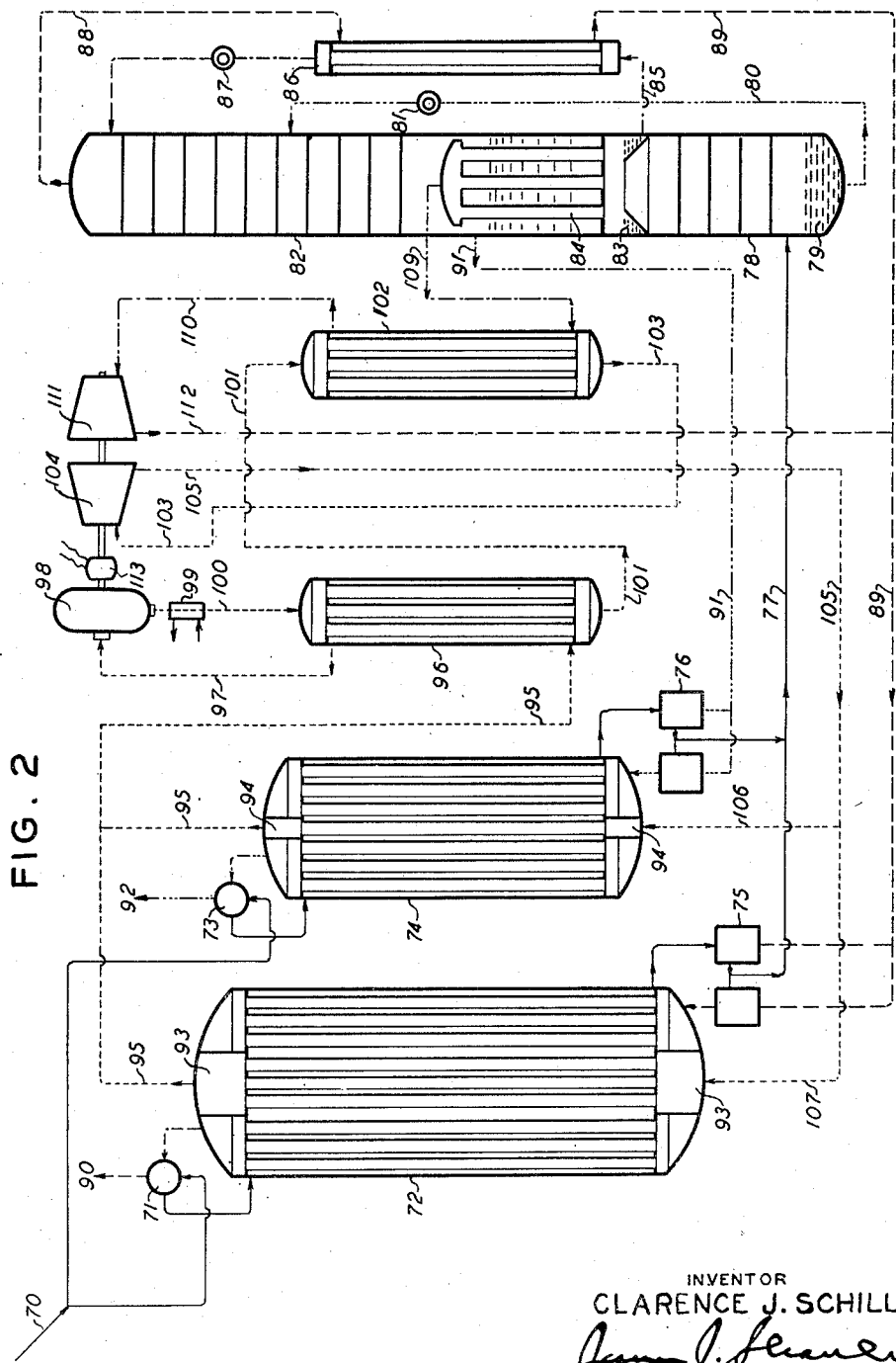
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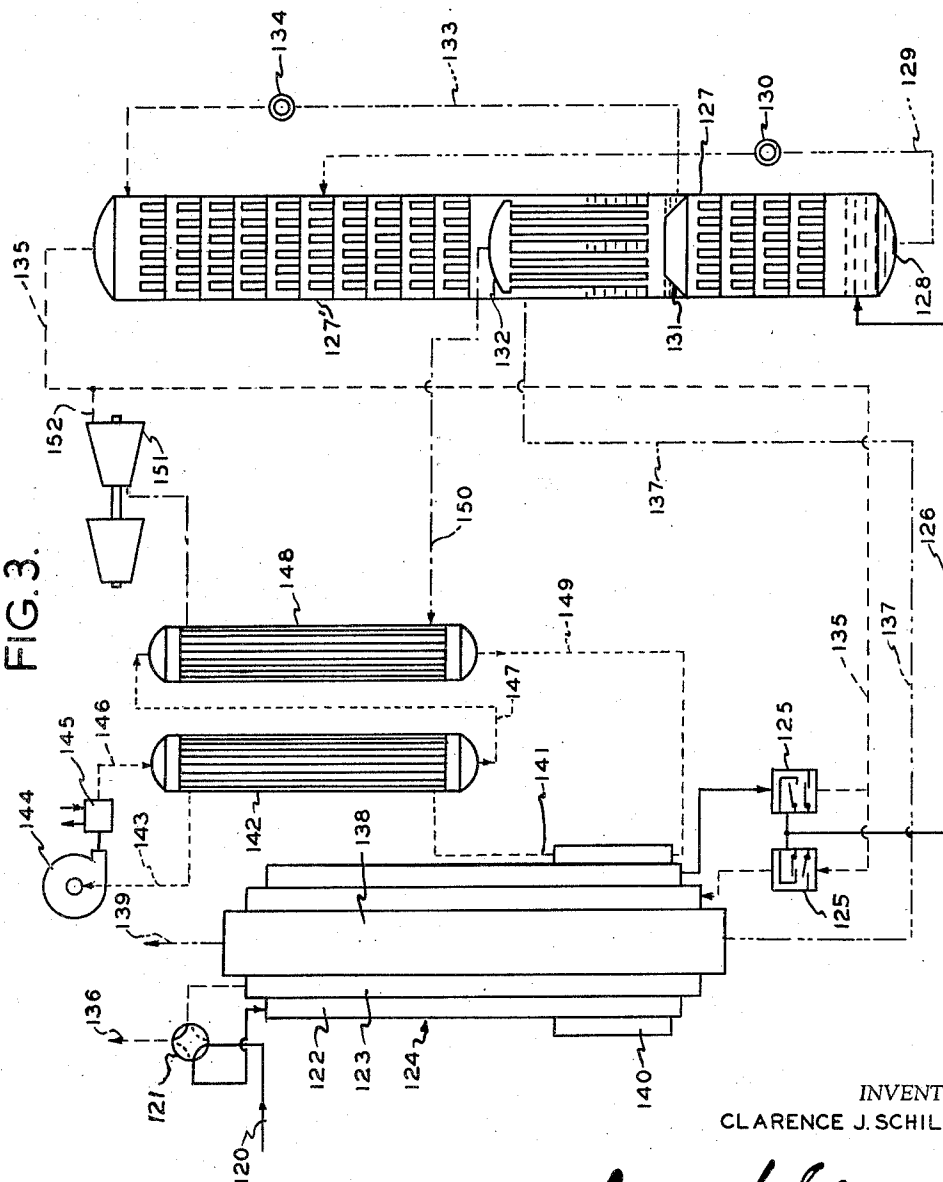
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3 Sheets-Sheet 3

FIG. 3.



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1

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FRACTIONATION OF AIR

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Application June 14, 1951, Serial No. 231,558

14 Claims. (Cl. 62—175.5)

This invention relates to an improved method for the separation of gas mixtures containing higher and lower boiling fractions and other constituents having boiling temperatures still higher than those of the higher boiling fraction, and more particularly to the separation of oxygen and nitrogen from atmospheric air by liquefaction and fractionation, and to the removal from the air of undesirable impurities, such as water vapor and carbon dioxide.

This application is a continuation-in-part of copending application Serial No. 755,287, filed June 18, 1947 and now abandoned.

In the older practice of this art, the refrigerative value of the cold fractionation products was recovered in interchangers, usually tubular, in which streams of warm air and cold fractionation products flow continuously in heat exchange relation in separate passages. This practice requires that both the carbon dioxide and the water content of the air supply be reduced as far as possible, by chemical treatment and adsorption, prior to the interchange, as otherwise the cold ends of the interchangers rapidly choke with carbon dioxide snow.

The necessity for preliminary treatment of the air may be avoided in the use of interchangers of the flow-reversing type. Such interchangers are known in two functionally identical forms:

The so-called "cold accumulators" of Frankl (U. S. Patent 1,890,646 and others) consist of shells packed with materials such as extended surfaces of sheet metal, which readily absorb and surrender heat and are used by passing the cold gas through the pack until it is reduced at the cold end to the desired low temperature, and then passing air through the pack with reversal of direction of flow so long as the air emerges at a sufficiently low temperature. Continuity of supply is maintained by the use of duplicate interchangers, air flowing through one while the cold gas is reducing the temperature of the other.

In the reversing tubular interchanger of Levin (British Patent 469,943 of 1939) the interchanger shell is provided with tubes. This form of interchanger is operated by using the shell and the tubes alternately for the passage of each gas: i. e., air is passed through the shell and the cold gas through the tubes until the permissible quantity of solids has accumulated outside the tubes and, after a suitable period, determined by the rate of accumulation of solids, the flows are reversed and air passed through the tubes and the cold gas through the shell.

As the vapor pressures of water and carbon dioxide are extremely low at the temperatures at which the product gases emerge from an air fractionating column, these flow-reversing interchangers may readily be so operated as to refrigerate atmospheric air, without preliminary purification or desiccation, and deliver the refrigerated air in condition suitable for fractionation in a column. This is possible because, unlike the continuous flow interchanger, these forms permit the solids deposited in cooling the air to be, at least in large part, removed by sublimation when the flows are reversed and cold gas flows through the passage in which the solids have been deposited.

It has long been recognized, however, that this removal by sublimation is not always nor necessarily complete and that there is usually a slow accumulation of deposited solids which ultimately requires that the interchanger be shut down for deriming by warming. Various methods for increasing the effectiveness of the sublimation step and thereby lengthening the period during which the interchanger may be used without warming up have

2

been proposed. These proposals have involved either the transfer of heat from one level to another in the interchanger (Le Rouge, U. S. Patent 2,355,660) or the passage through the interchanger of a greater mass of the cold gas than of air (Frankl, U. S. Patents 1,945,634 and 2,002,941).

The present invention follows the general principle set forth by Frankl but provides a different means for supplying the excess mass of cold gas. The manipulation described is particularly adapted to use in an operation producing great quantities of oxygen of a relatively low order of purity, although it may be used in the separation of any mixtures of highly volatile liquids. Such operations, to be commercially feasible, must require the minimum of power, attendance and maintenance. The invention is illustrated in the three figures of the attached drawings, in which:

Figure 1 is a flow-sheet of an operating cycle in which the substantially continuous deriming effect (sometimes termed "unbalancing") is produced by passing an auxiliary flow of cold gas in a closed cycle through only the nitrogen interchanger, the excess cold gas flow through the oxygen interchanger being provided by diverting through the nitrogen interchanger an excess proportion of the total air supply;

Figure 2 is a similar flow-sheet illustrating the use of the closed auxiliary cycle in both interchangers, and

Figure 3 is a similar flow-sheet showing the use of the closed auxiliary cycle in a single interchanger for both the returning nitrogen and oxygen.

While Figures 1 and 2 show the Levin type of tubular, flow-reversing interchanger, it will be understood that a pair of the Frankl type interchangers may be substituted for either unit illustrated without other modification of the cycles.

Referring first to Figure 1, the air supply previously compressed to a suitable pressure, as for example 100 pounds absolute, returned to atmospheric temperature and freed from dust but not from atmospheric moisture or carbon dioxide, enters the system at 10. The stream is divided at 11, the larger portion of the air supply passing through conduit 11A to a switching valve 12 adapted to be rotated through 90° by automatic mechanism not illustrated. With the valve rotor in the position shown, the air passes through port 13 and conduit 14 to the outer chamber 15 of nitrogen interchanger 16. Leaving the shell of the interchanger through conduit 17 the air stream passes through a check valve 18 and conduit 19 to the high pressure section 20 of a two-stage fractionating column. This column may be of any conventional or preferred type, functioning generally as follows:

The air receives a preliminary fractionating in the high pressure section, crude oxygen of more or less 40% purity collecting in the base of the section as a pool 21 while more or less pure nitrogen vapor is partially condensed in the nitrogen condenser 22. A portion of the liquid nitrogen is collected in a pool 23 immediately below the condenser, and the balance flows downwardly in the column as reflux. The crude oxygen passes through conduit 24 and an expansion valve 25 to a small interchanger 26 and thence through conduit 27 to the low pressure section 28 of the column at a medial height.

Liquid nitrogen drawn from pool 23 passes through conduit 29 to interchanger 26 in which it is in counterflow to the crude oxygen, and thence through conduit 30 and expansion valve 31 to the upper end of the low pressure section, in which it functions as reflux liquid.

The intermediates thus introduced are refractionated in the low pressure section, liquid oxygen of a desired purity, as for example 95%, collecting in a pool 32 surrounding the tubes of condenser 22.

Gaseous nitrogen, at a pressure slightly above atmospheric, leaves the top of the column through conduit 33 and passes through check valve 34 and conduit 35 to the end space 36 communicating with tubes 15A in the interchanger 16. From these tubes, after heat interchange with the entering air, the nitrogen passes at substantially atmospheric temperature through conduit 37 and port 38 of valve 12 to a conduit 39 by which it is vented from the system.

On rotating valve 12 through a quarter turn counter-clockwise, port 13 places conduits 11A and 37 in communication and introduces the air supply to tubes 15A, while the check valves 34 and 18 detour the nitrogen flow through the shell and out of the system through conduits 14, port 38 and conduit 39.

The remainder of the air feed flows through conduit 40 to a switching valve 41 which directs the air alternately through the shell 42 and the tubes 43 of the oxygen interchanger 44.

Gaseous oxygen produced by the boiling of oxygen pool 32 leaves the column through conduit 45 and passes through one or the other of check valves 46 and 47, thence through the passage of the interchanger not momentarily occupied by air, and emerges through conduit 48 at substantially atmospheric temperature and pressure.

In the cycle of Figure 1, the excess mass of cold gas required for substantially complete sublimation of frozen solids is provided in a novel manner which has advantages over methods heretofore disclosed. First, the oxygen interchanger is unbalanced by passing through it a somewhat smaller proportion of the total air feed than that which corresponds with the percentage yield of oxygen of the desired purity. For example, the air supply to the oxygen interchanger may be perhaps 20% to 21% of the total air supply rather than the 22% which would represent the yield of an oxygen at 95% purity.

Second, the nitrogen interchanger is unbalanced by the use of a closed cycle in which a gas is circulated, as will now be described first with reference to Figure 1.

A relatively small proportion of the nitrogen separating in high pressure column section 20, (for example, one-fourth of the nitrogen content of the air supply) is withdrawn in gaseous form and at about 96° K. from the dome of the condenser 22 and flows through conduit 49 to a heat interchanger 50 in which it is warmed to about 146° K. by heat exchange with a cycled gas later referred to. The warmed high-pressure nitrogen flows through conduit 51 to an expansion engine 52, preferably a turbo-expander, in which it is reduced to a pressure close to atmospheric and to about 116° K.

The nitrogen, cooled by this expansion, is discharged through conduit 53 into conduit 33 by which it is conveyed, together with the gaseous product nitrogen from the low pressure column section 28 to interchanger 16 and thus out of the system.

Intergchanger 16 is provided with a third or unbalancing passage which may be a jacket enclosing a part of the length of the shell but is here illustrated as a bank of tubes 54 in heat interchange relation with the fluid momentarily passing through the shell, these tubes terminating in chambers 55 and 56. One of these chambers, preferably chamber 56, communicates through conduit 57 and one pass of an interchanger 58 with the intake side of a blower 59 which discharges through conduit 60 into the other pass of interchanger 58. In this interchange the gas entering the blower is warmed to about 295° K. by heat interchange against the blower discharge, which leaves the blower at about 300° K. The gas leaving chamber 56 is at a temperature about 150° K. and the gas leaving the interchanger 58 through conduit 61 is at about 155° K.

Conduit 61 communicates with the pass in interchanger 50 which is not occupied by high pressure nitrogen as above described, and the gas leaving this interchanger through conduit 62 returns to chamber 55 at the cold end of main interchanger 16 at about 105° K.

The circuit above described, consisting of chambers 55 and 56, secondary interchanger 58, one side of the secondary interchanger 50, the blower 59 and the connecting conduits, is a closed system which may be filled with any gas, though preferably one which is not liquefied at the temperature existing at the cold end of interchanger 16, as for example, nitrogen, helium or hydrogen.

Assuming the heat capacity of this gas to be approximately equal to that of nitrogen, the quantity of gas cycled through this closed circuit may be equal to about one-fourth of the total nitrogen of the air supply to the column, and the total quantity of cold gas passing through the main interchanger will consist of 20 parts expanded high pressure nitrogen plus 60 parts of low

pressure product nitrogen, intermixed and passing through tubes 15A, and 20 parts cycled gas passing through tubes 54.

This closed circulating system is a device of extreme simplicity and flexibility for transferring a small amount of heat from the warm or intermediate zone of the interchanger to its cold end, and for bringing the mass of cold gas up to that required for substantially complete elimination of frozen deposits on reversal of interchanger flows. As no pressure on the circulated gas is required beyond that needed to overcome resistance to flow through the interchanger passage, the power consumption is negligible and the functioning of the column is not disturbed by regulation of the volume of gas circulated in the closed system.

In practical operation, the quantity of gas circulated through the closed cycle will be the minimum required for substantially complete scavenging and the quantity of high pressure nitrogen withdrawn from the column will be that which is raised to the temperature most favorable to expansion in turbo-expander 52 by the heat interchange in exchanger 50.

The turbo-expander is illustrated as loaded by a turbo-compressor 63 which may be used to compress air but is illustrated as receiving the gaseous oxygen product from conduit 48 and delivering it under a desired super-atmospheric pressure through conduit 64, as to a pipe line.

The flow-sheet of Figure 2 differs from that of Figure 1 in that the oxygen as well as the nitrogen interchanger is unbalanced by the closed gas cycle. This flow-sheet also shows the high-pressure reflux nitrogen as being cooled and stabilized by gaseous low-pressure nitrogen instead of by expanded crude oxygen, but this is no part of the present invention.

Air under pressure enters the system at 70 and a portion of the supply approximately corresponding with the yield of nitrogen is diverted by switching valve 71, alternately through the shell and the outer banks of tubes of nitrogen interchanger 72. The remainder of the air supply, substantially equal to the oxygen yield of the column, is diverted by switching valve 73, alternately through the shell and the outer banks of tubes of oxygen interchanger 74. Passing through the pairs of check valves 75 and 76, in the manner already described, the refrigerated air, at approximately its liquefaction temperature, is collected in conduit 77 and enters high pressure section 78 of the column.

Crude oxygen collecting in pool 79 is transferred through conduit 80 and expansion valve 81 to the low pressure section 82 of the column. Liquid nitrogen collecting in pool 83 below condenser 84 passes through conduit 85 and interchanger 86, in which it is cooled and stabilized, and thence through an expansion valve 87 into the top of the column. Gaseous nitrogen separated in the low pressure section flows through conduit 88 and interchanger 86, in which it is in counter-flow to the liquid nitrogen, and thence through conduit 89 to nitrogen interchanger 72, leaving the system at 90.

Oxygen of the desired purity, in gaseous form, is withdrawn from the low pressure section of the column through conduit 91 and passes through interchanger 74 to leave the system at 92.

The closed circuit used for ensuring the removal of frozen deposits from the main interchangers includes a pair of end chambers 93 in nitrogen interchanger 72 and a similar pair of end chambers 94 in oxygen interchanger 74, each pair of chambers being connected by one or more tubes through which the cycled gas flows continuously in one direction, this preferably being the direction contrary to that of the air flow.

The cycled gas, which leaves chambers 93 and 94 at about 150° K., is collected in branched conduit 95 by which it is conducted to one pass of a heat interchanger 96, in which it is interchanged with the same stream returning in compressed condition and is warmed to about 295° K. The stream then passes through conduit 97 to a turbo-compressor or high pressure blower 98 in which it is raised to a moderate pressure, the compressed stream, if above 300° K., is water-cooled as at 99, and flows through conduit 100 to the other pass of interchanger 96, in which it is cooled to about 155° K. in warming the stream flowing toward the blower.

The cooled stream then flows through conduit 101 to one pass of an interchanger 102 in which it is cooled to

about 130° K. by interchange against high pressure gaseous nitrogen and passes through conduit 103 to a turbo-expander or other expansion engine 104 by which it is reduced to slightly above atmospheric pressure and to about 100° K. The expanded gas then passes through conduit 105 and branch conduits 106 and 107 to the two chambers 93 and 94 at the cold ends of the main interchangers, thus completing the closed unbalancing cycle.

A small portion of the nitrogen separated from the air in the high pressure section of the column (for example, about one-eighth of the total nitrogen content of the air fractionated) is withdrawn from the high pressure section in gaseous form through conduit 109 and passes through interchanger 102 in heat exchange with cycled gas as above described. The high pressure gas, warmed by this interchanger to about 146° K., is expanded in an engine or turbo-expander 111 to approximately atmospheric pressure, the expansion cooling the nitrogen to about 116° K. The expanded stream passes through conduit 112 to a point of junction with conduit 89, in which it is intermixed with the gaseous product nitrogen from the low pressure column section and is thus introduced into nitrogen interchanger 72.

The power required to operate the blower will in large part be supplied by the two expanders 111 and 104 if coupled to it as shown, but an independent source of power such as the motor indicated at 113 should be provided.

While the modified cycle of Figure 2 requires some additional apparatus over that required by the cycle of Figure 1, it has compensating advantages. One of these is that it is adapted to small as well as to large plants (the former, as is well known, requiring more make-up refrigeration than the latter) by reason of the additional refrigeration produced by compressing the cycled gas at 98 and re-expanding it at 104. The amount of make-up refrigeration thus produced may be controlled by varying the degree to which the cycled gas is compressed.

Another advantage of the modified cycle is in reducing the quantity of high pressure nitrogen which must be withdrawn and thus increasing the quantity of liquid nitrogen available for refluxing the final low pressure fractionation.

The flow sheet of Figure 3 illustrates the present invention in connection with a cycle employing a single interchanger for cooling and purifying the incoming air by heat interchange with the returning nitrogen and oxygen. In this form of interchanger, three passages are provided there through, and operation thereof is similar to that described in the aforementioned Levin British patent. In the first phase of its operating cycle, the stream of feed air passes through one passage of the interchanger in heat interchange relation with a stream of product nitrogen and a stream of product oxygen flowing through separate passages in the same direction opposite to the direction of the feed air flow. During the other phase, the feed air and product nitrogen streams are caused to flow through the interchanger in reverse relation without changing their direction of flow, i. e., each stream utilizing the passage used by the other during the first phase of the cycle. The oxygen product stream flows continuously through the same passage during both phases.

As illustrated, feed air under pressure enters the system through conduit 120 and is directed by switching valve 121 alternately through passages 122 and 123 of the single interchanger 124. The refrigerated air leaving the interchanger flows through one or the other of check valves 125, through conduit 126, and enters the high pressure section 127 of the column at approximately its liquefaction temperature.

Crude oxygen collecting in pool 128 is transferred through conduit 129 and expansion valve 130 to the low pressure section 127' of the column. Liquid nitrogen collecting in pool 131 below condenser 132 passes through conduit 133 and thence through an expansion valve 134 into the top of the column. Gaseous nitrogen separated in the low pressure section flows through conduit 135, alternately through passages 122 and 123 of the interchanger 124, and leaves the system at outlet 136.

Oxygen of desired purity, in gaseous form, is withdrawn from the low pressure section of the column through conduit 137 and passes through interchanger 124, by way of central passage 138, to leave the system through conduit 139.

The closed circuit provided by the present invention for

ensuring the removal of frozen deposits from the reversing interchanger includes a passage 140, located in heat interchange relation with the cold end of the interchanger 124, through which the cycled gas flows continuously in one direction, preferably in a direction contrary to that of the air flow. While the passage 140 is illustrated as a jacket positioned externally of the cold end of the interchanger 124, it may take other forms and may also occupy different heat interchange relations with the other passages of the interchanger, such as a tubular helix formed between adjacent surfaces of the passages 122 and 123.

The cycled gas, which leaves the passage 140 through conduit 141 at about 150° K., flows to one pass of a heat interchanger 142, in which it is interchanged with the same stream returning in compressed condition and is warmed to about 295° K. The stream then passes through conduit 143 to blower 144 which discharges through conduit 146 to the other pass of the interchanger 142. The compressed stream, if above 300° K., is water-cooled as at 145 to approximately that temperature. The stream leaves the interchanger 142 at about 155° K. and flows, by way of a conduit 147, through one pass of an interchanger 148 and is returned to the passage 141 through a conduit 149. In the interchanger 148, the cycled gas is further cooled, by heat interchange with high pressure gaseous nitrogen, to about 105° K.

The high pressure gaseous nitrogen stream flowing through the other pass of the interchanger 148 is derived from the high pressure section of the column through a conduit 150. This high pressure gaseous nitrogen is warmed by the heat interchange with the cycled gas to about 146° K. and is, subsequently, expanded in an engine turbo-expander 151 to approximately atmospheric pressure, reducing the temperature thereof to about 116° K. The expanded nitrogen stream then pass through conduit 152 to a point of junction with conduit 135, wherein it is intermixed with the gaseous product nitrogen from the low pressure column section and is thus introduced into the interchanger 124.

In the flow sheet of Fig. 3, the product nitrogen stream and the feed air stream are alternately reversed as they flow through the interchanger, and the oxygen product stream is never brought in physical contact with the solidified impurities. This arrangement provides several advantages. In addition to the obvious result of an oxygen product uncontaminated with re-evaporated impurities, a system utilizing only physical contact of the nitrogen product with the solid deposits for deriming, together with the novel closed cycle system for establishing unbalancing, provides for more efficient operations, inasmuch as the optimum temperature differential between the feed air and the nitrogen product at the cold end of the interchanger can be more readily obtained and maintained. While the oxygen product does not pass in physical contact with the solidified or re-evaporated impurities, it does affect the deriming function. Inasmuch as the optimum temperature differential at the cold end of the interchanger is obtained by introducing an excess of cold gas thereto, the cold oxygen product passing in heat interchange there-with aids in achieving the desired result.

In some installations, adequate circulation in the closed cycle may be obtained by thermal forces alone, in which cases the blower need not be employed.

The unbalancing cycles disclosed in the above modifications and described heretofore provide for the minimum disturbance of column operating conditions while permitting the attainment of the optimum temperature relations for substantially complete, continuous deriming.

I claim:

1. In an operation in which a refrigerated mixture of gases is provided for a fractionation operation by passing a warm mixture containing solidifiable vapors and a cold gaseous product of said fractionation operation alternately and in opposite directions through a common flow path in which heat in the mixture is transferred to the gaseous product, the method of removing solidified vaporizable substances from said common flow path which comprises: passing a gaseous stream continuously through a second flow path in heat interchange relation with the gases flowing through said common flow path and from the colder end to the warmer end of said latter flow path; further passing said stream through a step of heat interchange against a second and colder gas of said fractionation operation and thereby cooling said stream, and returning said

cooled stream to again pass through said second flow path to complete a closed cycle.

2. In an operation in which refrigerated air is provided for a two-stage fractionation by passing warm air containing solidifiable vapors and a cold product of said fractionation alternately through a common flow path in which heat in the air is transferred to the cold fractionation product, the method of removing solidified vaporizable substances from said common flow path which comprises: passing a gaseous stream continuously through a second flow path in heat interchange relation with the gases flowing through said common flow path; further passing said stream through a step of heat interchange against cold gaseous nitrogen withdrawn from the higher-pressure stage of said fractionation and thereby cooling said stream; returning said cooled stream to again pass through said second flow path to complete a closed cycle; expanding said withdrawn nitrogen stream following last said heat interchange to substantially the lower pressure maintained in said fractionation, and introducing said expanded nitrogen stream into said common flow path together with said cold fractionation product.

3. The method of substantially continuously deriming a heat interchanger through which a stream of warm mixture of gases and a stream of cold dry gas product of fractionation of said mixture of gases are flowed alternately and in opposite directions through a common passage and which has a secondary passage in heat interchange relation with the gases flowing through said common passage, comprising: passing a gaseous stream through said secondary passage from the colder toward the warmer end of said interchanger; cooling said gaseous stream by heat interchange against a second and colder gas of said fractionation other than said cold dry gas product stream, and returning said cooled stream to again pass through said secondary passage to complete a closed cycle.

4. The method of substantially continuously deriming a heat interchanger having a common passage arranged for the alternate flow of warm moist air toward a two-stage fractionation and a cold product from said fractionation, said interchanger having a secondary passage in heat interchange relation with the gases flowing through said common passage, comprising: passing a gaseous stream through said secondary passage and thereby warming said stream; bringing the warmed stream into heat interchange with gaseous nitrogen withdrawn from the higher-pressure stage of said fractionation and thereby cooling said stream; returning the cooled gaseous stream to again pass through said secondary passage to complete a closed cycle; expanding said nitrogen to substantially the lower pressure maintained in said fractionation, and introducing the expanded nitrogen together with said cold product into said common passage.

5. A method substantially as recited in claim 4, in which said nitrogen is expanded with the performance of external work.

6. The method of substantially continuously deriming a heat interchanger having a primary passage through which a warm mixture of gases and a cold dry gas flow alternately and in opposite directions and a secondary passage in heat interchange relation with the gases flowing through said primary passage, comprising: passing a gaseous stream through said secondary passage and thereby warming said stream; compressing the warmed gaseous stream and removing the heat of compression; passing said compressed stream through a step of heat interchange against a colder gas and thereby cooling said stream; further cooling the compressed stream by expanding the same to a lower pressure with the performance of external work; and returning said stream to again pass through said secondary passage to complete a closed cycle.

7. The method of substantially continuously deriming a heat interchanger having a primary passage arranged for the alternate flow of warm moist air toward a two-stage fractionating operation and of a cold product proceeding from said fractionation and a secondary passage in heat interchange relation with the gases flowing in said primary passage, comprising: passing a gaseous stream through said secondary passage and thereby warming said stream; compressing the warmed gaseous stream and removing the heat of compression; cooling the compressed stream by bringing the same into heat interchange with gaseous nitrogen withdrawn from the high-pressure stage of said fractionation, expanding the cooled stream with the performance of external work and thereby further cooling

said stream; returning said further cooled stream to again pass through said secondary passage to complete a closed cycle; expanding said gaseous nitrogen to a lower pressure with performance of external work, and introducing the expanded nitrogen together with said cold fractionation product into said primary passage.

8. The method of substantially continuously deriming a tubular heat interchanger having a plurality of primary passages through which a warm mixture of gases and a cold dry gas product of fractionation of said mixture of gases are passed alternately in opposite directions and a secondary passage in heat interchange relation with said primary passages, comprising: circulating a gaseous stream, in a closed cycle, through said secondary passage from the colder end of said interchanger to the warmer end thereof to warm the stream, and then through a cooling step by heat interchange with a second and colder gas of said fractionation applied to said stream outside said passage.

9. The method of substantially continuously deriming a tubular heat interchanger having a plurality of primary passages through which a stream of warm mixture of gases and a stream of cold dry gas product of fractionation of said mixture of gases are passed alternately in opposite directions and a secondary passage in heat interchange relation with said primary passages, comprising: passing a gaseous stream through said secondary passage from the cold end toward the warmer end of said interchanger and thereby warming said stream; cooling said warmed stream by heat interchange with a second and colder gas of said fractionation other than said cold dry gas product stream, and returning said cooled gaseous stream to again pass through said secondary passage in a closed cycle.

10. The method of substantially continuously deriming a tubular heat interchanger having a plurality of primary passages arranged for the alternate flow of a warm mixture of gases toward a two-stage fractionation and of a cold product from said fractionation and a secondary passage in heat interchange relation with the gases flowing through said primary passages, comprising: passing a gaseous stream through said secondary passage and thereby warming said stream; bringing the warmed stream into heat interchange with a gaseous intermediate product withdrawn from the higher-pressure stage of said fractionation and thereby cooling said stream; returning the cooled gaseous stream to again pass through said secondary passage to complete a closed cycle; expanding said gaseous intermediate product to substantially the lower pressure of said fractionation, and introducing the expanded intermediate product together with said cold fractionation product alternately into said primary passages not carrying the mixture of gases.

11. In an air fractionating operation in which the air to be fractionated is refrigerated by heat interchange against the products of said fractionation, the steps comprising: dividing the warm air stream; producing heat interchange between the oxygen product of said fractionation and a portion of said air stream of which the mass is materially less than that of said oxygen; producing countercurrent heat interchange between the remainder of said air stream and the nitrogen product stream of said fractionation, and circulating a confined gaseous stream in a closed cycle in heat interchange with the gases taking part in last said interchange, said confined gaseous stream flowing in a direction opposite to that of said remainder of said air stream said closed cycle including a step of cooling said circulated stream at a point external to either of the aforesaid interchanges by interchange against another and colder gas stream of said fractionation.

12. In a two-stage air fractionating operation in which the air to be fractionated is refrigerated by heat interchange against the products of said fractionation, the steps comprising: dividing the warm air stream; producing heat interchange between the oxygen product of said fractionation and a portion of said air stream of which the mass is materially less than that of said oxygen; producing heat interchange between the remainder of said air stream and the nitrogen product of said fractionation; circulating a confined gaseous stream in a closed cycle in heat interchange with the gases taking part in last said interchange; cooling the gaseous stream circulating in said closed cycle by heat interchange against high-pressure gaseous nitrogen withdrawn from said fractionation; expanding said high-pressure nitrogen to the lower pressure maintained in said fractionation, and passing the ex-

9

panded nitrogen together with the low-pressure product nitrogen to second said step of interchange.

13. The method of substantially continuously deriming a tubular heat interchanger having a plurality of flow paths through which a warm mixture of gases and a cold dry gas product of fractionation of said mixture of gases are passed alternately in opposite directions, comprising: passing a gaseous stream continuously through another flow path in heat interchange relation with the gases flowing through the plurality of flow paths at the cold end of the interchanger and countercurrently to the direction of flow of said mixture of gases, further passing said stream in heat interchange against a second and colder gas of said fractionation, and returning said stream to said another flow path to complete a closed cycle.

14. The method of substantially continuously deriming a tubular heat interchanger having a plurality of flow paths through which a warm mixture of gases and a cold dry gas product of fractionation of said mixture of gases

10

are passed alternately in opposite directions, comprising: passing a gaseous stream through another flow path in heat interchange relation with the colder end of the plurality of flow paths from the cold end toward the warm end of said interchanger; further passing said stream through a step of heat interchange against a second and colder gas of said fractionation, and returning said stream to again pass through said another flow path to complete a closed cycle.

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