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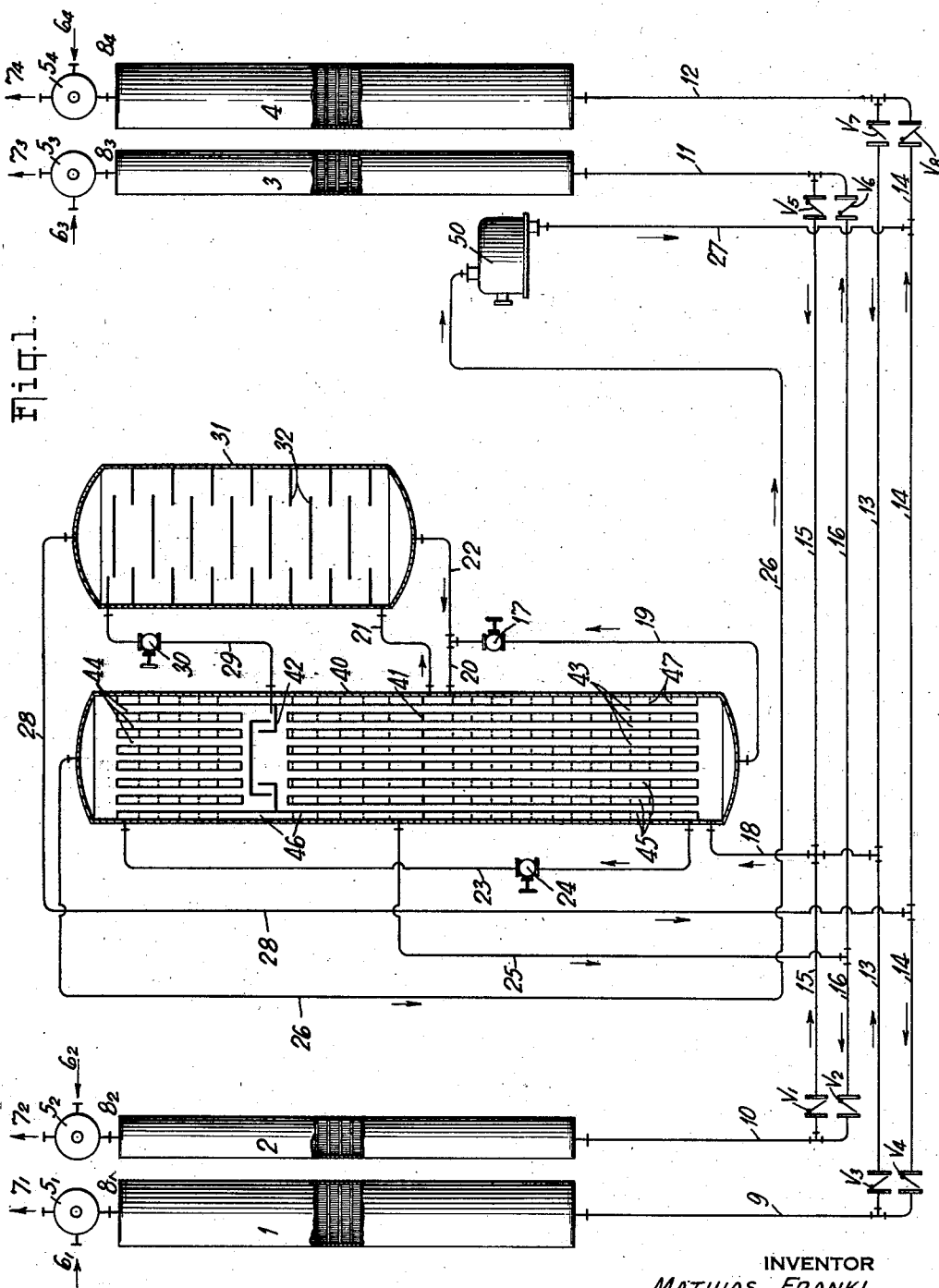
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2,084,334

PROCESS FOR THE RESOLUTION OF GASEOUS MIXTURES

Filed Jan. 26, 1934

2 Sheets-Sheet 1



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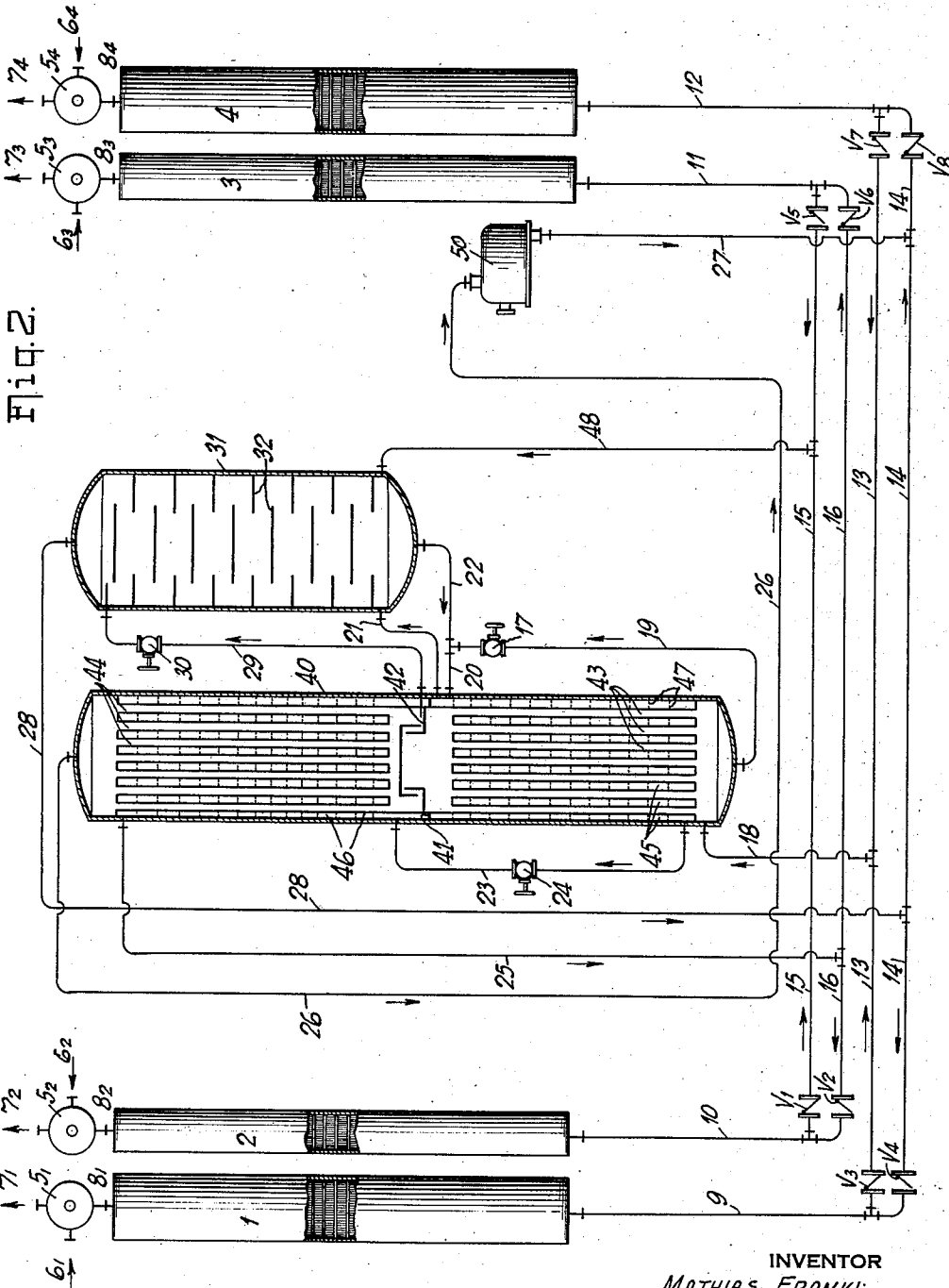
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2 Sheets-Sheet 2.



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UNITED STATES PATENT OFFICE

2,084,334

PROCESS FOR THE RESOLUTION OF GASEOUS MIXTURES

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Application January 26, 1934, Serial No. 708,367
In Austria February 1, 1933

20 Claims. (Cl. 62—175.5)

The invention relates to a process for the resolution of a gaseous mixture into components. More particularly, it relates to a process for the resolution of air into oxygen and nitrogen, and includes correlated improvements and discoveries whereby the separation of gaseous mixtures is enhanced.

In the resolution of a gaseous mixture into its principal constituents, as for example, air into oxygen and nitrogen, or simply for the separation of a portion of the lower boiling constituent, as nitrogen therefrom, it is necessary to liquefy about one-half of the gaseous mixture, thus for air, from about 45–60%. The quantity of liquid produced depends upon the volume of lower boiling constituent it is desired to separate. The liquid containing a lower boiling constituent may be enriched by means of rectification, and the enriched liquid so produced evaporated and used or stored as desired.

An advantageous procedure for effecting such a resolution is described and claimed in my co-pending application Serial No. 568,715, filed October 14, 1931, now matured into Patent No. 1,963,840, issued June 19, 1934. This method is particularly efficacious for the production of a low purity oxygen, that is, having an oxygen content of from 45–50%, or, in other words, for the separation of approximately two-thirds of the nitrogen content of the air.

It is an object of the invention to provide a process for the separation of gaseous mixtures which results in the obtainment of components of a high but not complete purity.

Another object of the invention is the provision of a process for the separation of a gaseous mixture into components wherein the resolution is effected with a lower consumption of power with respect to the elimination of the amount of lower boiling component of the gaseous mixture and to the obtainment of the higher boiling component in a state of higher purity.

An additional object of the invention is to provide a process for the separation of gaseous mixtures, especially air, into oxygen of a purity of from 75% to 80% by partial liquefaction of a greater portion of the amount of air to be separated (about 60–75%), whereas from the remaining portion (25–40%) the oxygen is separated without compressing the air.

A further object of the invention is to provide a process for the resolution of a gaseous mixture into components in which a compressed and cooled gaseous mixture is partially liquefied in a plurality of stages, and the liquid so produced

vaporized in a plurality of stages at different pressures on the vaporizer side of condensers with a rectification taking place in the first vaporizer.

A specific object of the invention is the provision of a process for the resolution of air into nitrogen and nitrogen containing oxygen, wherein a liquid of 75–90% oxygen content may be obtained by vaporization and rectification in a first vaporizer.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others thereof, which will be exemplified in the process hereinafter disclosed, and the scope of the application of which will be indicated in the claims.

In the practice of the invention a gaseous mixture is separated into components by compressing and then cooling to a low temperature. The cooling of the gas is effected by passage through a cold yielding zone and preferably by conducting the same in direct contact with cold regenerative bodies which have previously been brought to a low temperature by contact with cold separated components. The flow of ingoing gas and outgoing components may be periodically and alternately reversed with respect to a given regenerative body. The cooled gaseous mixture is now separated into higher and lower boiling components by partial liquefaction in a plurality of stages which may be arranged in series. The first partial liquefaction effects the formation of a liquid enriched in higher boiling component and a gas or a vapor enriched in lower boiling component, which is then partially liquefied in a second condenser.

The liquid component so obtained in the second condenser is conducted to a by-rectifier wherein it flows countercurrently to vapors arising from the first vaporizer and there results a liquid product having a considerably higher content of higher boiling component. Such liquid is admixed with that arising from the first partial liquefaction, prior to entry into the first vaporization stage where it is partially vaporized with simultaneous rectification to a high content of higher boiling component. The liquid so obtained in the first vaporization is then further and completely vaporized in a second stage at a pressure which is lower than that of the earlier stage. The vaporization in the later stage under a lower pressure is effected by flowing, more particularly by trickling, a liquid preferably counter-

currently in continuous uni-directional indirect heat exchange relation with the gas mixture. More particularly the liquid may be in contact with the entire heat exchange surface and have cocurrent flow in a continuous manner in thin streams with continuity of direct contact of vapor and liquid.

Higher and lower boiling components in gaseous form are warmed prior to use, or storage, by passing separately through cold absorbing zones. The cold absorbing zones may be in the form of regenerators through which the components pass in direct contact with regenerative bodies. Further, the non-liquefied portion of the lower boiling component vapors in compressed state may be expanded by conducting it through an expansion turbine whereby cold losses are recovered.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawings, in which Fig. 1 illustrates diagrammatically an apparatus suitable for accomplishing resolution of the gaseous mixture into components according to the novel procedure herein described, and Fig. 2 depicts a modification of the apparatus shown in Fig. 1 whereby a portion of the cooled gaseous mixture is led into a by-rectifier.

The apparatus (Fig. 1) comprises in combination a plurality of regenerators 1, 2, 3 and 4 which are operated in pairs for cooling an ingoing gaseous mixture and absorbing cold from outgoing separated components. The regenerators are subjected to alternate and periodical reversal through the medium of reversing valves 51, 52, 53 and 54 positioned at the tops thereof. By means of suitable conduits positioned in operative relation the regenerators are connected with a separating means 40. The separating means is divided into compartments by suitably positioned diaphragms and therein is effected a partial liquefaction of a gaseous mixture with simultaneous rectification. A rectifying column 31 is operatively connected with the separating means, and by means of a conduit the top of the second condenser is connected with an expansion turbine 50. The conduits through which the gaseous mixture and separated components are passed are provided with suitable valves, some of which are of the expanding type, by means of which the flow of gaseous mixture and components to and from the separating apparatus is controlled.

Operation for the separation of a gaseous mixture into components may be carried out in the following manner. The procedure will be illustrated with respect to the separation of air into an oxygen and a nitrogen component. It will be realized that the process is not limited to the separation of air, and that reference to air hereinafter is wholly illustrative.

The air to be separated may be compressed in the usual manner to approximately two atmospheres (absolute). The thus compressed air is cooled by passing through two of the four regenerators 1, 2, 3 and 4 alternately, from whence the cooled and compressed air passes, for example, having been cooled in regenerators 1 and 2 through conduits 9, 10, 15 and 13 to a pipe 18 which introduces it into the base of a separating means 40. In the separating means it passes through two condensers or liquefying stages 43 and 44 in series. A separation or resolution of the air is brought about in the separating column 40 so that there is effected a partial separation of nitrogen by means of partial liquefaction and

fractional condensation in the two condensers. These condensers are connected in series in such a way that the entire oxygen content of the air, together with a practically equal volume of nitrogen, is condensed in the first condenser 43 in the form of a low purity oxygen containing approximately 45% O_2 . A portion of the remaining nitrogen is liquefied in the condenser 44 while another portion remains in gaseous condition, passes from the condenser through the conduit 26 to an expansion engine, or turbine 50 in which it is expanded in order to cover cold losses of the plant.

The nitrogen leaves the expansion engine through a pipe 27 and thence through pipes 14 and 12 to the regenerator 4 from which it passes through conduit 84, reversing valve 54 and conduit 74. The liquid produced in the condenser 43, that is the low purity oxygen, passes therefrom through a conduit 19, expansion valve 17, and conduit 20 into the vaporizing chamber 45. This vaporizing chamber surrounds the tubes forming the vaporizer side of the condenser 43, and is provided with trays to assist in the rectification or enrichment, of the liquid in oxygen content. Approximately three-fifths of the introduced liquid is vaporized in the vaporizer 45 with simultaneous rectification, the vapors and liquid flowing in countercurrent relation to one another, and there results a liquid containing approximately 80% oxygen. This liquid is conducted by means of pipe 23 having an expansion valve 24 to the vaporizer 46. It is introduced into this vaporizer at the top thereof, flows downwardly there-through, trickles over the surfaces of the tubes forming the condenser, is completely or largely vaporized therein, and passes out at the bottom through conduit 25. Thence it passes through conduits 16 and 11 to regenerator 3 from which it is withdrawn through conduit 83, reversing valve 53 and pipe 73.

The partial liquefaction is effected at a pressure of about two atmospheres, the vaporization in the vaporizer 45 at a pressure of about one atmosphere, and that in vaporizer 46 at a reduced pressure, e. g., approximately 0.5 atmosphere. The condenser 43 traverses the whole of the vaporizing chamber 45 and a considerable part of the vaporizing chamber 46, whereas the condenser 44 traverses only the upper part of the vaporizer 46. On the condenser side 43 the air is partially liquefied with a gas flow that is countercurrent to the flow of liquid on the vaporizer side, and the liquid here formed contains substantially all of the oxygen. The nitrogen remaining unchanged passes from the condenser 43 to condenser 44 by means of the bell cap diaphragm 42. A portion thereof is liquefied, and collects upon the diaphragm from which it may be conducted through pipe 29 provided with valve 30 to the rectifier 31.

Vaporization in the vaporizing stage 45 is carried out in a manner such that the liquid containing approximately 45% oxygen coming from the condenser 43 is introduced at the upper end thereof by the conduit 20. This liquid, which was condensed at a pressure of two atmospheres is expanded to substantially one atmosphere by the valve 17, and vaporization is effected at substantially this pressure. The liquid is partially vaporized (approximately three-fifths) during its downward flow, and is thereby enriched to approximately 80% oxygen content through simultaneous rectification, which is augmented by means of the rectification trays 47. In this va-

porization stage the vapors flow upwardly through the trays or plates 47, are conducted from the vaporizer by the conduit 21 and introduced into the rectifier 31. This rectifier is also provided with rectifying trays 32. The rectifier 31 serves to remove oxygen contained in the vapors passing from the vaporizer 45, and the rectification is effected by means of nitrogen wash liquid introduced through the conduit 29 and arising in the condenser 44. The liquid nitrogen consisting of approximately one sixth of the air volume introduced to be separated is introduced on to the head of the rectifier and washes the oxygen out of the vapors entering at the bottom thereof through the conduit 21 and arising from vaporizer 45. In the rectifier is thus obtained an additional 15% of a liquid containing approximately 50% oxygen. Such liquid leaves the rectifier through the conduit 22, and joins that arising in the condenser 43, and entering the vaporizer 45 through the conduit 20.

The liquid formed in the vaporizer 45 is conveyed to the vaporizer 46 which is constructed in the form of a trickle evaporator provided with trays. The liquid enriched in oxygen to about 80% is introduced at the top of this vaporizer, flows downwardly with cocurrent flow of vapor and liquid, is wholly evaporated and leaves by means of the conduit 25. In Fig. 2 the liquid oxygen is introduced at the bottom of the second stage vaporizer, is completely evaporated and leaves at the top by the conduit 25. The oxygen vapors are removed from the vaporizer 46 under a reduced pressure of about 0.5 atmosphere, and are warmed prior to exit by passing through a regenerator, either 2 or 3.

The operation of the vaporizer 46 which may have cocurrent flow of liquid and vapor is accompanied by several advantages. However, if it is desired to waive these advantages this vaporizer could, if required, be of the customary construction and mode of operation, that is, filled with liquid from which vapors would be withdrawn in an upward direction. It is desirable, however, always to operate the vaporizer 45 in such a manner that the vapors are conducted upwards in countercurrent relation to the liquid, that is, flowing cocurrently with the gas mixture which is undergoing condensation or partial liquefaction on the condenser side. The liquid in this vaporizer flows downwardly in countercurrent relation both to the vapors being evolved and to the flow of the gas mixture undergoing liquefaction.

It is in this manner that it is possible to accomplish liquefaction of the low purity oxygen in the first condenser 43 at a pressure of about two atmospheres absolute, inasmuch as the evaporation and condensation temperatures very closely approach those required for condensation at the pressure employed. In addition to this, it is desirable that the liquid flow through the vaporizer 45 from the top to the bottom due to the fact that a liquid having an oxygen content of approximately 80% is to be withdrawn at the bottom and conducted to the vaporizer 46. Such a liquid could not be withdrawn from the top because the liquid at that point has an oxygen content of only 45-50%. The oxygen resulting in the separation of air is withdrawn from the vaporizer 46 at approximately 0.5 atmosphere absolute, and is alternately led out through regenerators 2 and 3.

The nitrogen arising from the rectifier 31 and from the separating means 40, after expansion

of that arising in the separating column in an expansion turbine 50, is united and led out alternately through regenerators 1 and 4. It will thus be observed that while one pair of regenerators is functioning to cool ingoing air, the other pair of regenerators acts as a cold absorbing zone and takes up cold from outgoing separated oxygen and nitrogen. The flow of ingoing air and outgoing oxygen and nitrogen is reversed alternately and periodically in rapid sequence, for example, every two to three minutes.

A pressure of approximately two atmospheres is sufficient to effect the liquefaction desired in the condenser 43 inasmuch as the oxygen which is easier to liquefy is condensed therein in countercurrent relation to a liquid containing about 45% oxygen descending on the vaporizer side. On the other hand, in condenser 44 only nitrogen is undergoing liquefaction, and since nitrogen is more difficult to liquefy, a greater difference in pressure is required between the condenser and vaporizer sides. The liquefaction of nitrogen requires a pressure differential of 1:4 whereas the liquefaction of approximately 50% oxygen content liquid requires a pressure differential of 1:2.

In the foregoing process, however, it is desired that the entire quantity of air be first conducted through the condenser 43 and then through the condenser 44, and in view of the fact that a pressure of only two atmospheres is permissible in condenser 43 it is impracticable to bring this pressure to four atmospheres prior to conductance to condenser 44. According to the present invention this difficulty is overcome by a reduced or sub-pressure of approximately 0.5 atmosphere in the vaporizer 46. This is effected by withdrawing the oxygen under such reduced pressure with a result that the pressure relationship of 1:4 is set up.

The procedure may also be carried out in that a quantity of air equal to the amount of oxygen withdrawn at a pressure of approximately 0.5 atmosphere through regenerators 2 and 3 is blown without excess pressure alternately and periodically through such regenerators into the rectifier 31. In the rectifier it contacts with the wash nitrogen and is separated into a liquid enriched in oxygen and nitrogen in gaseous state. When so operating less of the low purity oxygen is liquefied in condenser 43, but more nitrogen must be liquefied in the condenser 44, as wash nitrogen. This additional amount is approximately double that required when introducing the air at two atmospheres and withdrawing oxygen at 0.5 atmosphere, and amounts approximately to 20% of the entire volume of air whereas when operating without the blowing in procedure only about 15% of the air to be separated is required as wash nitrogen. (This case being illustrated in Fig. 2 of the accompanying drawings.)

The mode of carrying out the process shown in Fig. 2 differs from that in Fig. 1 only in that that portion of the gaseous mixture to be separated which is alternately introduced through regenerators 2 and 3 in cold exchange relation with the higher boiling constituent, is not liquefied but is directly blown into rectifier 31 through conduit 48 without excess pressure, and that the higher boiling constituent of this portion is washed out in this rectifier by the medium of the wash liquid.

Thus, for example, if 10,000 cubic meters of air per hour are to be separated into approximately 80% oxygen and technically pure nitrogen without a blowing in of a part of the air, a lique-

fraction of about 4,500 cubic meters of air would be required in form of a low purity oxygen, whereas about 1,500 cubic meters of nitrogen would be liquefied to form the wash liquid for rectifier 31. However, with the blowing in operation there would be required only about 3,500 cubic meters of low purity oxygen and about 2,500 cubic meters of wash nitrogen. In both cases 6,000 cubic meters of air must be compressed to two atmospheres for liquefaction and 2,500 cubic meters of oxygen withdrawn at 0.5 atmosphere. In the second case an additional 2,500 cubic meters of air must be blown into the rectifier 31 at a pressure of about 1.1 atmospheres. In practice, however, 10,000 cubic meters must be compressed, in the first case, inasmuch as 4,000 cubic meters of nitrogen separated in compressed condition are conducted to the expansion turbine for expansion whereby the cold losses of the plant are covered. In the second case, on the other hand, 7,500 cubic meters of air must be compressed, 6,000 cubic meters thereof are liquefied and 1,500 cubic meters are conducted to the expansion engine or turbine, whereas 2,500 cubic meters are blown in without excess pressure.

The process hereinbefore described is of particular practical importance when utilized in connection with regenerators which are operated periodically with alternation of flow of ingoing gas and separated components. This is the case inasmuch as the foregoing method of vaporization results in an appreciable reduction of the pressure required under which the gas mixture is condensed, while on the other hand the volume becomes somewhat greater due to withdrawal of a separated component under reduced pressure. With a lowering of the pressure there is an increase in the heat transfer surfaces required for cold exchange between the gas mixture and separated components whereby cooling to liquefaction temperature is occasioned and such cooling always precedes the separation.

The production of oxygen of approximately 70-90% purity applies especially to plants having large capacities inasmuch as such plants are designed for large scale manufacturing operations, such as are found in the iron and steel, the chemical and metallurgical industries, and also others in which operations are conducted at high temperature. The production costs of such plants are materially affected by the cost of the cold exchangers, and since the efficiency of cold exchange is a determining factor in the consumption of power, and further, inasmuch as the cold losses cannot be materially reduced with the continuously operating tubular type of cold exchanger, it will be realized that the procedure herein described is of special importance, and especially designed for use in conjunction with cold accumulators through which the gases and components flow periodically in alternation.

Since certain changes may be made in carrying out the above process 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.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described my invention, what I claim

as new and desire to secure by Letters Patent, is:

1. A process for the resolution of gaseous mixtures, which comprises cooling a gaseous mixture by conducting it through a cold yielding zone, partially and fractionally liquefying said cooled gaseous mixture in a first stage whereby the content of higher boiling constituent is gradually decreasing in an upward direction, producing wash liquid for a by-rectification stage by condensing another portion of the gaseous mixture largely freed of higher boiling constituent in a second stage, said wash liquid consisting substantially of lower boiling constituent, conducting the higher boiling constituent enriched liquid obtained in the first stage of fractional liquefaction to a first stage of vaporization, vaporizing this liquid with simultaneous rectification whereby said liquid is enriched in higher boiling constituent while the lower boiling constituent, together with a small portion of higher boiling constituent is evaporated, said evaporated lower boiling constituent being conducted to a by-rectification stage wherein the higher boiling constituent is washed out by the medium of the liquid arising from the second condensation stage whereby this liquid is enriched in higher boiling constituent, conducting said higher boiling constituent enriched liquid to the first vaporization stage where it joins the liquid arising from the first condensation stage, partially vaporizing this liquid now formed while the remaining portion of this liquid is conducted to a second vaporization stage where it is wholly vaporized at reduced pressure, warming the vapor arising and the lower boiling constituent separated partly at excess pressure and partly at atmospheric pressure, by conducting them through cold absorbing zones.

2. A process for the resolution of gaseous mixtures, which comprises cooling a compressed gaseous mixture by conducting it through a cold yielding zone, partially and fractionally liquefying said gaseous mixture in a first stage whereby the content of higher boiling constituent is gradually decreasing in an upward direction, producing wash liquid for a by-rectification stage by condensing another portion of the gaseous mixture largely freed of higher boiling constituent in a second stage, said wash liquid consisting substantially of lower boiling constituent, conducting the higher boiling constituent enriched liquid obtained in the first stage of fractional liquefaction to a first stage of vaporization, vaporizing this liquid with simultaneous rectification whereby said liquid is enriched in higher boiling constituent while the lower boiling constituent, together with a small portion of higher boiling constituent is evaporated, said evaporated lower boiling constituent being conducted to a by-rectification stage wherein the higher boiling constituent is washed out by the medium of the liquid arising from the second condensation stage whereby this liquid is enriched in higher boiling constituent, conducting said higher boiling constituent enriched liquid to the first vaporization stage where it joins the liquid arising from the first condensation stage, partially vaporizing this liquid now formed while the remaining portion of this liquid is conducted to a second vaporization stage where it is wholly vaporized at reduced pressure, warming the vapor arising and the lower boiling constituent separated partly at excess pressure and partly at atmospheric pressure, by conducting them through cold absorbing zones, after having ex-

panded the lower boiling constituent separated in compressed condition in order to cover cold losses.

3. A process for the resolution of gaseous mixtures, which comprises cooling a gaseous mixture partially compressed and partially inblown in uncompressed state by conducting it through cold yielding zones, partially and fractionally liquefying the compressed portion of said gaseous mixture in a first stage whereby the content of higher boiling constituent is gradually decreasing in an upward direction, producing wash liquid for a by-rectification stage by condensing another portion of the gaseous mixture largely freed of higher boiling constituent in a second stage, said wash liquid consisting substantially of lower boiling constituent, conducting the higher boiling constituent enriched liquid obtained in the first stage of fractional liquefaction to a first stage of vaporization, vaporizing this liquid with simultaneous rectification whereby said liquid is enriched in higher boiling constituent while the lower boiling constituent together with a small portion of higher boiling constituent is evaporated, said evaporated lower boiling constituent being conducted to a by-rectification stage wherein the higher boiling constituent is washed out by the medium of the liquid arising from the second condensation stage whereby this liquid is enriched in higher boiling constituent, conducting said higher boiling constituent enriched liquid to the first vaporization stage wherein it joins the liquid arising from the first condensation stage, partially vaporizing this liquid now formed while the remaining portion of this liquid is conducted to a second vaporization stage where it is wholly vaporized at reduced pressure, while the portion inblown in uncompressed state is conducted to a rectifying stage in order to wash out the higher boiling component from said inblown portion of the gaseous mixture, warming the vapor arising and the lower boiling constituent separated partly at excess pressure and partly at atmospheric pressure, by conducting them through cold absorbing zones, after having expanded the lower boiling constituent separated in compressed state in order to cover cold losses.

4. A process for the resolution of gaseous mixtures, which comprises cooling a gaseous mixture by conducting it in contact with regenerative bodies, partially and fractionally liquefying said cooled gaseous mixture in a first stage whereby the content of higher boiling constituent is gradually decreasing in an upward direction, producing wash liquid for a by-rectification stage by condensing another portion of the gaseous mixture largely freed of higher boiling constituent in a second stage, said wash liquid consisting substantially of lower boiling constituent, conducting the higher boiling constituent enriched liquid obtained in the first stage of fractional liquefaction to a first stage of vaporization, vaporizing this liquid with simultaneous rectification whereby said liquid is enriched in higher boiling constituent while the lower boiling constituent, together with a small portion of higher boiling constituent, is evaporated, said evaporated lower boiling constituent being conducted to a by-rectification stage wherein the higher boiling constituent is washed out by the medium of the liquid arising from the second condensation stage whereby this liquid is enriched in higher boiling constituent, conducting said higher boiling constituent enriched liquid to the first vaporization

stage where it joins the liquid arising from the first condensation stage, partially vaporizing this liquid now formed while the remaining portion of this liquid is conducted to a second vaporization stage where it is wholly vaporized at reduced pressure, warming the vapor arising and the lower boiling constituent separated partly at excess pressure and partly at atmospheric pressure, by conducting them in contact with regenerative bodies.

5. A process for the resolution of air, which comprises compressing a greater portion of the air to be separated to about 2 atmospheres and a smaller portion to about 1.2 atmospheres, chilling the air by passing it in direct contact with cold regenerative bodies, separating the thus cooled air into a liquid component enriched in oxygen and a gaseous component containing nitrogen in two stages in series, vaporizing the liquid component thus obtained in two stages, the first stage of vaporization being effected with accompanying rectification at a pressure of about 1 atmosphere with countercurrent flow of vapor and liquid, rectifying the vapors produced during said first stage of vaporization in a by-rectifying stage and returning liquid produced by the rectification to the first stage, conducting the liquid obtained in the first evaporation stage to the second stage and effecting the second stage of vaporization at a pressure of about 0.5 atmosphere by trickling liquid resulting from the first stage countercurrently in continuous uni-directional indirect heat exchange relation with the air undergoing liquefaction, said liquid being in contact with the entire heat exchange surface and with cocurrent flow in a continuous manner in thin streams with continuity of direct contact of vapor and liquid, warming the oxygen and nitrogen components by passing them in direct contact with warm regenerative bodies, expanding the nitrogen separated in compressed condition, and alternately and periodically reversing the flow of ingoing air and outgoing oxygen and nitrogen with respect to the regenerative bodies.

6. A process for the resolution of gaseous mixtures, which comprises cooling said gaseous mixture, partially liquefying at uniform condensation pressure in two stages arranged in series whereby liquid enriched in higher boiling component is obtained, vaporizing the liquid thus obtained in two stages, the first stage being effected by vaporizing the liquid enriched in higher boiling component and containing initially a considerable amount of lower boiling component at a pressure greater than that present in the second stage of vaporization, said first stage of vaporization being attended by rectification whereby a smaller portion of liquid more highly enriched in higher boiling component is obtained, and vaporizing the remaining liquid so produced in a second stage of vaporization at a reduced pressure by flowing the liquid in continuous uni-directional indirect heat exchange relation with the gas mixture, the liquid being in contact with the heat exchange surface and having cocurrent flow in a continuous manner with continuity of direct contact of vapor and liquid.

7. In a process for the resolution of a gaseous mixture, the improvement which comprises vaporizing a liquid enriched in a higher boiling component in two stages at different pressures the vaporization in one stage being effected by flowing liquid resulting from an earlier stage in continuous uni-directional heat exchange rela-

tion with the gas mixture, said liquid being in contact with the heat exchange surface and having cocurrent flow in a continuous manner with continuity of direct contact of vapor and liquid.

8. A process for the resolution of a gaseous mixture, which comprises vaporizing a liquid enriched in a higher boiling component in two stages at different pressures, the first stage being accompanied by simultaneous rectification, and the second stage effecting complete evaporation of the liquid enriched in higher boiling component by the rectification in the first stage of vaporization, said complete evaporation being brought about by flowing the liquid in continuous uni-directional heat exchange relation with the gas mixture undergoing liquefaction, said liquid being in contact with the heat exchange surface and having cocurrent flow in a continuous manner with continuity of direct contact of vapor and liquid.

9. In a process for the resolution of air into oxygen and nitrogen, the improvement which comprises vaporizing a liquid enriched in oxygen in two stages at different pressures one of said pressures being sub-atmospheric the vaporization of the oxygen liquid in the second stage being effected by trickling the liquid resulting from the first stage countercurrently in continuous uni-directional indirect heat exchange relation with the air undergoing liquefaction, said liquid being in contact with the entire heat exchange surface and having cocurrent flow in a continuous manner in thin streams with continuity of direct contact of vapor and liquid.

10. In a process for the resolution of air into oxygen and nitrogen, the improvement which comprises vaporizing a liquid enriched in oxygen in two stages at different pressures, the first stage being at about atmospheric pressure and the second stage at a sub-atmospheric pressure of about 0.5 atmosphere absolute by trickling the liquid formed in the first stage countercurrently in continuous uni-directional indirect heat exchange relation with the air undergoing liquefaction, said liquid being in contact with the entire heat exchange surface and having cocurrent flow in a continuous manner in thin streams with continuity of direct contact of vapor and liquid.

11. A process for the resolution of a gaseous mixture, which comprises cooling said gaseous mixture, partially liquefying in two stages whereby a liquid enriched in a higher boiling component and a gas enriched in a lower boiling component are obtained, vaporizing the liquid obtained in two stages at different pressures, the first stage of vaporization being effected with countercurrent flow of liquid and vapors and simultaneous rectification, and the second stage with cocurrent flow of liquid and vapors and accompanying complete vaporization, warming the higher boiling component substantially to atmospheric temperature, and warming the portion of lower boiling component separated in compressed state by liquefaction of a small portion of compressed gas, expanding said lower boiling component whereby cold losses are covered, further warming said lower boiling component substantially to atmospheric temperature.

12. A process for the resolution of a gaseous mixture, which comprises cooling said gaseous mixture, partially liquefying the cooled gas mixture in two stages having countercurrent liquid and gas flow, and vaporizing liquid so produced in two stages, the liquid and vapors flowing countercurrently with respect to one another in the

first stage, and effecting the vaporization in the second stage by trickling liquid resulting from an earlier stage countercurrently in continuous uni-directional indirect heat exchange relation with the gas mixture, said liquid being simultaneously in contact with the entire heat exchange surface and with vapor and liquid.

13. A process for the resolution of a gaseous mixture, which comprises cooling said gaseous mixture, partially liquefying the cooled gas mixture in a plurality of stages having countercurrent liquid and gas flow, and vaporizing liquid so produced in a plurality of stages, the liquid and vapors flowing countercurrently with respect to one another in an earlier stage, and effecting the vaporization in a later stage under reduced pressure by trickling liquid resulting from an earlier stage countercurrently in continuous uni-directional indirect heat exchange relation with the gas mixture, said liquid being in contact with the entire heat exchange surface and with cocurrent flow in a continuous manner in thin streams with continuity of direct contact of vapor and liquid.

14. A process for the resolution of air into oxygen and nitrogen, which comprises compressing said air to about 2 atmospheres, cooling, liquefying said compressed and cooled air with accompanying fractionation and rectification in two stages arranged in series and having countercurrent flow of gas and liquid whereby there is produced a liquid enriched in oxygen, vaporizing said liquid in two stages, the first stage being carried out at a pressure of about 1 atmosphere with countercurrent flow of liquid and gas giving simultaneous rectification, and the second stage being effected under a pressure of about 0.5 atmosphere by trickling liquid resulting from the first stage countercurrently in continuous uni-directional indirect heat exchange relation with the air, said liquid being in contact with the entire heat exchange surface and with cocurrent flow in a continuous manner in thin streams with continuity of direct contact of vapor and liquid.

15. A process for the resolution of a gaseous mixture which comprises cooling said gaseous mixture, partially liquefying the cold gaseous mixture in a plurality of stages having countercurrent liquid and gas flow and vaporizing liquid so produced in a plurality of stages, the liquid and vapors flowing countercurrently with respect to one another in an earlier stage of vaporization, and effecting the vaporization in a later stage by flowing liquid resulting from an earlier stage in continuous uni-directional indirect heat exchange relation with the gaseous mixture, said liquid being simultaneously in contact with the heat exchange surface and with vapors produced, and flowing cocurrently with said vapors.

16. A process for the resolution of gaseous mixtures which comprises cooling a gaseous mixture by conducting it through a cold yielding zone, partially liquefying said cooled gaseous mixture in a plurality of stages whereby a liquid enriched in a higher boiling constituent and a gaseous lower boiling component are obtained, vaporizing said liquid in a plurality of stages at different pressures, the vaporization in one of said stages being effected by flowing liquid resulting from an earlier stage in continuous uni-directional indirect heat exchange relation with the gas mixture, said liquid being in contact with the heat exchange surface and having cocurrent flow in a continuous manner with continuity of direct contact of vapor and liquid, and

warming the vapors arising from said vaporization and the gaseous lower boiling component by conducting them through cold absorbing zones.

5 17. A process for the resolution of gaseous mix-
1 tures, which comprises cooling a gaseous mix-
ture by conducting it through a cold yielding zone,
partially liquefying said cooled gaseous mixture
at uniform condensation pressure in a plurality
10 of stages whereby a liquid enriched in a higher
boiling constituent and a gaseous lower boiling
component are obtained, vaporizing said liquid
in a plurality of stages at different pressures,
the vaporization in one of said stages being ef-
15 fected by flowing liquid resulting from an earlier
stage in continuous uni-directional indirect heat
exchange relation with the gas mixture, said
liquid being in contact with the heat exchange
surface and having cocurrent flow in a continuous
20 manner with continuity of direct contact of vapor
and liquid, subjecting vapors arising in a preced-
ing vaporization stage to rectification, and re-
turning liquid so produced to said vaporization
stage, and warming the vapors arising from a
25 succeeding stage of vaporization and the gaseous
lower boiling component by conducting them
through cold absorbing zones.

18. A process for the resolution of air, which
comprises compressing air, chilling the com-
30 pressed air by contacting with cold regenerative
bodies, separating the thus cooled air into a liquid
component enriched in oxygen and a gaseous
component enriched in nitrogen in a plurality
of stages, vaporizing the liquid component in a
35 plurality of stages at different pressures, the va-
porization in one of said stages being effected by
flowing liquid resulting from an earlier stage in
continuous and uni-directional indirect heat ex-

change relation with the gas mixture, said liquid
being in contact with the heat exchange surface
and having cocurrent flow in a continuous man-
ner with continuity of direct contact of vapor
and liquid, and warming the oxygen enriched 5
and nitrogen enriched components by conduct-
ing said components in contact with regenerative
bodies.

19. A process for the resolution of a gaseous
mixture, which comprises cooling said gaseous 10
mixture, partially liquefying the cold gaseous
mixture with countercurrent liquid and gas flow,
and vaporizing liquid so produced in a plurality of
stages, the liquid and vapors flowing countercur-
rently with respect to one another in an earlier 15
stage of vaporization, and effecting the vaporiza-
tion in a later stage by flowing liquid resulting
from an earlier stage in continuous uni-direc-
tional indirect heat exchange relation with the
gaseous mixture, said liquid being simultaneously 20
in contact with the heat exchange surface and
with vapors produced, and flowing cocurrently
with said vapors.

20. A process for the resolution of a gaseous
mixture, which comprises cooling said gaseous 25
mixture, partially liquefying the cold gaseous
mixture and vaporizing liquid so produced in a
plurality of stages, the liquid and vapors flowing
countercurrently with respect to one another in
an earlier stage of vaporization, and effecting the 30
vaporization in a later stage by flowing liquid
resulting from an earlier stage in continuous uni-
directional indirect heat exchange relation with
the gaseous mixture, said liquid being simulta-
neously in contact with the heat exchange surface 35
and with vapors produced, and flowing cocurrent-
ly with said vapors.

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