April 21, 1942. W. L. DE BAUFRE 2,280,383

METHOD AND APPARATUS FOR EXTRACTING AN AUXILIARY PRODUCT OF RECTIFICATION

Filed Sept. 8, 1939

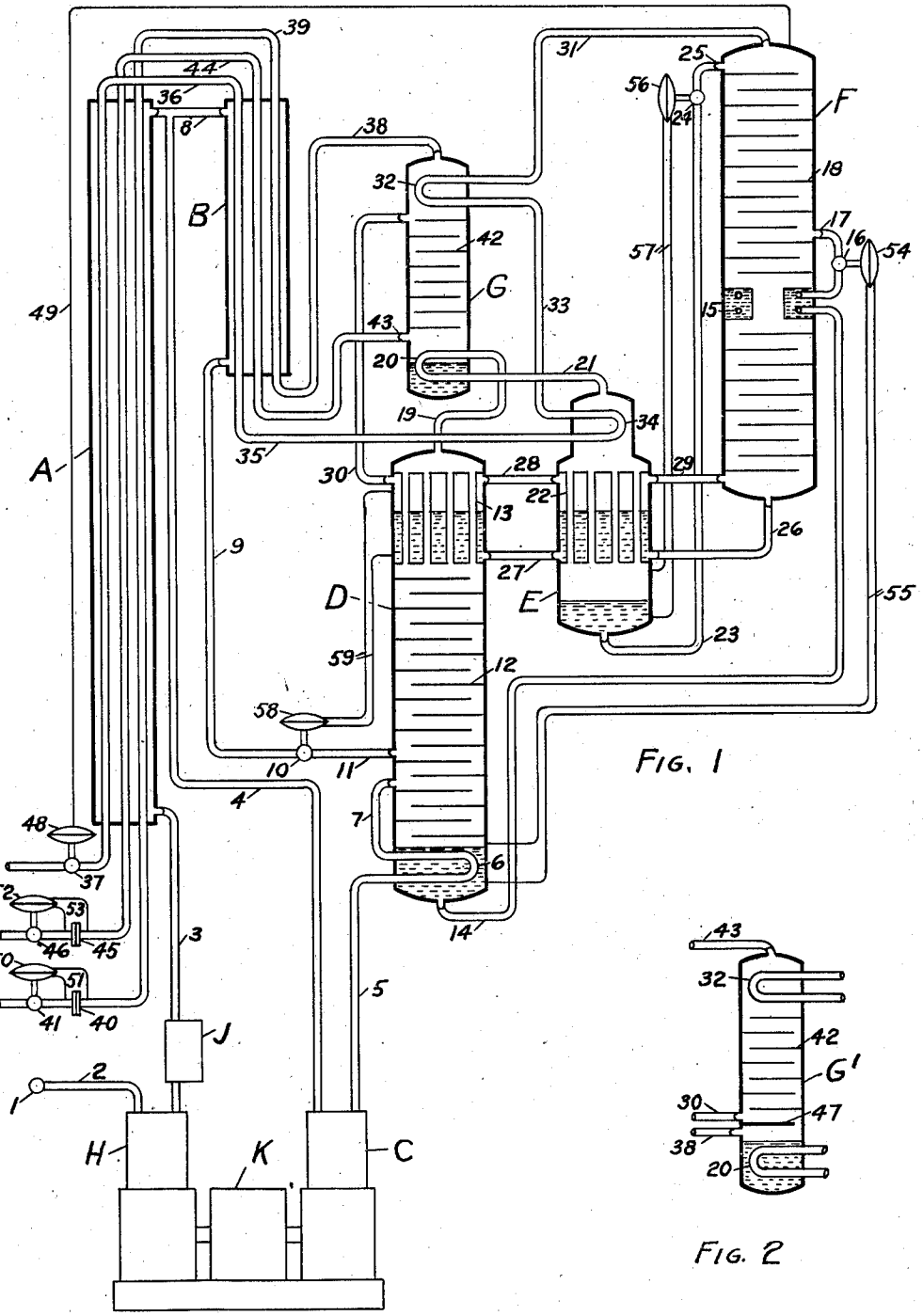

FIG. 1

FIG. 2

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Patented Apr. 21, 1942

2,280,383

UNITED STATES PATENT OFFICE

2,280,383

METHOD AND APPARATUS FOR EXTRACTING AN AUXILIARY PRODUCT OF RECTIFICATION

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Application September 8, 1939, Serial No. 293,935

19 Claims. (Cl. 62—122)

This invention relates to the rectification of atmospheric air and other gaseous mixtures when they are separated into two principal products and a third product is desired having a different purity than one of the principal products or containing a third constituent existing as an impurity in one of the principal products.

Thus, atmospheric air is usually rectified into two products only, namely, more or less pure oxygen and nitrogen. In large oxygen plants for metallurgical and other industrial purposes, a high recovery of oxygen is necessary to reduce the cost of production. When the oxygen lost as an impurity in the nitrogen product of rectification is reduced to a small percentage, the oxygen product of rectification is only 95 to 96 per cent pure by reason of the argon in atmospheric air. The principal impurity in the oxygen product of rectification is argon. While oxygen of 95 to 96 per cent purity is satisfactory for oxygen enrichment in metallurgical processes, a small amount of high purity oxygen may be desired for welding. Or, it may be desired to withdraw a small amount of argon-rich gas from a large plant for producing oxygen of 95 to 96 per cent purity.

An object of the present invention is to withdraw a small quantity of an auxiliary product from a rectification process for separating a fluid mixture into two principal products. The auxiliary product may be one of the principal products in a higher state of purity or it may consist mainly of an impurity in one of the principal products.

Another object of the invention is to enable this auxiliary product to be withdrawn as desired without materially affecting the production of the principal products.

Another object of the invention is to produce refluxes necessary for the extraction of the auxiliary product by heat exchange within the system, no heating nor cooling being required from external sources.

A further object of the invention is to secure the maximum possible refluxes throughout the system and thereby secure the most effective rectification of the fluid mixture into the principal and auxiliary products.

A still further object of the invention is to render the whole system largely automatic in operation so as to attain and maintain the most efficient rectification with minimum attention and manual operation. This is particularly important when an auxiliary product of rectification is withdrawn from the system.

These objects and such other advantages as are inherent in the invention, are realized by the method and apparatus shown in preferred form on the accompanying drawing wherein: Figure 1 shows the invention applied to the rectification of atmospheric air into nearly pure nitrogen and impure oxygen as principal products with provision for withdrawing a small quantity of nearly pure oxygen as an auxiliary product. Figure 2 shows a modification in one part of the method and apparatus for withdrawing a small quantity of argon-rich gas as an auxiliary product.

The main pieces of equipment include:

Interchanger A for cooling compressed atmospheric air or other fluid mixture to be rectified, by heat exchange with returning products of rectification.

Liquefier B for liquefying a portion of the cooled compressed air by heat exchange with returning products of rectification.

Expansion engine C for expanding another portion of the cooled compressed air with performance of mechanical work whereby heat is removed from the expanding air.

Preliminary rectifier D for separating the expanded and liquefied air into nearly pure nitrogen vapor and oxygen-rich liquid.

Condenser E for condensing nearly pure nitrogen vapor from preliminary rectifier D.

Main rectifier F for rectifying oxygen-rich liquid from preliminary rectifier D with nearly pure nitrogen liquid from condenser E as reflux, into nearly pure nitrogen vapor and impure oxygen liquid containing argon.

Auxiliary rectifier G for rectifying a portion of impure oxygen to obtain a small quantity of high purity oxygen.

Compressor H for withdrawing from a compressed air main purified atmospheric air to be rectified and for further compressing this purified air to the proper pressure for processing it.

After-cooler J for removing heat of compression from the further compressed air.

Motor K for driving the compressor-expander unit including compressor H and expansion engine C.

Auxiliary rectifier G in Figure 2 replaces auxiliary rectifier G in Figure 1 when it is desired to obtain a small quantity of argon-rich gas by an auxiliary rectification of a portion of the impure oxygen.

In Figure 1 of the drawing, the several pieces of equipment are shown in their correct relative positions except that the compressor-expander

unit may be on a different level. The relative levels of liquids and the relative positions of valves, etc., are thus correctly shown.

Compressed air main 1 is supplied with compressed air purified of carbon dioxide as described and claimed in U. S. Patent 2,128,692 issued August 30, 1938. Compressor H withdraws through pipe 2 a measured quantity of purified compressed air from main 1 as explained in the patent mentioned, further compresses this air and discharges it through after-cooler J where the heat of compression is removed by cooling water circulated therethrough. The power required to operate compressor H is supplied partly by expansion engine C and partly by motor K. All of the mechanical work of expansion engine C is thus recovered and used in compressing the air to be rectified.

The purified compressed air after being cooled to about atmospheric temperature in after-cooler J, flows through pipe 3 to interchanger A. Within interchanger A, the purified compressed air is cooled by heat exchange with returning products of rectification.

Part of the cooled compressed air flows through pipe 4 to expansion engine C where the cooled compressed air is expanded in doing mechanical work. The quantity of heat removed from the expanded air corresponds to the amount of work done. The expanded air flows through pipe 5 to coil 6 where the expanded air is cooled by heat exchange with liquid surrounding coil 6. The cooled expanded air then flows through pipe 7 and is discharged into preliminary rectifier D.

Another part of the cooled compressed air flows through pipe 8 into liquefier B where the cooled compressed air is more or less liquefied by heat exchange with returning products of rectification. The liquefied air flows through pipe 9 to valve 10 where the liquefied air is throttled to a lower pressure. The throttled liquid is then discharged through pipe 11 into preliminary rectifier D together with any vapor mixed therewith.

Within preliminary rectifier D, the throttled and expanded air is rectified upon trays 12 into nearly pure nitrogen vapor and oxygen-rich liquid. The oxygen-rich liquid accumulates around coil 6 where some of it is vaporized by heat exchange with the expanded air flowing through coil 6. This heat exchange occurs when the initial pressure and temperature of the compressed air entering expansion engine C through pipe 4 is such that the air after expansion is superheated above its saturated vapor temperature at the exhaust pressure. A temperature difference then exists between the expanded air exhausted from expansion engine C and the oxygen-rich liquid surrounding coil 6. The superheat of the expanded air is reduced in vaporizing the oxygen-rich liquid. The vaporized liquid serves as vapor reflux in rectifying the throttled and expanded air. Liquid reflux for the preliminary rectification is produced by liquefying some of the nearly pure nitrogen vapor within tubes 13.

Since saturated vapor of the composition of atmospheric air is in phase equilibrium with a liquid richer in oxygen than atmospheric air, the throttled liquid air is introduced into preliminary rectifier D upon a tray above the inlet for the expanded air vapor. Where the expanded air vapor is introduced, the composition of the vapor rising from the tray within the rectifier is substantially the same as that of the expanded air. Where the throttled liquid air is introduced, the composition of the liquid upon the tray within the rectifier is substantially the same as that of the throttled liquid air. The composition of this liquid is somewhat higher in oxygen than atmospheric air due to vapor mixed therewith.

This arrangement of inlets for the throttled and expanded air is particularly desirable when the superheat in the expanded air is largely removed by heat exchange with the oxygen-rich liquid product of the preliminary rectification as it accumulates around coil 6. Vaporization of the oxygen-rich liquid surrounding coil 6 produces vapor reflux to increase the oxygen enrichment. There should be a few trays for this further oxygen enrichment between the inlet for the desuperheated expanded air and the oxygen-rich liquid surrounding coil 6.

The oxygen-rich liquid surrounding coil 6 is discharged through pipe 14 as rapidly as it accumulates so as to keep the liquid level substantially constant within preliminary rectifier D. This oxygen-rich liquid flows through coil 15 where the oxygen-rich liquid is cooled before it is throttled through valve 16. The throttled liquid then flows through inlet pipe 17 into main rectifier F. Here the oxygen-rich liquid is rectified upon trays 18 into nearly pure nitrogen vapor and impure oxygen liquid containing argon as an impurity.

The nearly pure nitrogen vapor from the preliminary rectification leaves preliminary rectifier D through pipe 19 and flows through coil 20 and pipe 21 into condenser E. Here the nearly pure nitrogen is liquefied largely within tubes 22. The resulting liquid accumulates in the bottom of condenser E. As fast as it accumulates, the nitrogen liquid is discharged through pipe 23 to maintain the liquid level substantially constant within condenser E. The nitrogen liquid is throttled through valve 24 and then discharged into the top of main rectifier F through pipe 25. This nearly pure nitrogen serves as liquid reflux in the rectification of the oxygen-rich liquid within main rectifier F. Vapor reflux for the main rectification of the oxygen-rich liquid is produced by vaporizing the impure oxygen liquid product of the main rectification.

This impure oxygen liquid product of the main rectification flows through pipe 26 into the space around tubes 22 where part of it is vaporized by heat exchange with nearly pure nitrogen vapor liquefying within these tubes. The remaining impure oxygen liquid flows through pipe 27 into the space surrounding tubes 13 where the vaporization is completed by heat exchange with nearly pure nitrogen vapor from the preliminary rectification. Impure oxygen vapor returns through pipes 28 and 29 to main rectifier F where this impure oxygen vapor serves as vapor reflux in the rectification of the oxygen-rich liquid. The remaining impure oxygen vapor flows through pipe 30 to auxiliary rectifier G.

The nearly pure nitrogen vapor product of the main rectification flows through pipe 31, coil 32, pipe 33, coil 34, pipe 35, liquefier B, pipe 36, interchanger A and valve 37 as one of the principal products of the rectification.

Within auxiliary rectifier G, impure oxygen vapor entering through pipe 30 flows over coil 32 at the top of the auxiliary rectifier. A portion of the impure oxygen vapor is liquefied by heat exchange with nearly pure nitrogen vapor flowing through coil 32. The remaining impure oxygen vapor flows through pipe 38, liquefier B, pipe 39, interchanger A, orifice 40 and valve 41 as one of the principal products of the rectification.

The impure oxygen liquefied within auxiliary rectifier G is richer in oxygen than the original vapor with which it is nearly in phase equilibrium. This impure oxygen liquid flows down as a liquid reflux over trays 42 within auxiliary rectifier G until it reaches coil 20 where the impure oxygen liquid is vaporized by heat exchange with nearly pure nitrogen vapor flowing therethrough from preliminary rectifier D. The vaporized liquid serves as vapor reflux within auxiliary rectifier G to rectify the down flowing liquid upon trays 42. As a result of this rectification of the down flowing liquid, the liquid accumulating around coil 20 is nearly pure oxygen. Some of the nearly pure oxygen vapor produced by vaporizing this liquid, is withdrawn through pipe 43, liquefier B, pipe 44, interchanger A, orifice 45 and valve 46 as an auxiliary product of the rectification.

Nearly pure nitrogen liquid produced by condensing nearly pure nitrogen vapor within coil 20 flows along with remaining vapor through pipe 21 into condenser E. Here the nearly pure nitrogen liquid augments the nitrogen liquefied within tubes 22. Thus, the cooling effect of warming nearly pure nitrogen vapor from the main rectification as this vapor flows through coil 32 in the top of auxiliary rectifier G, is transmitted by down-flowing liquid upon trays 42 to coil 20 in the bottom of auxiliary rectifier G. Since coil 20 is arranged to drain into condenser E, the cooling effect of coil 32 eventually augments the liquid in condenser E.

The liquid in condenser E is further augmented by additional warming of nearly pure nitrogen vapor from the main rectification as this vapor flows through coil 34 after flowing through coil 32. As liquid from condenser E serves as liquid reflux in main rectifier F, the liquid reflux in the main rectification is augmented by warming the more volatile product of the main rectification within coils 32 and 34 as claimed in application Serial No. 108,913 filed Nov. 2, 1936.

Vapor reflux in the main rectification is augmented near the inlet to the main rectifier by cooling oxygen-rich liquid before it is rectified. This oxygen-rich liquid flows through coil 15 where it is in heat exchange with impure oxygen liquid undergoing rectification. This feature is claimed in application Serial No. 292,081 filed August 26, 1939.

If auxiliary rectifier G' in Figure 2 is substituted for auxiliary rectifier G in Figure 1, an argon-rich gas can be withdrawn as the auxiliary product of the rectification instead of high purity oxygen. In this case, impure oxygen vapor enters auxiliary rectifier G' through pipe 30 just above baffle 47 and leaves through pipe 38 just below baffle 47 near the bottom of the auxiliary rectifier. A portion of this impure oxygen vapor rises through trays 42 until it reaches coil 32. Some of the rising vapor is liquefied by heat exchange with nitrogen vapor flowing through coil 32. The resulting liquid flows down through trays 42 as liquid reflux. This liquid reflux rectifies the rising vapor and thus increases the argon fraction in the rising vapor. The result is that an argon-rich vapor eventually surrounds coil 32. Some of this argon-rich vapor can then be withdrawn through pipe 43.

The liquid reflux in auxiliary rectifier G' eventually reaches coil 20 where it is vaporized. The resulting vapor commingles with the impure oxygen vapor leaving through pipe 38. The function of baffle 47 is to cause all of the vaporized liquid reflux to leave through pipe 38. This insures that the vapor subjected to the auxiliary rectification is always fresh vapor from the main rectification with the maximum argon fraction rather than a leaner mixture with vapor from which some argon has been extracted.

Either auxiliary rectifier G or G' becomes dormant so far as producing an auxiliary product of rectification is concerned when valve 46 is closed to prevent flow through outlet pipe 43. The auxiliary rectifier continues to serve as a heat exchanger, however, between coil 32 and coil 20. Coil 20 has sufficient heat transfer capacity to vaporize all liquid condensed by coil 32. Normally, coil 20 will be only partly immersed in liquid surrounding it due to its excess heat exchange capacity. When no auxiliary product of rectification is withdrawn through valve 46 and pipe 43, all liquid condensed by coil 32 in either auxiliary rectifier is vaporized by coil 20 and discharged through pipe 38 as part of the impure oxygen product of rectification. When valve 46 is opened slightly, a small quantity of very pure oxygen is withdrawn with auxiliary rectifier G or a small quantity of argon-rich vapor is withdrawn with auxiliary rectifier G'. In the latter case, the argon will be contaminated with nitrogen due to this impurity in the impure oxygen. The quantity of very pure oxygen or of argon-rich gas is limited by the cooling capacity of coil 32 to produce liquid reflux for the auxiliary rectification.

Different arrangements of the plant can be used under the claims for the invention. Thus, the positions of preliminary rectifier D and condenser E can be reversed so that impure liquid oxygen from main rectifier F enters the vaporizer in preliminary rectifier D before entering the vaporizer in condenser E. Coil 20 can be arranged to drain back into preliminary rectifier D rather than into condenser E. If so arranged, liquid reflux in preliminary rectifier D would be augmented by liquid nitrogen from coil 20 rather than liquid reflux in main rectifier F.

The operation of the whole plant is almost entirely automatic. Thus, during normal operation, valve 37 through which nearly pure nitrogen flows, is automatically adjusted to maintain a substantially constant pressure at the top of main rectifier F. For this purpose, operating mechanism 48 for valve 37 is connected by control line 49 to the top of rectifier F. Valve 41 is automatically adjusted to maintain a substantially constant rate of flow of impure oxygen therethrough by means of operating mechanism 50 connected by control lines 51 to points before and after orifice 40. Valve 46 is automatically adjusted to maintain a substantially constant flow of the auxiliary product of rectification therethrough by means of operating mechanism 52 connected by control lines 53 to points before and after orifice 45.

With compressor H supplying the fluid mixture to be rectified at a substantially constant rate of mass flow, with valve 37 automatically adjusted to maintain a substantially constant rectification pressure, and with valves 41 and 46 automatically adjusted to maintain substantially constant rates of flow of one of the principal products and the auxiliary product of rectification, the purities of the products will be maintained substantially constant when the composition of the fluid mixture rectified remains substantially constant with internal fluid flows controlled as will later be described.

When the nitrogen product of rectification is wasted to the atmosphere, the rectification pressure can be maintained substantially constant by omitting regulating valve **37**. The pressure at the top of main rectifier is then equal to the substantially constant atmospheric pressure plus the pressure drop through interchanger A, liquefier B, coils **32** and **34**, and connected piping. This pressure drop will be substantially constant with the fluid mixture supplied at a substantially constant rate of mass flow and with one principal and the auxiliary product of rectification withdrawn at substantially constant rates of flow through valves **46** and **41** respectively.

During normal operation, flow of oxygen-rich liquid through valve **16** is automatically adjusted by mechanism **54** so as to maintain the liquid level substantially constant in the bottom of preliminary rectifier D. For this purpose, control lines **55** run from mechanism **54** to the vessel containing the oxygen-rich liquid, being connected above and below the liquid level. The flow of nearly pure nitrogen liquid through valve **24** is automatically adjusted by mechanism **56** so as to maintain the liquid level substantially constant in the bottom of condenser E. For this purpose, mechanism **56** is connected by control lines **57** to condenser E, above and below the liquid level.

With these two liquid levels substantially constant, any variation in the relation of the refrigeration required to balance heat leak, etc., to the refrigeration supplied for this purpose, will cause a variation of the liquid level around tubes **13** and **22**. Control mechanism **58** for automatically operating valve **10** is therefore connected by control lines **59** near the top and bottom of the space for this liquid. Control mechanism **58** automatically operates valve **10** so as to maintain this liquid level substantially constant, thereby automatically adjusting the refrigeration produced to equal the refrigeration required as claimed in patent application Serial No. 108,913, filed November 2, 1936.

Special arrangements for starting and cooling the plant and for defrosting the same after a period of operation are the subjects of other patents and are not material to the present invention.

I claim:

1. Method of rectifying atmospheric air which includes subjecting the air to a preliminary rectification into nearly pure nitrogen vapor and oxygen-rich liquid, condensing the nearly pure nitrogen vapor, subjecting the oxygen-rich liquid to a main rectification with the nearly pure nitrogen liquid as a liquid reflux into nearly pure nitrogen vapor and impure oxygen liquid, producing liquid reflux for the preliminary and main rectifications and vapor reflux for the main rectification by heat exchange between nearly pure nitrogen vapor from the preliminary rectification and impure oxygen liquid from the main rectification thereby vaporizing the impure oxygen liquid, subjecting a portion of the impure oxygen vapor to an auxiliary rectification, producing liquid reflux in the auxiliary rectification by warming nearly pure nitrogen vapor from the main rectification, and producing vapor reflux in the auxiliary rectification by liquefying nearly pure nitrogen vapor from the preliminary rectification.

2. Method of rectifying atmospheric air as in claim 1 wherein the portion of the impure oxygen vapor is liquefied in warming the nearly pure nitrogen vapor from the main rectification, the resulting liquid reflux is rectified by a vapor reflux produced by vaporizing the rectified liquid in heat exchange with nearly pure nitrogen vapor from the preliminary rectification, and part of the vaporized liquid is withdrawn as an auxiliary product of rectification.

3. Method of rectifying atmospheric air as in claim 1 wherein a portion of the impure oxygen vapor is rectified with liquid reflux produced by liquefying a part of the rectified vapor in warming the nearly pure nitrogen vapor from the main rectification, and part of the rectified vapor is withdrawn as an auxiliary product of rectification.

4. Method of rectifying atmospheric air as in claim 1 wherein the liquefied nearly pure nitrogen vapor from the preliminary rectification is used to augment liquid reflux in the rectification.

5. Method of rectifying mixed fluids which includes subjecting the mixed fluids to rectification into two principal vapor products, liquefying a portion of one principal vapor product by heat exchange with the other principal vapor product, rectifying the resulting liquid by a vapor reflux produced by vaporizing the rectified liquid, withdrawing part of the vaporized liquid as an auxiliary product of the rectification, and commingling the remaining part of the vaporized liquid after rectification with the first principal vapor product.

6. Method of rectifying mixed fluids which includes subjecting the mixed fluids to rectification into two principal vapor products, rectifying a portion of one principal vapor product by a liquid reflux produced by liquefying part of the rectified vapor in heat exchange with the other principal vapor product, withdrawing the unliquefied part of the rectified vapor as an auxiliary product of the rectification, and commingling the liquefied part after rectification with the first principal vapor product.

7. Method of rectifying a compressed gaseous mixture which includes expanding a portion of the compressed gaseous mixture with performance of mechanical work, liquefying another portion of the compressed gaseous mixture, subjecting the expanded and the liquefied portions to rectification into a vapor component and a liquid component, bringing the expanded portion before rectification into heat exchange with the liquid component, introducing the expanded portion into the rectification where the composition of the vapor is substantially the same as the gaseous mixture, and introducing the liquefied portion into the rectification where the composition of the liquid is substantially the same as the gaseous mixture, the pressure and temperature of the compressed gaseous mixture before expansion being such that the expanded portion is superheated above its saturation temperature whereby the liquid component is vaporized in desuperheating the expanded portion.

8. Apparatus for rectifying atmospheric air which includes a preliminary rectifier for rectifying the air into nearly pure nitrogen vapor and oxygen-rich liquid, a condenser for liquefying the nearly pure nitrogen vapor, a main rectifier for rectifying the oxygen-rich liquid with the nearly pure nitrogen liquid as liquid reflux into nearly pure nitrogen vapor and impure oxygen liquid, vaporizers within the preliminary rectifier and the condenser for vaporizing the impure oxygen liquid by heat exchange with nearly pure nitrogen vapor from the preliminary rectifier, an auxiliary rectifier for extracting an auxiliary

product of rectification from the impure oxygen vapor, heat transfer means near the top of the auxiliary rectifier for liquefying vapor therein by heat exchange with nearly pure nitrogen from the main rectifier, and heat transfer means near the bottom of the auxiliary rectifier for heat exchange with nearly pure nitrogen from the auxiliary rectifier.

9. Apparaus for rectifying atmospheric air as in claim 8 wherein the heat transfer means near the bottom of the auxiliary rectifier is arranged to drain into the condenser.

10. Apparatus for rectifying atmospheric air as in claim 8 wherein the inlet and the outlet for the impure oxygen vapor are near the top of the auxiliary rectifier and the outlet for the auxiliary product of rectification is near the bottom of the auxiliary rectifier, whereby a portion of the impure oxygen vapor is liquefied by the heat transfer means near the tap of the auxiliary rectifier, the resulting liquid is purified by rectification, the purified liquid is vaporized by the heat transfer means near the bottom of the auxiliary rectifier, part of the nearly pure oxygen vapor is withdrawn as the auxiliary product of rectification, and the remaining nearly pure oxygen vapor serves as vapor reflux in the rectification and is then commingled with the remaining impure oxygen vapor.

11. Apparatus for rectifying atmospheric air as in claim 8 wherein the inlet and the outlet for the impure oxygen are near the bottom of the auxiliary rectifier and the outlet for the auxiliary product of rectification is near the top of the auxiliary rectifier, whereby a portion of the impure oxygen vapor is rectified into argon-rich vapor, a part of the argon-rich vapor is withdrawn as the auxiliary product of rectification, the remaining argon-rich vapor is liquefied by the heat transfer means near the top of the auxiliary rectifier, the liquefied vapor serves as liquid reflux in the rectification and is then vaporized by the heat transfer means near the bottom of the auxiliary rectifier, and the resulting vapor is commingled with the remaining impure oxygen vapor.

12. Apparatus for rectifying atmospheric air as in claim 8 wherein the heat transfer means near the bottom of the auxiliary rectifier has a capacity to vaporize more liquid than produced by the heat transfer means near the top of the auxiliary rectifier, thereby preventing an overaccumulation of liquid within the auxiliary rectifier.

13. Apparatus for rectifying atmospheric air which includes a preliminary rectifier for rectifying the air into nearly pure nitrogen vapor and oxygen-rich liquid, a condenser for liquefying the nearly pure nitrogen vapor and within which the resulting nitrogen liquid accumulates, a main rectifier for rectifying the oxygen-rich liquid with the nearly pure nitrogen liquid as liquid reflux, a pipe for conveying the nearly pure nitrogen liquid from the condenser to the main rectifier, a throttle valve in said pipe above the level of nitrogen liquid within the condenser, and a mechanism for operating said valve controlled by the liquid nitrogen level within the condenser, whereby nearly pure nitrogen liquid is withdrawn from the condenser as rapidly as it accumulates and the liquid level therein is maintained substantially constant.

14. Apparatus for rectifying atmospheric air which includes a preliminary rectifier for rectifying the air into nearly pure nitrogen vapor and oxygen-rich liquid and within which the oxygen-rich liquid accumulates, a main rectifier for rectifying the oxygen-rich liquid, a pipe for conveying the oxygen-rich liquid from the preliminary rectifier to the main rectifier, a throttle valve in said pipe above the level of the oxygen-rich liquid within the preliminary rectifier, and a mechanism for operating said valve controlled by the level of the oxygen-rich liquid within the preliminary rectifier, whereby oxygen-rich liquid is withdrawn from the preliminary rectifier as rapidly as it accumulates and the liquid level therein is maintained substantially constant.

15. Apparatus for rectifying atmospheric air which includes a preliminary rectifier for rectifying the air into nearly pure nitrogen vapor and oxygen-rich liquid which accumulates within the preliminary rectifier, a main rectifier for rectifying the oxygen-rich liquid, an inlet thereto, heat transfer means within the main rectifier for cooling the oxygen-rich liquid before rectifying it by heat exchange with fluid undergoing rectification, pipes for conveying the oxygen-rich liquid from the preliminary rectifier to the heat transfer means and from the heat transfer means to the inlet of the main rectifier, a throttle valve in the latter pipe, and a mechanism for operating said valve controlled by the level of the oxygen-rich liquid within the preliminary rectifier, whereby oxygen-rich liquid is withdrawn from the preliminary rectifier as rapidly as it accumulates and the liquid level therein is maintained substantially constant.

16. Apparatus for rectifying atmospheric air which includes a preliminary rectifier for rectifying the air into nearly pure nitrogen vapor and oxygen-rich liquid, a condenser for liquefying the nearly pure nitrogen vapor, a main rectifier for rectifying the oxygen-rich liquid with the nearly pure nitrogen liquid as liquid reflux into nearly pure nitrogen vapor and impure oxygen liquid, vaporizers within the preliminary rectifier and the condenser for vaporizing the impure oxygen liquid by heat exchange with nearly pure nitrogen vapor from the preliminary rectifier, an auxiliary rectifier for producing an auxiliary product of rectification by rectifying impure oxygen vapor, heat transfer means for producing liquid reflux in the auxiliary rectifier by warming nearly pure nitrogen vapor from the main rectifier, and heat transfer means in the condenser for further warming the nearly pure nitrogen vapor from the main rectifier.

17. Apparatus for rectifying atmospheric air which includes main rectifying apparatus for rectifying the air into nearly pure nitrogen and impure oxygen as principal products, auxiliary rectifying apparatus for separating an auxiliary product from the impure oxygen, valves for withdrawing the two principal products and the auxiliary product, a mechanism for operating one of the valves for withdrawing a principal product of rectification controlled by the pressure within the rectifying apparatus whereby the pressure of rectification is maintained substantially constant, and mechanisms for operating the valves for withdrawing the other principal product and the auxiliary product of rectification controlled by the rates of flows through the respective valves whereby these flows are maintained substantially constant.

18. Apparatus for rectifying a fluid mixture which includes a rectifier for separating the fluid mixture into two or more products, valves for withdrawing these products, a mechanism for

operating one of the valves controlled by the pressure within the rectifier whereby the pressure of rectification is maintained substantially constant, and a mechanism for operating each of the other valves controlled by the rate of flow through the valve in question whereby the rate of flow of each product of rectification is maintained substantially constant.

19. Apparatus for rectifying atmospheric air which includes a compressor for compressing the air, an expansion engine for expanding a portion of the compressed air with performance of mechanical work, a liquefier for liquefying another portion of the compressed air, a rectifier containing trays for bringing down-flowing liquid into contact with rising vapor and thereby rectifying the expanded and liquefied air into a vapor component and a liquid component, heat transfer means for cooling the expanded portion of the compressed air by heat exchange with the liquid component of rectification, means for introducing the cooled expanded portion into the rectifier at a tray where the composition of the rising vapor is substantially the same as the expanded air, and means for introducing the liquefied portion into the rectifier at a tray where the composition of the down-flowing liquid is substantially the same as the liquefied air.

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