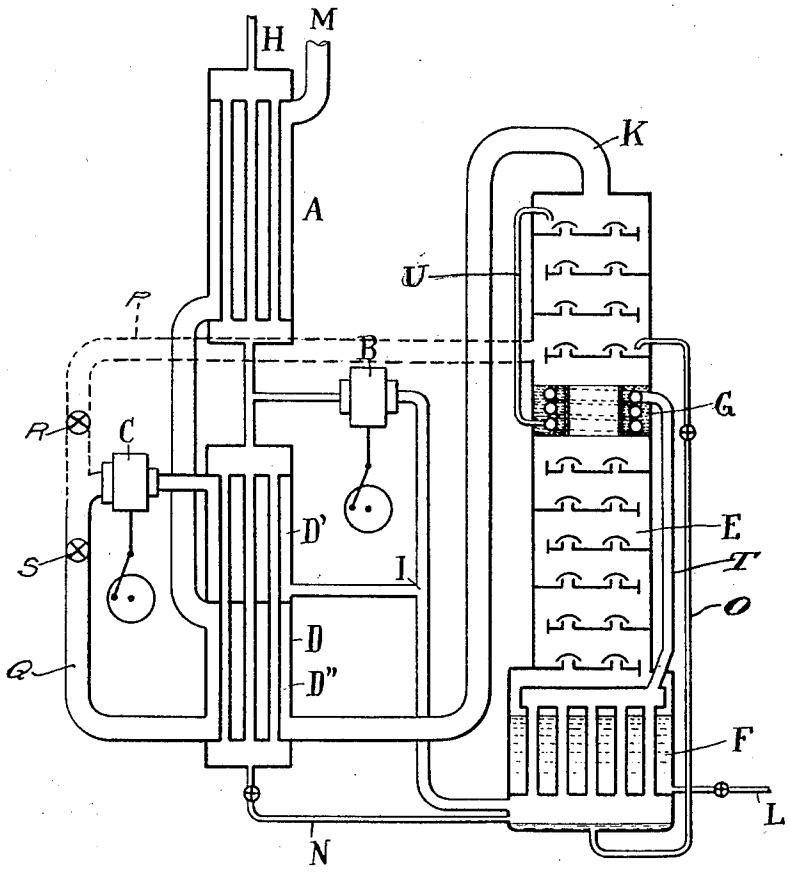
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J. LE ROUGE

METHOD OF SEPARATING GASEOUS MIXTURES

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INVENTOR
Jean Le Rouge
BY Dennie Davis Mason & Edmonds
ATTORNEYS

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JEAN LE ROUGE, OF BOULOGNE, FRANCE, ASSIGNOR TO SOCIETE L'AIR LIQUIDE (SOCIETE ANONYME POUR L'ETUDE ET L'EXPLOITATION DES PROCEDES GEORGES CLAUDE), OF PARIS, FRANCE.

METHOD OF SEPARATING GASEOUS MIXTURES.

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This invention relates to methods of separating the constituents of gaseous mixtures, for example, air, in which the necessary low temperature is maintained by expansion of compressed gas with external recoverable work. According to the usual methods of this type, particularly in the case of air, to which the following description will be directed for the purpose of simplicity, the additional liquid, which is necessary to compensate for unavoidable losses of cold in the apparatus, is produced by liquefaction under pressure of a portion of the air treated by heat interchange with the gaseous product or products of the separation.

In certain cases, particularly in the manufacture of liquid oxygen, the above-described method can be materially improved, from the standpoint of production. This can be accomplished by the use of an independent cycle producing liquid air of which the desired quantity can be added to that produced by the method described. But that involves an important and additional apparatus which can be avoided by modifying the method above described in the following manner: a certain quantity of the cold expanded air leaving the expansion engine and still under pressure is expanded a second time to the final low pressure of the separation apparatus, preferably after partial reheating. This final pressure may be substantially atmospheric pressure. The refrigerative effect of this expanded air, together with that of the nitrogen leaving the rectification column, produce the additional liquid air. In this manner it is possible to submit to the supplementary treatment a suitable quantity of air to sufficiently compensate for losses of cold in the apparatus when oxygen in a liquid state is withdrawn therefrom, and the quantity of this oxygen will be materially greater than is possible if we utilize the earlier method without increasing the pressure of the air treated.

Furthermore, if instead of liquid oxygen it is desired to produce gaseous oxygen, it suffices to send the cold air from the second expansion into the rectification column at the level where the vapors therein are of like composition, the air being thus subjected to rectification, and the usual products of rectification of liquid air supplemented by those from the rectification of the expanded air being utilized to furnish by their cold the additional liquid air as hereinbefore described. It is possible to further increase the yield of the method by utilizing for the two expansions a single expansion engine, for example, with a single piston, each expansion being conducted on opposite sides of this piston.

These and other objects of the invention will be apparent as it is better understood by reference to the following specification and accompanying drawing, in which the single figure diagrammatically represents an apparatus which is adapted for use in the application of the method in the production of liquid oxygen.

As indicated in the drawing, the apparatus comprises an exchanger A, a primary expansion engine B, an auxiliary expansion engine C, a liquefier D, and a rectification column E provided, for example, with two vaporizer-liquefiers F and G.

The compressed air is delivered by a pipe H to the exchanger A, wherein it is cooled by circulating in the inverse direction with the cold gases as hereafter explained. From the outlet from the exchanger H a part of the cold air is delivered to the expansion engine B while the balance goes to the liquefier D.

In the expansion engine B the air expands, in the normal operation to produce liquid oxygen, to an intermediate pressure, for example, 4 to 5 atmospheres, sufficient to permit it to liquefy in the tubes of the vaporizer F. A portion of this expanded air is withdrawn at I and is expanded in the auxiliary expansion engine C to the final low pressure, this expansion being accomplished preferably as indicated in the drawing after the air is reheated by circulation in the compartment D′ of the liquefier D. The cold air escaping from the engine C through a pipe Q, circulates in the lower compartment D″ of the liquefier D together with the nitrogen coming from the upper part of the rectification column at K. The liquid oxygen obtained at the bottom of this column is withdrawn at L. The mixture of expanded air and nitrogen, after circulating in the compartment D″ of the liquefier in which the mixture is partially reheated, passes into the exchanger

A which it leaves at M after being reheated to substantially the temperature at which the air enters the exchanger.

In the liquefier D the portion of the partially expanded air coming from I and circulating in D', together with the cold nitrogen from the column and the cold air escaping from the engine C, cause by their refrigerative effect the liquefaction of the compressed air in the interior of the tubes of the liquefier D. The liquid air thus produced passes through the pipe N into the rectification column, for example, at the bottom thereof. It is delivered thence with the addition of the liquid formed in the tubes of the liquefier F by a pipe O to the rectification column. The gases which escape liquefaction in the liquefier F are delivered by a pipe T to the liquefier G, and the liquid produced therein is conveyed by a pipe U to the top of the column. Valves are provided as required to control the flow of gases and liquids through the apparatus.

It is apparent that if it is desirable to separately recover the gas rich in nitrogen escaping at K, it would be necessary to construct the liquefier D and exchanger A in such a manner that this gas cannot mix with the expanded air from the engine C. This is accomplished by providing separate compartments for the gases.

In case it is desirable to recover a part of the oxygen and nitrogen from the air leaving the engine C, it suffices to deliver this air to a convenient level of the rectification column E instead of sending it to the liquefier D. The air in this case passes from the engine C through a pipe P to the level of the rectification column at which liquid is delivered through the pipe O. Valves R and S control the pipes P and Q so that the air can be diverted through either at will. The cold gases from the column will then be delivered either wholly or in part to the compartment D'' of the liquefier and to the exchanger A.

While the invention has been described with particular reference to the treatment of air, it is understood that other gaseous mixtures may be similarly treated. Various changes may be made in the details of procedure and in the apparatus employed without departing from the invention or sacrificing the advantages thereof.

I claim:—

1. The method of separating the constituents of gaseous mixtures, which comprises subjecting a portion of the compressed gaseous mixture before liquefaction to a partial expansion with external work and further expanding with external work a portion of the partly expanded mixture.

2. The method of separating the constituents of gaseous mixtures, which comprises subjecting a portion of the compressed gaseous mixture before liquefaction to a partial expansion with external work, further expanding with external work a portion of the partly expanded mixture and utilizing the refrigerative effect of this expanded portion to cool and liquefy the compressed non-expanded remaining portion.

3. The method of separating the constituents of gaseous mixtures, which comprises subjecting a portion of the compressed gaseous mixture to a partial expansion with external work, reheating a portion of the partly expanded mixture and further expanding this portion.

4. The method of separating the constituents of gaseous mixtures, which comprises subjecting a portion of the compressed gaseous mixture to a partial expansion with external work, reheating a portion of the partly expanded mixture, further expanding this portion, and utilizing the refrigerative effect of this portion to cool and liquefy the compressed non-expanded remaining portion.

5. The method of separating the constituents of gaseous mixtures, which comprises subjecting a portion of the compressed gaseous mixture to a partial expansion with external work, reheating a portion of the partly expanded mixture by indirect contact with the compressed non-expanded remaining portion, further expanding the reheated portion, and utilizing its refrigerative effect to further cool and liquefy said compressed non-expanded remaining portion.

6. The method of separating the constituents of gaseous mixtures, which comprises subjecting a portion of the compressed gaseous mixture to a partial expansion with external work, further expanding a portion of the partly expanded mixture and subjecting this expanded portion to rectification.

7. The method of separating the constituents of gaseous mixtures, which comprises subjecting a portion of the compressed gaseous mixture to a partial expansion with external work, reheating a portion of the partly expanded mixture by indirect contact with the compressed non-expanded remaining portion, further expanding the reheated portion and subjecting the expanded reheated portion to rectification.

8. The method of separating the constituents of gaseous mixtures, which comprises subjecting a portion of the compressed gaseous mixture to a partial expansion with external work, reheating a portion of the partly expanded mixture by indirect contact with the compressed non-expanded remaining portion, further expanding the reheated portion and subjecting the expanded reheated portion to rectification with the balance of the partly expanded mixture.

9. The method of separating the constit-

uents of gaseous mixtures, which comprises cooling the compressed gaseous mixture by indirect contact with the gaseous separated constituents, partly expanding with external work a portion of it, subjecting a portion of the partly expanded mixture to rectification, reheating the remaining portion of the partly expanded mixture by indirect contact with the compressed non-expanded remaining portion, further expanding the reheated portion, subjecting it to rectification, cooling and liquefying the compressed non-expanded remaining portion by indirect contact with the cold gaseous separated constituents issuing from the rectification which thereafter cool the whole compressed gaseous mixture.

10. The method of separating the constituents of gaseous mixtures, which comprises, partly expanding with external work a portion of the compressed gaseous mixture, subjecting a portion of the partly expanded mixture to rectification, reheating the remaining portion of the partly expanded mixture by indirect contact with the compressed non-expanded remaining portion, further expanding the reheated portion, cooling and liquefying the compressed non-expanded remaining portion by indirect contact with the cold gaseous separated constituents issuing from the rectification and with the further expanded portion of the gaseous mixture, and then cooling the compressed gaseous mixture by indirect contact with the separated constituents and with said further expanded portion.

11. The method of separating the constituents of gaseous mixtures, for example, air, which comprises subjecting a portion of the compressed gaseous mixture before liquefaction to a partial expansion with external work and further expanding a portion of the partly expanded mixture.

12. The method of separating the constituents of gaseous mixtures, which comprises subjecting a portion of the compressed gaseous mixture to partial expansion with external work, further expanding a portion of the partly expanded mixture and liquefying the remaining portion of the partly expanded mixture.

13. The method of separating the constituents of gaseous mixtures, which comprises subjecting a portion of the compressed gaseous mixture to a partial expansion with external work, further expanding a portion of the partly expanded mixture, utilizing the refrigerative effect of this expanded portion to cool and liquefy the compressed non-expanded remaining portion and liquefying the remaining portion of the partially expanded mixture.

In testimony whereof I affix my signature.

JEAN LE ROUGE.