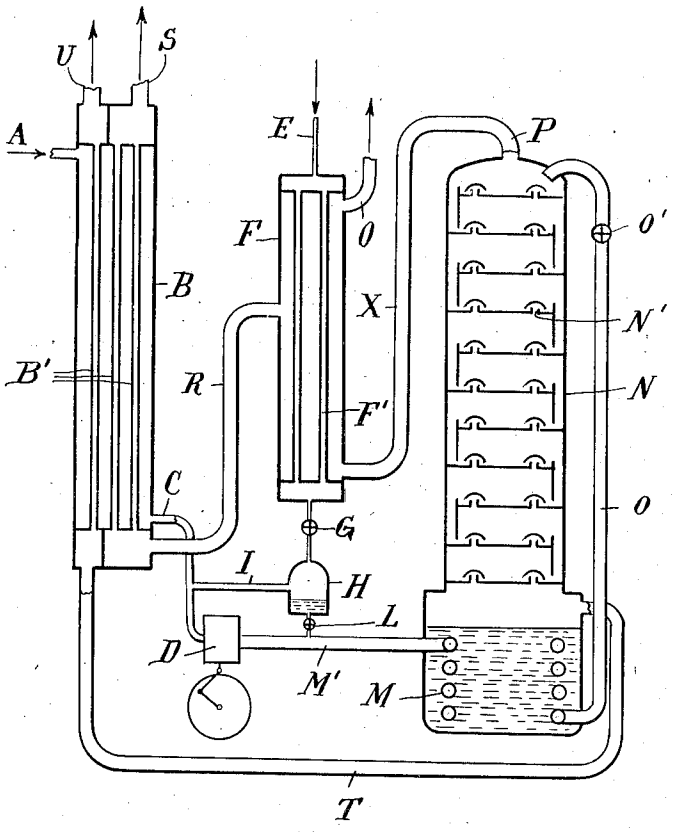
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SEPARATION OF GASEOUS MIXTURES

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SEPARATION OF GASEOUS MIXTURES.

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This invention relates to the separation of the constituents of gaseous mixtures by liquefaction and rectification, and particularly to improvements whereby the efficiency of such separation is materially increased.

In Letters Patent of the United States, No. 981,748, a method is disclosed in which a compressed gaseous mixture is subjected to heat-interchange with the gaseous products of the separation and a part thereof is expanded with the production of external work and then liquefied and separated in a rectification column while the remainder is liquefied at its initial pressure by heat-interchange with cold products of the separation in which the liquid portion is utilized. In this process the initial pressure of all parts of the entering gaseous mixture is uniform, the pressure being selected so that the expansion of a part of the gaseous mixture with external work produces refrigeration which just suffices to compensate for losses of cold in the operation.

It is the object of the present invention to increase the efficiency of liquefaction processes and particularly to modify and improve the process described in said Letters Patent.

Further objects and advantages of the invention will be apparent as it is better understood by reference to the following specification and accompanying drawing which illustrates diagrammatically a form of apparatus adapted to the accomplishment of the present purpose. It is to be understood that details of the apparatus which are well understood by those skilled in the art have been omitted from the drawing and that other details, particularly with reference to the rectification, may be varied without departing from the invention or sacrificing the advantages thereof.

The present invention depends upon the initial compression of a portion of the gaseous mixture entering the system to a materially higher pressure than that to which the remaining portion is subjected. This portion of the gaseous mixture at high pressure is caused to travel through a temperature exchanger wherein it is subjected to heat interchange with cold products of the separation. The cold liquefied gaseous mixture is then permitted to expand through an expansion valve to an intermediate pressure eventually together with some of the gaseous mixture. After the expansion valve the part which is gaseous, if any, is preferably mingled with the portion of the gaseous mixture which has been compressed to a lower pressure after the latter has passed through a temperature exchanger in which it is subjected to heat-interchange with cold products of the separation. The mingled portions of the gaseous mixture are then delivered to a suitable expansion device such as an engine or turbine and expanded with external work to a relatively low pressure corresponding substantially to the pressure at which rectification is subsequently conducted. The cold expanded mixture from the engine or turbine is delivered to a liquefier wherein it is subjected to heat-interchange with a body of liquid resulting from the rectification. Heat-interchange between the gaseous mixture and the liquid results in liquefaction of the former and evaporation of the latter, and the liquid formed is preferably augmented by the liquid previously produced from the high pressure portion of the entering gaseous mixture which is delivered under the control of a valve to the liquefier.

The combined liquids are then subjected to rectification in any suitable manner, for example, by causing them to descend through a column in which they are subjected to vapors resulting from the vaporization of liquid at the bottom of the column. Rectification results in the separation of the constituents of the liquid, the more volatile constituents accumulating in the rising vapors while the less volatile are retained in the descending liquid. In the case of air the rectification results in the production of a body of liquid which is substantially pure oxygen at the bottom of the column. The liquid oxygen is vaporized by heat-interchange with the entering gaseous mixture as hereinbefore described and a portion of the vapor is withdrawn as a product of the

operation while the balance rises as a rectifying agent through the column. The other product is nitrogen containing more or less oxygen which is withdrawn from the top of the column. Both products, being extremely cold, are utilized by heat-interchange to cool the incoming gaseous mixture.

The process may be modified by eliminating the expansion valve through which the gaseous mixture at high pressure passes after initial cooling. Instead of utilizing such a valve that part of the gaseous mixture which is not liquefied by the preliminary cooling may be caused to pass through a suitable expansion device such as an engine or turbine wherein it is subjected to expansion with external work. The cold expanded mixture may be delivered then to the liquefier with the expanded portion of the mixture which has been previously compressed to a comparatively low pressure.

Referring to the drawing and applying the invention particularly to the treatment of air, a portion of the air is compressed to a comparatively low pressure, ten atmospheres, for example, and enters an exchanger B at A. It circulates in the exchanger countercurrent to separated oxygen and nitrogen traveling through the tubes B′ of the exchanger. The compressed air after cooling leaves the exchanger through a pipe C and is delivered to an expander D wherein it is expanded with external work. The cold expanded mixture is delivered through a pipe M′ to a coil M in the bottom of a column N wherein it is subjected to the cooling effect of a body of liquid oxygen accumulated in the bottom of the column.

The other portion of the air, for example, one-sixth of the total air treated, is compressed to a high pressure, two hundred atmospheres, for example, and enters a temperature exchanger F through a pipe E. In passing through the tubes F′ of the exchanger the air is subjected to heat-interchange with a cold product of the rectification such as the effluent nitrogen delivered from the top of the column through a pipe X. The liquefied portion of the gaseous mixture eventually with a part of the gaseous mixture under high pressure is delivered through an expansion valve G to a reservoir H under a pressure which is the same as that of the first portion of air and the liquid separates from the gas in the reservoir H. This latter gas is delivered through a pipe I to the pipe C wherein it joins the low pressure gaseous mixture and is delivered to the expander D. The liquid from the reservoir H is delivered through a valve L to the pipe M′ leading to the coil M, where it joins the cold expanded gases from the expander D.

The liquid formed in and delivered to the coil M is transferred through a pipe O controlled by a valve O′ to the top of the column N and flows downwardly therein over a plurality of trays N′ of the usual form employed in rectification columns. During its downward travel the liquid is subjected to the action of vapors rising through the column with resulting rectification and separation of nitrogen from the liquid which descends to the bottom of the column as substantially pure oxygen. The nitrogen or mixture of nitrogen and oxygen forming the effluent from the column escapes through the pipe X to the exchanger F. After passing through the exchanger a portion of the effluent escapes through the outlet and the remainder is delivered through a pipe R to the exchanger B where it serves to cool the incoming gaseous mixture. The gaseous oxygen produced by vaporization of liquid in the bottom of the column is delivered through a pipe T to another section of the exchanger B. The effluent nitrogen escapes from the exchanger B through an outlet S and the oxygen escapes through an outlet U.

An advantage of the process as described results from the possibility of compressing the major portion of the gaseous mixture to a relatively low pressure. Only so much of the gaseous mixture is compressed to a high pressure as is necessary to supply an amount of liquid equivalent to the losses which inevitably occur in the system. The invention is particularly desirable in connection with large installments adapted to handle great volumes of gases.

I claim:—

1. The process of separating the constituents of gaseous mixtures by liquefaction and rectification, which comprises initially compressing a portion of the total volume of the mixture to be treated to a high pressure, partially expanding this portion, compressing the balance of the gaseous mixture to a lower pressure, expanding this portion with external work, combining both portions under conditions effecting liquefaction thereof and subjecting the liquid formed to rectification.

2. The process of separating the constituents of gaseous mixtures by liquefaction and rectification, which comprises initially compressing the gaseous mixture to a high pressure, expanding the mixture, by throttling to an intermediate pressure, whereby it is partially liquefied, expanding the unliquefied residue with external work, subjecting the expanded residue to conditions effecting liquefaction thereof, combining this liquid with the liquid produced by throttling and subjecting the combined liquids to rectification.

3. The process of separating the constituents of gaseous mixtures by liquefaction and rectification, which comprises initially compressing a portion of the total volume of the

gaseous mixture to be treated to a high pressure, partially expanding this portion by throttling, compressing the balance of the gaseous mixture to a lower pressure, combining and expanding both portions with external work, subjecting the expanded gaseous mixture to conditions effecting the liquefaction thereof and rectifying the liquid formed.

4. The process of separating the constituents of gaseous mixtures by liquefaction and rectification, which comprises initially compressing a portion of the total volume of the gaseous mixture to be treated, compressing the balance of the gaseous mixture to a higher pressure, expanding the highly compressed portion to the pressure of the other portion, expanding both portions with external work, liquefying the expanded gaseous mixture and subjecting the liquid to rectification.

5. The process of separating the constituents of gaseous mixtures by liquefaction and rectification, which comprises initially compressing a portion of the gaseous mixture to be treated to a high pressure, expanding this portion by throttling to an intermediate pressure, separating the liquid formed from the gaseous portion, compressing the balance of the gaseous mixture to substantially the intermediate pressure, combining the unliquefied residue with this compressed balance of the gaseous mixture, expanding the combined gases with external work, liquefying the expanded gases and rectifying the liquid formed with the liquid above separated.

6. Improvements in processes of separation of gaseous mixtures, employing expansion with external work and in which the separated gas or gases upon leaving the separation apparatus proper cool down a part of the gaseous mixture to be treated in order to liquefy it totally or partially, consisting in compressing this latter part of the gaseous mixture to a pressure higher than that of the other part, then expanding by simple throttling the liquid thus produced with eventually a part of the gas, to a pressure intermediate between the very high pressure and the pressure of the separation apparatus proper; then expanding with production of external work the gaseous part resulting from the preceding expansion, and then liquefying and separating this gaseous part in the separation apparatus proper.

7. A mode of operation according to claim 6, consisting in that the intermediate expansion of that part of the gaseous mixture which is at very high pressure takes place at the initial pressure of the other part of the gaseous mixture treated.

8. A mode of operation of the process, according to claim 7, consisting in mixing the gaseous part resulting from the expansion to intermediate pressure with the other part of the other gaseous mixture treated as the latter leaves the exchangers and then expanding together these two gaseous parts with production of external work.

9. In the application of the process, according to claim 6, to the separation of air, a mode of operating consisting in causing the nitrogen leaving the rectification column to cool down, first the air compressed to the highest pressure and then delivering a part only of this nitrogen, thus partially reheated into the exchanger carrying the part of the air at lower pressure.

10. Improvements in processes of separation of gaseous mixtures employing expansion with external work and in which the separated gas or gases upon leaving the separation apparatus proper cool down a part of the gaseous mixture to be treated in order to liquefy it partially, consisting in compressing this latter part of the gaseous mixture to a pressure higher than that of the other part, then expanding with production of external work the gaseous part resulting from the partial liquefaction and then liquefying and separating this gaseous part in the separation apparatus proper.

11. The process of separating the constituents of gaseous mixtures by liquefaction and rectification, which comprises initially compressing a portion of the total volume of the mixture to be treated to a high pressure, cooling this portion, separating the liquid formed from the gaseous portion, partially expanding this gaseous portion with external work, compressing the balance of the gaseous mixture to a lower pressure, cooling and partially expanding this portion with external work, subjecting both expanded gaseous portions to liquefaction and rectification and using the above separated liquid for this rectification.

12. The process of separating the constituents of gaseous mixtures by liquefaction and rectification, which comprises initially compressing a portion of the total volume of the mixture to be treated to a high pressure, cooling and partially expanding this portion by throttling, separating the liquid formed from the gaseous portion, partially expanding this gaseous portion with external work, compressing the balance of the gaseous mixture to a lower pressure, cooling and partially expanding this portion with external work, subjecting both expanded gaseous portions to liquefaction and rectification and using the above separated liquid for this rectification.

13. The process of separating the constituents of gaseous mixtures by liquefaction and rectification, which comprises initially compressing a portion of the total volume of the mixture to be treated to a high pressure,

cooling and partially expanding this portion by throttling to an intermediate pressure, separating the liquid formed from the gaseous portion, compressing the balance of the gaseous mixture to the intermediate pressure, cooling it, partially expanding it with the above separated gaseous portion with external work, subjecting both expanded gaseous portions to liquefaction and rectification and using the above separated liquid for this rectification.

In testimony whereof I affix my signature.

JEAN LE ROUGE.