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LIQUEFACTION OF AIR AND ITS SEPARATION INTO ITS CONSTITUENTS.

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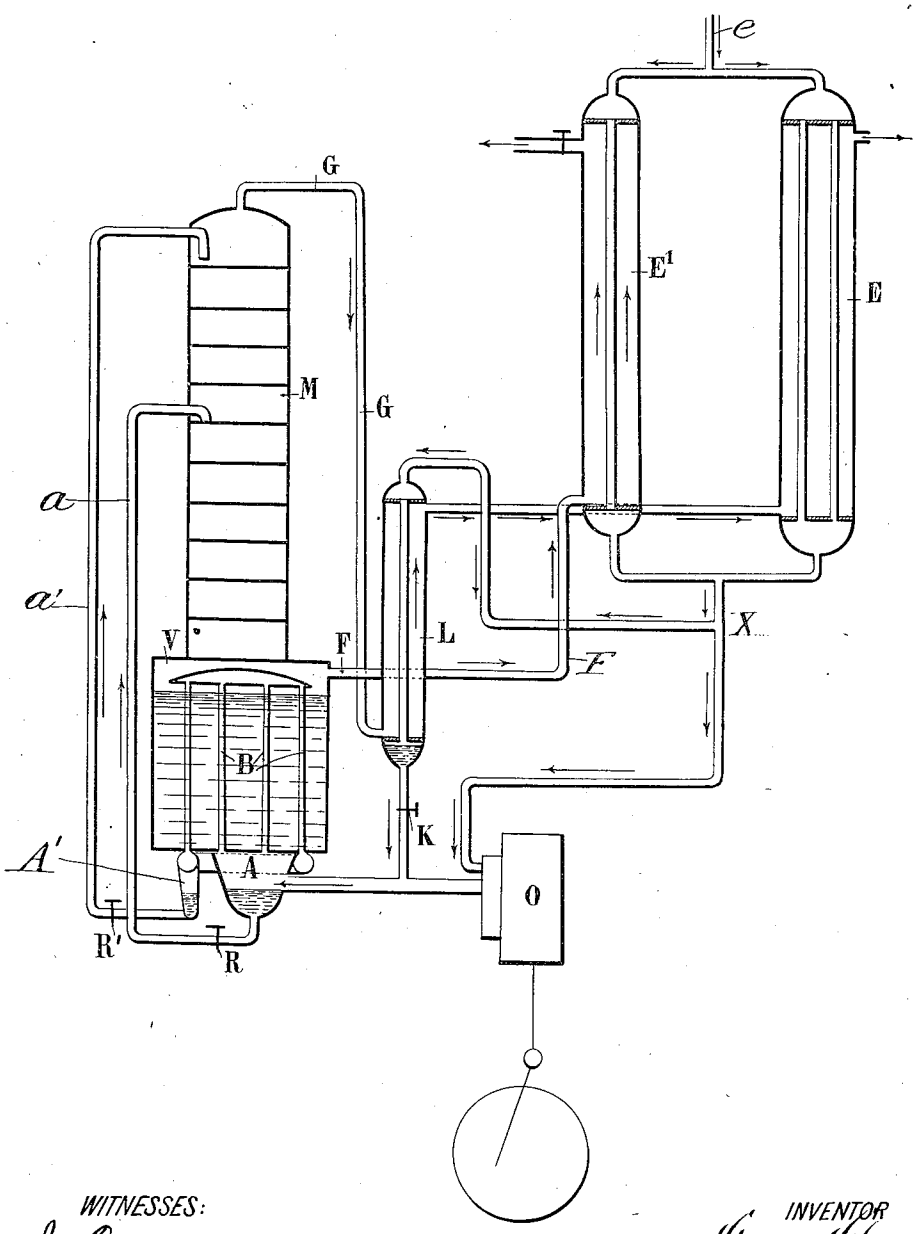
981,748. Patented Jan. 17, 1911.



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LIQUEFACTION OF AIR AND ITS SEPARATION INTO ITS CONSTITUENTS.

981,748. Specification of Letters Patent. Patented Jan. 17, 1911.

Application filed June 1, 1909. Serial No. 499,415.

To all whom it may concern:

Be it known that I, GEORGES CLAUDE, a citizen of the Republic of France, and resident of Paris, France, have invented a new and useful Improvement in the Liquefaction of Air and its Separation into its Constituents, which improvement is fully set forth in the following specification.

This invention relates to the liquefaction of air and the separation of it into its constituents.

A process of liquefying air under pressure by utilizing the low temperature of air that has undergone expansion with production of external work has been disclosed in the specification of the prior U. S. application 139,753 of 1903, the object being to improve the expansion of the air with production of external work. In this prior process, the cold expanded air from a machine capable of performing useful work is utilized to cool and liquefy air under pressure; this expanded air, in withdrawing heat from the compressed air to be liquefied, itself becomes heated. If it were desired to separate the expanded air into its constituents by a process of liquefaction it would not be advisable to employ it after having used it to cool and liquefy compressed air, because of the heating effect referred to, the opposite effect, namely, cooling, being required to bring about the desired liquefaction of this expanded air. Hence either the use of the expanded air for effecting the liquefaction of the air under pressure must be abandoned, the expanded air being instead used, immediately after its expansion, for separation purposes, or this expanded air is used only for liquefying air under pressure to make liquid air; this liquid air is then used to make up the losses of cold which occur in a distinct and independent cycle of separation of air into its constituents.

The chief object of the present invention is to devise a process for the liquefaction of air and the separation of it into its constituents, in which the supplementary liquid necessary to make up for unavoidable losses of cold in the apparatus employed, is produced in an improved manner, avoiding the necessity of adopting either of the two courses above referred to, and involving all the advantages incidental to liquefaction under pressure.

According to this invention the air under pressure is cooled by means of the cold products of separation, and part only of it is then expanded, with production of external work, to such a degree that when it is caused to come into indirect contact with the liquid at the foot of a separating apparatus it is liquefied, the liquid so produced being passed into the said separating apparatus and the separated gases issuing therefrom being utilized in cooling further quantities of the air under pressure that is to be treated. The remainder of the cooled compressed air is liquefied by means of the low temperature of the whole or part of the cold separated gases escaping from the aforesaid separating apparatus, and serves as supplementary liquid to compensate for the unavoidable losses of cold therein; it may be added to the other portion of the liquefied air and the whole then undergoes a separation or partial separation into its constituents.

The invention is applicable to methods involving a single expansion of the air with production of external work, or a succession of such expansions; in the latter case, for instance, when using a compound expansion engine, the air resulting from the first expansion is used to cool or liquefy a part of the air under pressure as indicated in the specification of the prior U. S. application No. 139,753 of 1903, above referred to. It is then further expanded and treated as above set forth. Another portion of the air under pressure is cooled and liquefied, as above described, by means of the cold gases escaping from the separating apparatus, and the whole of the air liquefied by these two operations is then used as the supplementary liquid for the separating apparatus.

In order that the invention may be clearly understood and readily carried into effect, the same will now be described more fully with reference to the accompanying drawing which illustrates in a diagrammatic manner one arrangement of apparatus suitable for the purpose.

The air to be treated, previously compressed, passes through a pipe *e* into temperature exchangers E E′ in which it is cooled by indirect contact with the cold gases resulting from the separation. The cooled compressed air after leaving the temperature exchangers arrives at a point X where it divides. Part of the air passes into a liquefying apparatus L, which is shown

constructed as a temperature exchanger; this part of the compressed air is liquefied in the apparatus L by indirect contact with some of the very cold gases resulting from the separation, which are made to circulate in the apparatus L immediately after their departure from the separating apparatus. The liquid produced in the apparatus L is the supplementary liquid. The other part of the air passes into an expansion motor O which is assumed, and is shown in the drawing, to be a single expansion motor. The expanded air escaping from the motor O is then conducted into the lower part of the separating apparatus, which is shown as comprising the rectifying column M, the vessel V in which the liquid from the column M collects, the tubes B, and the chamber A and A′. The tubes B, which are immersed in the liquid contained in the vessel V at the foot of the rectifying column M, may consist of one group conducting the air upward, or of two groups, one conducting it upward and the other conducting it downward, as disclosed in the specification of the prior U. S. Patent No. 881,176 of 1906; the latter arrangement of tubes is shown in the drawings of the present application, where the upwardly conducting tubes communicate at their lower ends with the chamber A, and the downwardly conducting tubes with the chamber A′. In this case the expanded air from the motor O is liquefied in the tubes B. Liquid rich in oxygen collects in the chamber A, and liquid rich in nitrogen collects in the chamber A′. These liquids then pass through the valves R R′ and pipes *a a′* into the middle and upper parts respectively of the rectifying column M. Liquid oxygen or liquid rich in oxygen collects in the vessel V and gaseous nitrogen or gases rich in nitrogen escape through the pipe G.

The heat of the liquefaction of the air in the tubes B of the vessel V is transmitted through the walls of the tubes and causes a vaporization of the liquid oxygen in said vessel, and a part of the vapors escape by way of the pipe F into and through the temperature exchanger E′. The gas or gases (chiefly nitrogen) escaping through the pipe G are exceedingly cold and are passed first through the liquefying apparatus L. As before stated, the air under pressure in the apparatus L is liquefied and passes through the valve K into the separating apparatus, for instance into the collecting chamber A as shown, where it serves as supplementary liquid to compensate for the unavoidable losses of cold; by suitably regulating the quantity of supplementary liquid employed, the temperature of admission of the air to the expansion motor O can be maintained fairly high, and consequently a high efficiency be attained from the motor; the gases that passed into the liquefying apparatus L from the tube G are afterward passed through the temperature exchanger E.

As regards the starting and the initial charging of the apparatus, these operations are effected in the simplest manner by first shutting the valve K and leaving the valves R and R′ wide open. The expanded air from the motor O, in circulating through the tubes and chambers progressively, cools the separating apparatus and the liquefying apparatus L until the liquefaction temperature of the air in the latter is reached. The valve K is then opened and the liquid produced in the liquefying apparatus L passes toward the chamber A out of which it is swept by further quantities of the expanded air, and is carried along therewith into the rectifying column M. As more and more liquid is produced in the apparatus L, and carried along into the rectifying column M, it distributes itself over matter or contrivances such as the perforated plates shown or equivalent arrangements such as are used in alcohol rectifying columns, and the said liquid ultimately collects in the vessel V. When the vessel V contains a sufficient quantity of liquid, the valves R and R′ are partly closed, being so regulated as to produce sufficient pressure in the tubes B to cause liquefaction to take place therein. These valves are further regulated until the production of oxygen and nitrogen in the rectifying column M takes place in a regular manner.

Although the invention has been particularly described in its application to apparatus capable of producing comparatively pure oxygen and pure nitrogen, it is equally applicable to apparatus merely producing gas rich in nitrogen and liquid rich in oxygen. It will also be understood that the oxygen or gas rich in oxygen might, directly after its escape from the separating apparatus, equally be employed in place of the nitrogen or in conjunction therewith, for effecting the liquefaction of the necessary quantity of supplementary liquid air.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A process for liquefying air and separating it into its constituents, which consists in expanding cold compressed air with production of external work, subjecting it to separation by liquefaction and rectification, liquefying another portion of compressed air by means of the cold gases resulting from the aforesaid separation, and using the liquefied portion in the separating process.

2. A process for liquefying air and separating it into its constituents, which consists in compressing and cooling the air, expanding one portion of it with production of external work, separating the said portion by liquefaction and rectification, liquefying the other portion of the compressed air by sub-

jecting it to the indirect cooling action of a part of the whole of the cold separated gases, using the liquid thus obtained for compensating the losses of cold which occur in the aforesaid separation, finally using the remaining cold of the separated gases for cooling the whole incoming compressed air to be either expanded or liquefied under pressure.

3. A process of liquefying air and separating it into its constituents, which consists in compressing and cooling the air and separating it into two portions, a working portion and a supplementary portion, expanding the working portion with production of external work, liquefying the said working portion by circulating it in indirect contact with liquid rich in oxygen, subjecting the resulting liquefied portion or portions to rectification, using part of the evaporated oxygen gas and the whole or part of the separated nitrogen gas to liquefy the supplementary portion of the cold air under pressure, using this liquefied air for compensating the losses of cold which occur in the aforesaid separation, finally using the remaining cold of the separated gases for cooling the whole incoming compressed air to be either expanded or liquefied under pressure.

4. A process of liquefying air and separating the whole of it into its constituents, which consists in compressing and cooling the air and separating it into two portions, a working portion and a supplementary portion, expanding the working portion with production of external work, liquefying the said working portion by circulating it in indirect contact with liquid rich in oxygen, subjecting the resulting liquefied portion or portions to rectification, circulating part of the evaporated oxygen gas and the whole or part of the separated nitrogen gas in indirect contact with the supplementary portion of the cold air under pressure to liquefy it, using the remainder of the cold of these gases to cool the whole incoming compressed air and continuing the process by submitting the liquid air thus obtained to separation into oxygen and nitrogen gas in the same manner.

5. A process for liquefying air and separating the whole of it into its constituents, which consists in compressing and cooling the air, expanding one portion of it with production of external work, liquefying the said portion by circulating it in indirect contact with liquid rich in oxygen, subjecting the resulting liquefied portion or portions to rectification, circulating the separated nitrogen gas in indirect contact first with the other portion of the cold air under pressure to liquefy it, then with the incoming compressed air to cool it, circulating the separated oxygen gas also in indirect contact with the incoming compressed air to cool it, adding the liquid air above obtained from the air under pressure to the expanded air to be separated.

6. A process for liquefying air and separating the whole of it into its constituents, which consists in compressing and cooling the air, partially expanding one first portion of it with production of external work, circulating this partially expanded air in indirect contact with the other second portion of the cold compressed air to cool it, further expanding the said first portion with production of external work, liquefying it by circulating it in indirect contact with liquid rich in oxygen, subjecting the resulting liquefied portion or portions to rectification, circulating the separated nitrogen gas in indirect contact first with the other second portion of the cold compressed air to liquefy it, then with the incoming compressed air to cool it, adding the liquid air above obtained from the air under pressure to the expanded air to be separated.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

GEORGES CLAUDE.

Witnesses:
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DEAN B. MASON.