M. LEBLANC.

EJECTOR.

APPLICATION FILED JUNE 22, 1915.

1,215,321.

Patented Feb. 6, 1917.

2 SHEETS—SHEET 1.

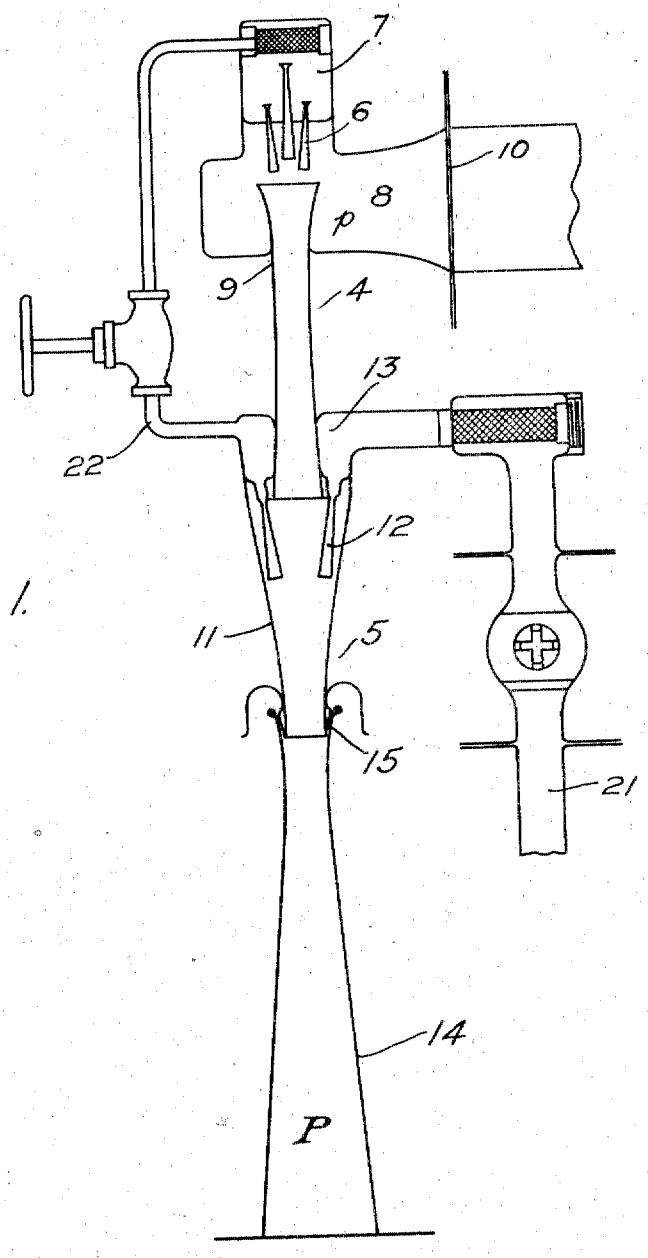


Fig. 1.

INVENTOR.

Maurice Leblanc

BY

HIS ATTORNEY IN FACT

WITNESSES.

V. Lon Zero

E. M. McCallister

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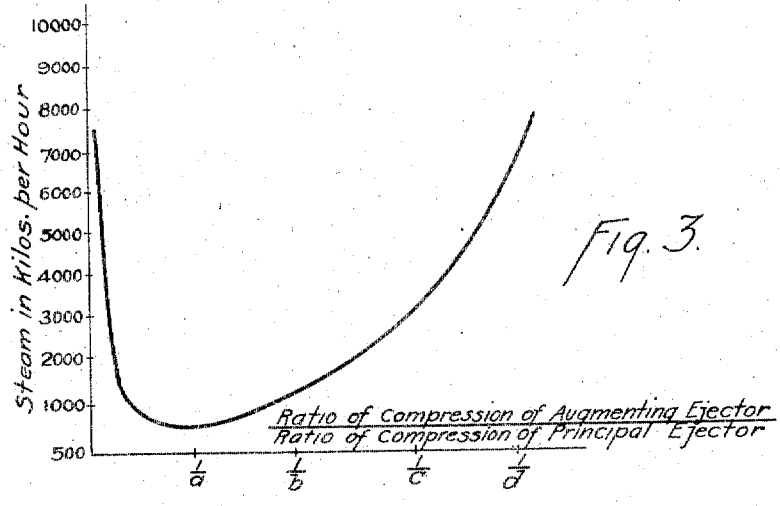


Fig. 3.

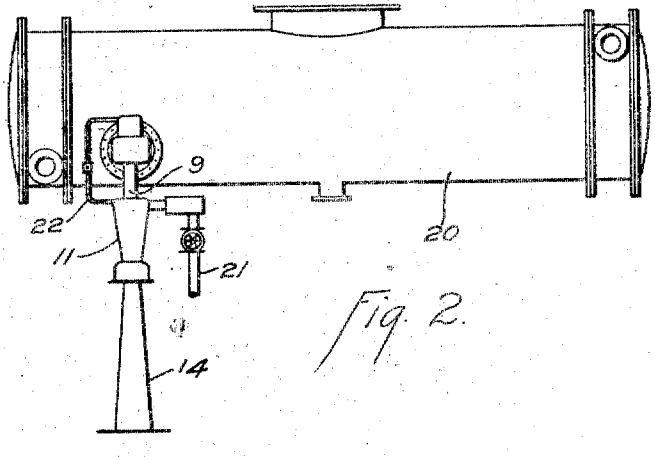


Fig. 2.

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WITNESSES:

UNITED STATES PATENT OFFICE.

MAURICE LEBLANC, OF VAL-SUR-SEINE, CROISSY, FRANCE, ASSIGNOR TO SOCIETE ANONYME POUR L'EXPLOITATION DES PROCEDES WESTINGHOUSE-LEBLANC, OF PARIS, FRANCE.

EJECTOR.

1,215,32. Specification of Letters Patent. **Patented Feb. 6, 1917.**

Application filed June 22, 1915. Serial No. 35,647.

To all whom it may concern:

Be it known that I, MAURICE LEBLANC, a citizen of the Republic of France, residing at Val-sur-Seine, Croissy, Seine-et-Cise, France, have made a new and useful Improvement in Ejectors, of which the following is a specification.

This invention relates to ejectors and has for an object to produce an efficient ejecting apparatus having a high ratio of compression.

A further object is to provide a multi-stage ejector, which is capable of operating efficiently in withdrawing air or non-condensable vapors from a condenser or similar apparatus and is capable of maintaining a relatively high vacuum in the condenser or the apparatus from which the non-condensable vapors or fluids are withdrawn.

A further object is to produce an ejecting apparatus which is simple in construction and is capable of operating effectively with a minimum amount of motive or impelling fluid, for convenience of description hereinafter termed steam, in compressing an elastic fluid, such as air, from a relatively low to a relatively high pressure.

These and other objects, which will be made apparent throughout the further description of the invention, are attained by means of apparatus embodying the features herein described and illustrated in the drawings accompanying and forming a part hereof.

In the drawings; Figure 1 is a more or less diagrammatic sectional view illustrating an ejecting apparatus embodying my invention.

Fig. 2 is a view corresponding to Fig. 1 showing the ejecting apparatus operatively connected to a surface condenser.

Fig. 3 is a curve showing different quantities of steam necessary for operating the ejecting apparatus having different ratios of compression in the different stages.

It has been proposed to employ ejectors as vacuum pumps or for withdrawing non-condensable gases from condensers. The advantages of such an arrangement of apparatus are apparent and result primarily from the fact that there are no moving parts employed in an ejector and consequently it does not need special and constant care. An ejector operating as a vacuum pump must compress air or the non-condensable vapors withdrawn from the condenser from an absolute pressure corresponding to 30 M. M.'s of mercury or approximately $\frac{6}{10}$ of a pound absolute to atmospheric pressure, or to approximately 14½ pounds absolute, or 760 M. M.'s of mercury. In other words, the ratio of compression of such an apparatus operating under such conditions is approximately the same as would be encountered in compressing air from atmospheric pressure to approximately 435 pounds above atmosphere. So far as I know, no simple and commercial ejecting apparatus has been produced up to the time of my present invention for handling such high ratios of compression as those described.

Various ejecting apparatus have been proposed for the purpose of overcoming the difficulties encountered with ejectors for use as vacuum pumps. For example, two or more ejectors have been arranged in series in such a way that the mixture of steam and the fluid ejected is discharged from each ejector to the next ejector of the series. In all such apparatus the separate ejectors of the series operate with relatively large ratios of compression and the result is that the second and subsequent ejectors of the series have to employ large quantities of the steam for the purpose of compressing and removing not only fluid ejected by the preceding ejector but also the steam or ejecting fluid employed in the preceding ejectors. As a result, the efficiency of such apparatus is so low as to be prohibitive.

In order to reduce the amount of steam necessary for operating the second and subsequent ejectors of the series, it has been proposed to employ a separate condenser between each ejector of the series for the purpose of condensing the steam employed as motive fluid in each ejector of the series and of thereby relieving the second and subsequent ejectors of the burden of removing the steam as well as the fluid to be ejected, which is discharged from the next preceding ejector. Such apparatus fulfils its purpose but it is complicated, expensive to manufacture and to maintain, and introduces new difficulties not encountered in simple ejecting apparatus.

My invention, therefore, is to produce a simple and effective ejecting apparatus, which is adapted to operate effectively and to accomplish, with a minimum amount of

steam, the desired compression of the fluid to be ejected. The apparatus illustrated as an embodiment of the invention comprises a multi-stage ejector in which the separate ejectors operate in series and are so proportioned and arranged that the ratio of compression of the first ejector is small in comparison with that of the second or subsequent ejector.

The ejecting apparatus shown in the drawings includes two ejectors, the first of which receives the air or non-condensable fluid from a condenser or vessel to be evacuated and the second receives the mixture of the fluid ejected and motive fluid discharged from the first. For convenience of description, the second ejector may be termed the principal ejector, while the first may be termed the augmenting ejector. If the ratio of compression of the first or augmenting ejector is small, it will operate with high efficiency and the quantity of steam employed in proportion to the quantity of air removed from the condenser or vessel to be evacuated will be small; consequently the total quantity of fluid discharged by it to the second or principal ejector will not be large in proportion to the amount of air or non-condensable fluid ejected.

For example, to remove 10 kilos (approximately 22 pounds) of air per hour from a condenser or vessel having an internal pressure corresponding to 30 M. M.'s of mercury (approximately .6 of a pound absolute) and to compress this air to a pressure corresponding to 100 M. M.'s of mercury (approximately 2 pounds absolute), the first ejector will employ about 20 kilos of live steam. The total quantity of fluid discharged from this first ejector will therefore be 30 kilos and it will be necessary to compress this quantity of fluid to atmospheric pressure in the principal ejector of the series. The quantity of fluid delivered to the principal ejector is therefore greatly diminished below what it would be if the two ejectors of the series were operating under the same compression ratio, and the second ejector is capable of compressing and removing, with comparatively high efficiency, the relatively small quantity of fluid delivered to it.

Theory and experience demonstrate that increasing the compression ratio of the first or augmenting ejector necessitates an increase in the amount of fluid discharged by the organized apparatus, and even if the compression ratio of the second ejector is reduced a corresponding amount by increasing the compression ratio of the first ejector, the live steam necessary in the second ejector, for accomplishing the compression of the mixture of fluids discharged from the first ejector, increases rapidly with an increase in the ratio of compression of the first ejector of the series, and as a result the efficiency of the organized ejecting apparatus is materially reduced.

The curve in Fig. 3 graphically illustrates this. It shows the different amounts of steam necessary, in apparatus such as illustrated in Fig. 1, for ejecting or withdrawing a given quantity of elastic fluid from a region of low pressure,—.6 of a pound absolute—and discharging it at atmospheric pressure when different ratios of compression are employed in the augmenting or first ejector with relation to the ratio of compression employed in the principal ejector. In this figure the ordinates indicate steam or motive fluid in kilos and the abscissa the quotients resulting by dividing the ratio of compression of the augmenting or first ejector by the ratio of compression of the principal or second ejector.

Reference to the curve will show that if the ratio of compression of the augmenting ejector is $1/a$ of the ratio of compression of the principal ejector, approximately 800 kilos of steam will be necessary for accomplishing the compression of elastic fluid; whereas, if the ratio of compression of the augmenting ejector is increased to $1/b$ of that of the principal ejector, the quantity of steam necessary for accomplishing the same compression will be approximately 1,200 kilos. From this it will be seen that the quantity of steam increases rapidly as the compression ratio of the first or augmenting ejector is increased with relation to that of the second or principal ejector. In carrying out my invention, I therefore so construct the apparatus that the ratio of compression of the principal ejector is relatively large as compared with the ratio of compression of the augmenting ejector. Reference to the curve shows that there is a minimum ratio of compression which can be employed in the first ejector and that after that minimum is reached a further decrease in the ratio of compression of the first ejector occasions a falling off in the efficiency of the apparatus. It may be well to state that high compressions absolutely cannot be obtained with a single ejector and that while the curve is approximately correct in showing the rise in the amount of steam employed as the size of the first ejector is reduced below the determined minimum, such apparatus could not perform the work for which it is designed.

In Fig. 1 of the drawings I have shown an ejecting apparatus including two ejectors 4 and 5, the latter of which may be termed the principal ejector. As illustrated, the ejector 4 includes a plurality of divergent or expanding nozzles 6 which receive motive fluid from a steam chamber 7 and which, after expanding the steam to the desired pressure, discharge it through a receiving or mixing

chamber 8 into a convergent divergent passage, which as illustrated, consists of a convergent divergent tube serving as a combined combining tube and diffuser. The receiving chamber 8 is provided with a port 10, which is adapted to communicate with the condenser or vessel to be evacuated.

The discharge end of the augmenting ejector 4 or the divergent end of the tube 9 communicates with and delivers the fluid traversing it to the inlet end of the combining tube 11, which forms a part of a convergent divergent working passage of the principal ejector 5. As illustrated, the tube 9 projects into the upper end of the converging tube 11 and is surrounded by a series of divergent or expanding nozzles 12 which receive steam or motive fluid from a steam chamber 13 and which, after expanding the steam to the desired pressure, discharges it in converging streams into the combining tube 11. The discharge end of the combining tube communicates with a convergent diverging tube or diffuser 14, which is axially alined with and forms a part of the convergent divergent working passage of the ejector 4 and communicates with the atmosphere or with the region into which the ejector discharges.

A plurality of ports or nozzles 15 are shown around the discharge end of the tube 11 and located between it and the adjacent wall of the tube 14 and in the vicinity of the throat of the tube 14. These ports or nozzles 15 communicate at their outer ends with the atmosphere or with the region into which the ejecting apparatus discharges and are adapted to admit a sheath of fluid or air to the interior passage of the ejecting apparatus for the purpose of varying the effective throat of the ejector 5 to meet the varying conditions encountered during the operation of the ejecting apparatus.

In ejectors operating under high degrees of compression it is essential to accurately design the fluid passages for the amounts of fluid traversing them and consequently variations in the pressure of the fluid at the inlet end of the ejector or variations in the amount of fluid traversing the ejector will either cause the apparatus to operate unsatisfactorily or render it ineffective. If it is considered that the pressure p is to be maintained in the chamber 8 and that the pressure P is the pressure existing at the discharge end of the ejecting apparatus, it will be apparent that the dimensions of the different parts of the ejector will be a function of the ratio $\frac{P}{p}$. It will therefore be understood that if an ejector, such as illustrated, is designed to obtain a high degree of compression in ordinary service, its dimensions will not be suitable for starting or for operation when the pressure p is varied.

At the moment of starting the ejector the pressure in the chamber 8 is equal to the pressure P and consequently the steam issuing from the nozzles 6 is over expanded, for the pressure existing in the chamber 8 and the nozzles does not operate efficiently. On the other hand, the density of the fluid entrained in the chamber 8 is much greater than under normal operating conditions and hence a larger quantity of fluid is delivered to the ejector 5 than is the case under normal operating conditions. If the throat of the combined tubes 11 and 14 has been designed for normal operating conditions, it will be too small for starting and the ejector will either be started with difficulty or will not start at all, due to the choking at the throat. If, on the contrary, the throat of the combined tubes 11 and 14 is designed to accommodate the flow of fluid encountered during the starting operation it will be too large to operate effectively during the normal operating conditions and as a result breaking down will occur, by which is meant that momentary equalization will take place between the pressure at the outlet of the tube 14 and the inlet of the tube 11, which will render the apparatus ineffective. If the throat of the combined tube is not of sufficient area to pass the fluid encountered during the starting operation but even so is too large for the amount of fluid delivered to it during normal operation, the fluid will not fill the tube and as soon as this condition exists eddies will be formed within the stream of fluid which will interfere with the operation of the apparatus and will ordinarily result in breaking down. These difficulties could be avoided if the walls of the diffuser 14 or of the combined tubes 11 and 14 could be made elastic in such a manner as to enable them to mold themselves at all times to the fluid column traversing them. This result, however, is obtained by providing the nozzles 15 in the combined tubes 11 and 14 and locating them at the place where the fluid column traversing the tubes tends to detach itself from the walls when insufficient fluid is delivered to fill the tube. Under such conditions these nozzles deliver fluid to the tubes in the form of a sheath and thereby in effect automatically proportion the area of the throat in accordance with the amount of fluid traversing the tube 11. This sheath will act as an elastic wall and will prevent the column of fluid issuing from the tube 11 from expanding and thus giving rise to eddies or creating the tendency for the apparatus to break down. These nozzles not only deliver the filling sheath of fluid to the condenser, but during the operation of starting excess fluid is discharged from them and as a result the effective area of the throat of the combined tubes 11 and 14 will be automatically varied

to suit all existing conditions of fluid flow, and the apparatus will not only be self-starting, but will operate efficiently under normal operating conditions. The nozzles 15 may be replaced by a single annular nozzle if desired. The nozzles 12 may also be replaced by a single annular nozzle, if desired.

In Fig. 2 I have illustrated the ejecting apparatus as applied to a surface condenser 20. In such an installation the chamber 8 is placed in communication with the air or non-condensable fluid off-take of the condenser. It will however be apparent that ejecting apparatus embodying my invention may be employed in connection with any type of condenser.

In the drawings I have shown a pipe 21 for delivering live steam or motive fluid to the chamber 13, of the principal ejector 5, and a valved pipe 22 between the chamber 13 and the chamber 7 of the augmenting ejector. It will, however, be understood that the main steam supply may be delivered directly to the chamber 7 and that the convergent divergent tube 9 may be made in two parts, one converging and one diverging, that the tubs 11 and 14 may be replaced by a single tube and that various changes, modifications, substitutions, additions and omissions may be made in the apparatus without departing from the spirit and scope of the invention as set forth in the appended claims.

What I claim is:

1. In combination in an ejecting apparatus, a principal ejector comprising a combined combining and diffuser tube having an inlet to which fluid to be ejected is delivered, and at least one expansion nozzle for delivering fluid to said tube, and an augmenting ejector having a relatively expansive small ratio of compression compared to the ratio of compression of the principal ejector arranged to communicate with the source of fluid to be ejected and to discharge both the fluid ejected and the motive fluid delivered to it to the inlet of the principal ejector.

2. In an ejecting apparatus, a plurality of steam actuated ejectors arranged to operate in series on the fluid to be ejected, the first ejector of the series communicating with the source of fluid to be ejected and having a relatively low ratio of compression as compared to the ratio of compression of the second ejector of the series.

3. An ejecting apparatus including an ejector comprising a convergent divergent tube communicating at its inlet with a source of fluid to be ejected, an expansion nozzle for delivering expansion motive fluid to said tube and a source of motive fluid supply communicating with said nozzle, and a second expansive fluid actuated ejector communicating with the outlet of the tube of the first ejector and having a relatively large ratio of compression as compared to the ratio of compression of the first ejector.

4. An ejecting apparatus including a steam actuated ejector communicating with a source of fluid to be ejected and having a relatively low ratio of compression, a second steam actuated ejector communicating with the outlet of the first ejector and receiving therefrom the fluid ejected and the steam employed in the first ejector and having a relatively high ratio of compression.

5. A vacuum pump comprising a plurality of fluid actuated ejectors operating in series on fluid to be ejected, the first of said ejectors communicating with the vessel to be evacuated and having a relatively low ratio of compression, the second ejector of the series receiving all of the fluid traversing the first ejector and comprising a convergent divergent passage to which the fluid discharged from the first ejector is delivered, and an expansion nozzle for delivering expansive motive fluid to the passage, said second ejector having a relatively high ratio of compression.

6. In combination with a condenser, a vacuum pump comprising two ejectors operating in series, the first of said ejectors including a convergent divergent passage, a mixing chamber communicating with the inlet end of said passage and with the condenser, and a plurality of motive fluid supply nozzles projecting into said mixing chamber for delivering motive fluid to said passage, the second ejector of the series comprising a convergent divergent passage communicating at its inlet end with the discharge end of the first mentioned passage and having at a point intermediate its ends openings communicating with the discharge end thereof, and a series of expansion nozzles surrounding the discharge end of the first mentioned passage for delivering motive fluid to the second mentioned passage, the ratio of compression of the first ejector being small with relation to the ratio of compression of the second ejector.

7. In combination with a condenser, a vacuum pump comprising two ejectors axially alined and arranged to operate in series, the first consisting of a convergent combining tube having an inlet for fluid to be ejected, a divergent diffuser and at least one divergent nozzle for discharging motive fluid through said convergent divergent member, the second ejector consisting of a convergent combining tube, the large end of which surrounds the outlet end of the divergent diffuser of the first ejector, divergent nozzles surrounding the outlet end of the divergent diffuser of the first ejector, for delivering motive fluid to the second ejector, means for delivering motive fluid to said nozzles, and a diffuser communicating with the combining tube of the second ejector, the ratio of com-

pression of the first ejector being materially less than the ratio of compression of the second ejector of the series.

8. An air pump comprising a number of divergent nozzles coöperating with a single combining tube and a diffuser for initially compressing air to be compressed, a second set of divergent nozzles coöperating with a second combining tube, and a second diffuser both axially alined with the first combining tube and diffuser and communicating therewith, and means for delivering steam to both sets of nozzles, said second set of nozzles and coöperating combining and diffuser tubes having a materially greater compression ratio than that of the first set of nozzles and coöperating and combining and diffuser tube.

9. In combination with a condenser, a vacuum pump comprising an ejector having a relatively low ratio of compression communicating with the air offtake of the condenser and having a convergent divergent working passage, and an expansion nozzle for delivering motive fluid to said passage, a second ejector having a relatively high ratio of compression and provided with a convergent divergent working passage communicating with the outlet of the first mentioned working passage and provided with means for varying the effective throat thereof in response to variations in the amount of fluid delivered thereto, an expansion nozzle for delivering motive fluid to the working passage of the second ejector, and means for delivering motive fluid to both of said nozzles.

10. In combination in an ejecting apparatus, two ejectors operating in series, the first ejector of the series communicating with the source of fluid to be ejected having a relatively low ratio of compression, the second ejector of the series receiving all the fluid discharged from the first ejector, and having a convergent divergent working passage provided with means for varying the effective throat thereof in accordance with variations in the amount of fluid passing therethrough, a series of expansion nozzles for delivering motive fluid to said passage and means for delivering motive fluid to said nozzles, said second ejector having a relatively high ratio of compression.

11. In combination with a condenser, an expansive-fluid actuated ejector comprising an inlet passage communicating with the air offtake port of said condenser, a divergent nozzle for expanding and delivering motive fluid, a combining and diffusion tube communicating with said inlet passage and receiving the expanded motive fluid delivered by said nozzle, a second expansive-fluid actuated ejector having a ratio of compression materially greater than that of the first ejector and comprising a diffuser communicating with the outlet of the first ejector, a divergent nozzle for expanding and delivering motive fluid into and through the diffuser, and means for delivering expansive motive fluid to the nozzles of both ejectors.

12. In combination with a condenser, an ejecting apparatus for withdrawing air and non-condensable vapors from the condenser, comprising two expansive motive fluid actuated ejectors operating in series, the first ejector of the series comprising a combining and diffusion tube and at least one expansion nozzle of gradually increasing area from the throat to the outlet thereof, for expanding motive fluid to substantially the pressure at the inlet of the combining and diffusion tube and for discharging the expanded fluid into the combining and diffusion tube, the second ejector comprising a combining and diffusion tube, and at least one expansion nozzle gradually increasing in area from the throat to the outlet thereof, for expanding motive fluid to substantially the pressure at the inlet of said last mentioned combining and diffusion tube, and means for delivering expansive motive fluid to the nozzles of both ejectors, the second ejector of the series having a materially greater ratio of compression than that of the first ejector of the series.

13. In combination in an ejecting apparatus, an ejector including a combining and diffusion tube, communicating at its inlet end with the source of fluid to be ejected, and at least one nozzle having gradually increasing areas from the throat to the outlet thereof for expanding motive fluid to substantially the pressure of the fluid at the inlet of the combining and diffusion tube and for discharging the fluid so expanded into and through said tube, a second ejector of a materially greater ratio of compression than the first ejector, operating in series with the first ejector and including a combining passage communicating with the outlet of the first ejector, and at least one nozzle gradually increasing in area from the throat to the outlet thereof for expanding motive fluid to substantially the pressure at the inlet of the combining passage, and for discharging the fluid so expanded into and through said passage and means for delivering expansive motive fluid to the expansion nozzles of both ejectors.

14. In combination in an ejecting apparatus, an ejector including a combining and diffusion tube communicating at its inlet end with a source of fluid to be ejected, and at least one nozzle gradually increasing in area from the throat to the outlet thereof for expanding motive fluid and for discharging the expanded fluid into and through said combining and diffusion tube, a second ejector of materially greater ratio of compression than the first ejector operating in series therewith and comprising a combin-

ing passage communicating with the outlet of the first ejector, at least one nozzle gradually increasing in area from the throat to the outlet thereof for expanding motive fluid and for discharging the expanded motive fluid into and through the combining passage, and means receiving combined fluid media from the combining passage for reducing the velocity of the combined media passing therethrough and thereby increasing its pressure.

15. In combination in an ejecting apparatus, an ejector including an inlet passage, a nozzle gradually increasing in area from the throat to the outlet thereof for expanding motive fluid to substantially the pressure existing in said passage, a combining and diffusion tube communicating with said passage and receiving the motive fluid discharged from said nozzle and the entrained fluid medium from said passage, a second ejecting device of materially greater compression ratio than said ejector, and including a combining passage communicating with the outlet of said ejector, a nozzle of gradually increasing area from the throat to the outlet thereof for expanding motive fluid, to substantially the pressure normally existing at the inlet of said combining passage, means receiving the expanded fluid issuing from said last mentioned nozzle and the medium entrained thereby and for effecting a conversion of the kinetic energy of the fluid media passing therethrough into potential energy as represented by an increase in pressure, and means for delivering expansive motive fluid to the nozzles of said ejector and ejecting device.

16. In combination in an ejecting apparatus, an ejector comprising an inlet communicating with a source of fluid medium to be exhausted, a nozzle of gradually increasing area from the throat to the outlet thereof for expanding motive fluid to substantially the pressure normally existing in said inlet passage, a combining and diffusion tube communicating with said passage and receiving the motive fluid discharged from said nozzle and entrained fluid medium from said passage, a second ejecting device having a ratio of compression materially greater than that of said ejector, and including a combining passage communicating with the outlet of the ejector, a nozzle of gradually increasing area from the throat to the outlet thereof for expanding motive fluid to substantially the pressure existing at the inlet of the combining passage, and means communicating with said passage, and receiving the expanded motive fluid issuing from said nozzle and the entrained fluid medium from said passage for effecting a conversion of kinetic energy of the fluid media passing therethrough into potential energy as represented by an increase in pressure, and means for delivering expansive motive fluid to the nozzles of said ejector and ejecting device.

In testimony whereof I have hereunto subscribed my name this 28th day of May, 1915.

MAURICE LEBLANC.

Corrections in Letters Patent No. 1,215,321.

It is hereby certified that in Letters Patent No. 1,215,321, granted February 6, 1917, upon the application of Maurice Leblanc, of Val-sur-Seine, Croissy, France, for an improvement in "Ejectors," errors appear in the printed specification requiring correction as follows: Page 4, line 40, claim 1, before the word "fluid" insert the word *expansive;* same page and claim, line 41, strike out the word "expansive"; same page, line 50, claim 2, before the word "fluid" cancel the article "the"; same page, line 60, claim 3, for the word "expansion" read *expansive;* and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 20th day of March, A. D., 1917.

[SEAL.] F. W. H. CLAY,

Cl. 230—13. *Acting Commissioner of Patents.*