

M. LEBLANC.
EJECTOR.

APPLICATION FILED JULY 26, 1906.

1,137,767.

Patented May 4, 1915.
3 SHEETS—SHEET 1.

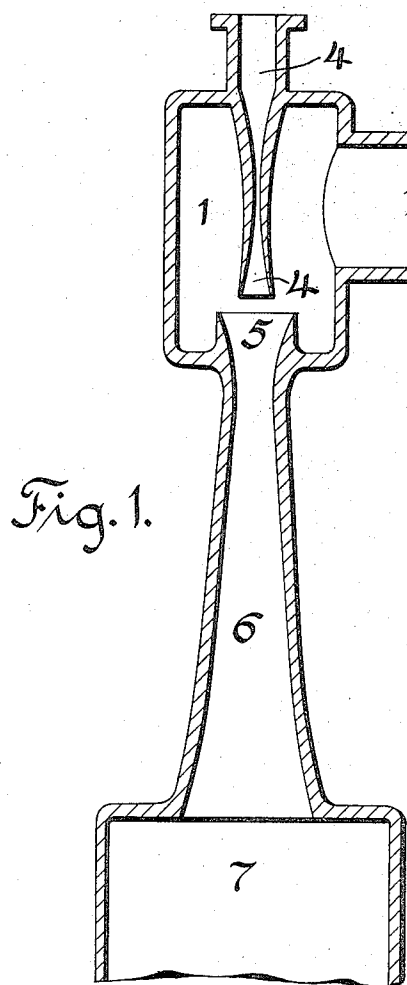


Fig. 1.

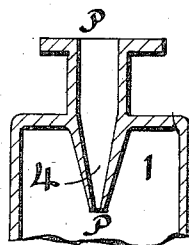


Fig. 2.

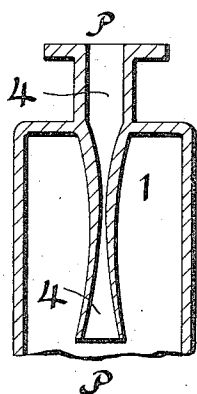


Fig. 3.

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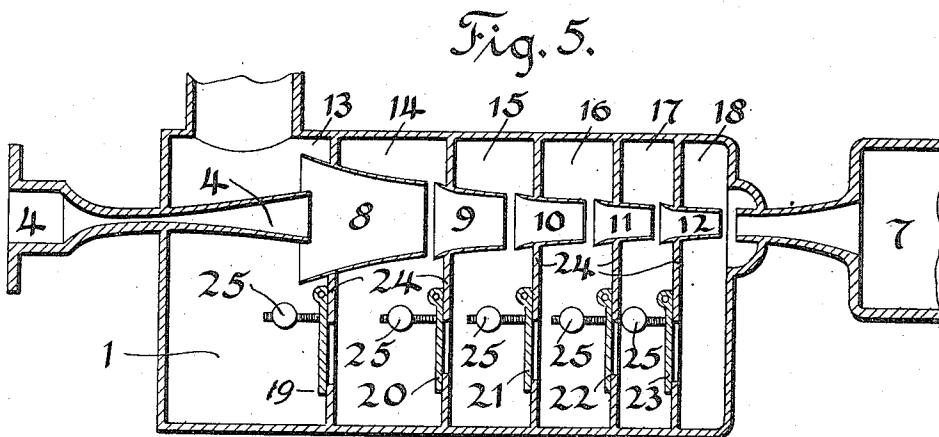
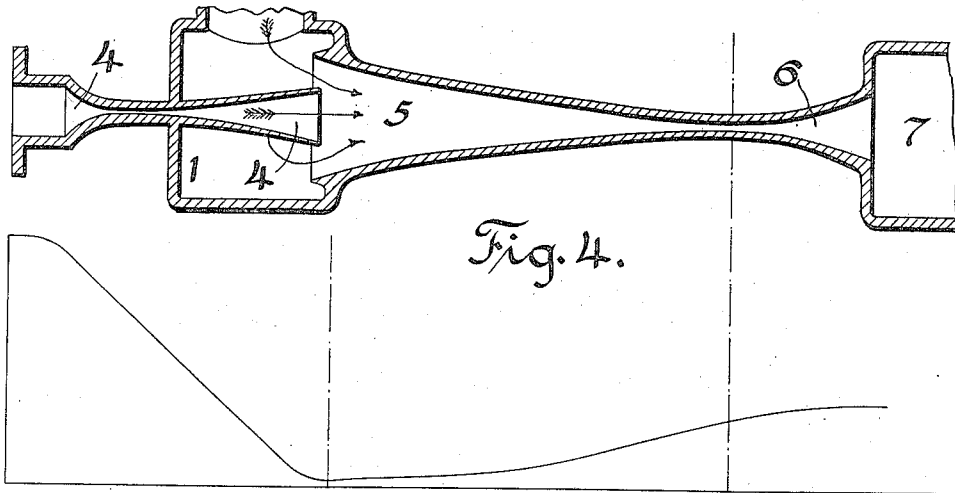


Fig. 6.

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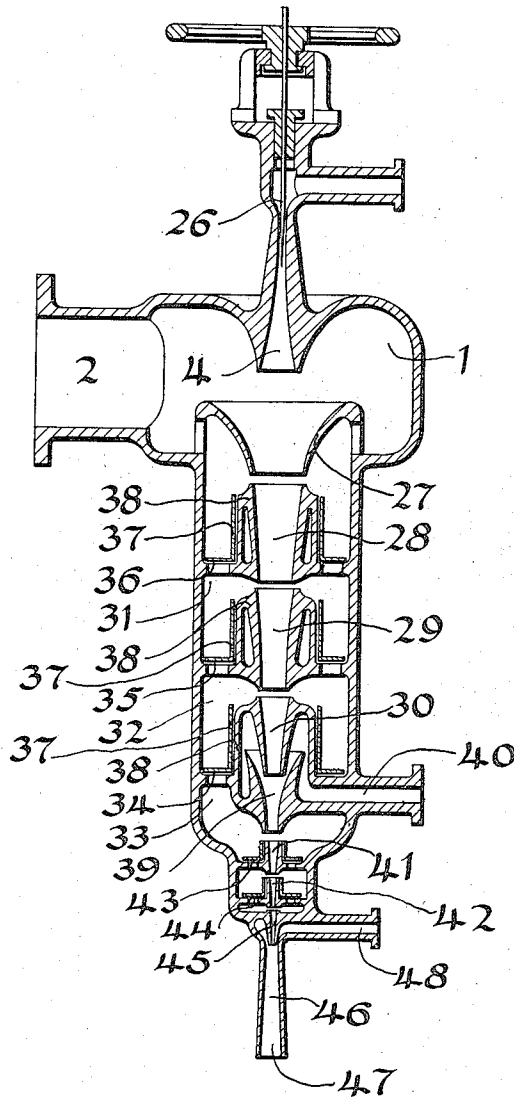


Fig. 7.

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EJECTOR.

1,137,767.

Specification of Letters Patent.

Patented May 4, 1915.

Application filed July 26, 1906. Serial No. 327,918.

To all whom it may concern:

Be it known that I, MAURICE LEBLANC, a citizen of the Republic of France, residing at Villa Montmorency, Auteuil, Paris, France, have made a new and useful Invention in Ejectors, of which the following is a specification.

In a previous application (filed February 10, 1904, Serial No. 192,908,) I have described a system of cooling a current of water consisting in the evaporation in a vacuum created by a steam ejector of a certain portion of the water delivered. The efficiency of this system depends above everything upon the qualities of the ejector, and I have therefore considered it advisable to improve this apparatus with a view to obtaining a greater vacuum in the receiver which it exhausts and by increasing its efficiency. In the application above referred to I dealt principally with domestic apparatus; and I there proposed to use steam at atmospheric pressure as a source of energy. In order to provide for the flow of this steam, it was necessary to supplement its deficiency in pressure, and with that object I caused it to exhaust into a nozzle traversed by a current of water delivered under pressure. In industrial apparatus of this character steam is supplied from high pressure boilers, in which case it is unnecessary to provide for the flow of steam by creating a preliminary vacuum.

In the simple apparatus forming the subject-matter of the present application, the vapor supplied to the ejector exhausts and delivers directly to the atmosphere not only the vapor and the air which it carries with it but also the condensing water.

In the accompanying drawings: Figures 1 to 4 are diagrammatic views showing various known forms of ejectors; Fig. 5 is a diagram showing the variations in pressure in the ejector shown in Fig. 4; Fig. 6 is a diagrammatic view showing one form of the improved ejector according to this invention; and, Fig. 7 is a diagrammatic view showing a modification of the ejector shown in Fig. 6.

Referring to Fig. 1, an ejector is usually arranged in the following manner:—Into a chamber 1 which communicates by a pipe 2 with a receiver 3 in which the vacuum is to be created there projects a nozzle 4 traversed either by steam from a boiler or a current of

compressed air or gas or some liquid under pressure. The nozzle 4 exhausts into a convergent nozzle 5 in which the exhausting fluid is mixed with the fluid exhausted. The nozzle 5 is extended by a delivery passage, generally formed as a divergent nozzle 6. The nozzle 6 exhausts into a space 7 under constant fluid pressure, which may be that of the atmosphere. In the nozzle 4 the pressure energy of the exhausting fluid is transformed and rendered available in the form of kinetic energy. This fluid as it flows carries with it the fluid contained in the chamber 1, and which comes from the receiver 3. The exhausting and exhausted fluids intermingle in the convergent nozzle 5 so as to form a homogeneous fluid, every molecule of which has the same speed. Finally, the kinetic energy of this mixture is transformed into the work of compression in the divergent nozzle 6. The ejector nozzle 4 has a very high efficiency when proportioned according to the laws of thermodynamics in the case of compressible fluids, and according to the rules laid down by M. Rateau in the "*Annales des Mines*" published January, 1902.

The loss of energy which will take place in the combining nozzle 5 during the process of equalization of the rates of flow of the exhausting and exhausted fluids is determined by mechanical laws. It depends on the weight of fluid exhausted by each unit of exhausting fluid. It is hardly possible to improve the efficiency of the nozzles 4 and 5. On the other hand, with the form which is generally given to the divergent nozzle 6, a high efficiency is impossible when the fluid mixture flowing through it is compressible unless the ratio of pressures at the inlet is at least equal to 0.5 of the outlet pressure. This efficiency diminishes very quickly when this ratio decreases. But in every case in point this ratio would always be very small. Let us take for example a nozzle through which steam flows from a boiler at a pressure P and which is exhausted into a receiver at a pressure p . It is known (see Rateau, "*Annales des Mines*" of January, 1902) that as long as the pressure p is greater than 0.58 P , the nozzle should be convergent (see Fig. 2). (In the case of compressed air 0.58 should be replaced by 0.52). If the pressure p is smaller than 0.58 P the nozzle should be composed of two

parts, the one convergent and the other divergent. (See Fig. 3).

The pressure at the throat of the nozzle, that is to say at the junction of the converging and diverging parts, is always equal to 0.58 P, whatever the pressure at the outlet may be.

If the nozzle be prolonged so that the steam when exhausted will have attained a pressure precisely equal to the desired exhaust pressure, the kinetic energy which it will possess at this moment will be very nearly equal to the work which it would have performed in a perfect machine with a boiler pressure P and condenser pressure p . Let us suppose that it is desired to use this kinetic energy to cause the return of the steam issuing from the nozzle from a chamber at a pressure p to a chamber at a higher pressure. If the nozzles 4, 5 and 6 have each an efficiency of 1, the steam could be returned to the boiler at the pressure P. At some point in the nozzle 6 the steam attains an intermediate pressure p' , a velocity and density equaling that of the steam at a particular point in the nozzle 4. Consequently the nozzle 6 should provide for the passage of the steam at a pressure p' , the same cross-sectional area as the nozzle 4; in other words, the nozzle 6 should have the same proportion as the nozzle 4. It should therefore be a divergent cone whenever p is greater than or at least equal to 0.58 P, and should be a convergent cone followed by a divergent cone whenever p is less than 0.58 P.

To simplify my reasoning I have supposed that the efficiency of the nozzles 4 and 6 was in each case equal to 1; my conclusions will be but slightly modified if these efficiencies are high. When the relation p is small diffuser should be composed of a long convergent cone followed by a small divergent cone as shown in Fig. 4, the diameter of the inlet orifice of the distributor being large in proportion to that of the throat.

The pressure should vary throughout the length of the nozzles 4 of the ejector, and 5 and 6 of the diffuser (Fig. 4) as shown by the curve in Fig. 5. But experience has shown that this is not the case. Such a nozzle 5, 6 would in some manner cause an obstruction. The pressure would rise suddenly in the immediate neighborhood of the inlet and the remainder of the nozzle would behave like a Venturi cone, where the pressure would pass at a minimum to the point of the throat. This obstruction would be due to the fact that the pressure would rise in the wide parts of the nozzle instead of rising especially in the narrow parts, which would necessitate a much greater increase of the quantity of motion, and consequently of kinetic energy, for overcoming a like difference in pressure. I have avoided this by preventing the pressure from rising more

rapidly than it should in the convergent part of the nozzle. In order to do this I have arranged the nozzle as shown in Fig. 6. I form the convergent part by means of a series of truncated cones 8, 9, 10, 11 and 12 arranged one after the other as shown, and which may be considered as consecutive portions of the convergent cone of Fig. 4. These various truncated cones are each supported by diaphragms 24 arranged perpendicularly to the axis of the cones, thus forming separate chambers 13, 14, 15, 16, 17 and 18. Each of these diaphragms has a valve as shown at 19, 20, 21, 22 and 23; these valves open in a direction opposite to the direction of motion of the fluid in the nozzle; they are loaded with adjustable weights or springs which may be regulated in accordance with a certain law. Under these conditions the difference in pressure which may be developed by the nozzle between two consecutive chambers is limited, and the limit depends only upon the load on the valve which affords communication between these two chambers. The difference in pressure between the ends of each truncated cone 8—12 is controlled in the same manner. If we designate by p the difference in pressure at the ends of one of these truncated cones, by a the cross-sectional area at the inlet, by m the mass of the fluid which flows through it during each second, and by dv the diminution in speed to which the fluid is subjected during its passage, we shall have: $m dv < a p$, all the other cross-sectional areas of this truncated cone being smaller than the cross-sectional area a .

The loads on the valves are arranged so that the pressure increases along the whole length of the improved nozzle in proportion to the diminution toward the outlet in cross-sectional area, following a law which approaches as nearly as possible to that which would give the best efficiency and which has been sufficiently described above.

In Fig. 6 the valves 19, 20, 21, 22 and 23 consist of hinged plates held by adjustable weights 25 in a position in which they close an opening made in the walls or diaphragms 24 by which they are supported. This arrangement of valves is only shown by way of example, as any suitable arrangement may be employed. In the arrangement shown each of the chambers 14, 15, 16, 17 and 18 is connected by a valve to the preceding chamber; nothing would prevent all the chambers being placed in communication with the one where the pressure is to be the lowest by suitably regulating the load on the valves. This method of arrangement of the converging part of the nozzle is applicable whenever the mixture of fluids which is to flow therethrough is compressible such for example as when a liquid is

utilized for gas or vapor of any kind, or when a current of gas or vapor is utilized to entrain gas vapor, or a combination of any two or of all of these fluids. This arrangement is even more applicable if all the kinetic energy of the mixture entering the diffuser is not to be used to compress it, and if a part of this energy is to be reserved to be utilized in doing some other useful work, which would be the case, for example, if we required a steam ejector to aspirate or compress another vapor, then to aspirate and discharge to the atmosphere the liquid which serves for condensing them. This utilization of my invention will be the one with which I may have to contend and which is covered by the system of ejectors shown in Fig. 7. This ejector has a nozzle 4 in which the cross-sectional area of the throat may be varied at will by inserting more or less a taper plug 26 by means of suitable mechanism, for the purpose of facilitating the starting. The cross-sectional area of the throat might be left constant by utilizing an arrangement which would permit of the advance or withdrawal of the nozzle with respect to the inlet of the combining and delivery nozzle. The convergent part of this nozzle will comprise in general an initial convergent truncated cone 27 with a free outlet arranged so that the pressure cannot increase in advance of the combining cone. The cone 27 is followed by a series of truncated cones such as 28, 29, 30 opening into chambers 31, 32, 33 respectively, each of which communicates with the anterior chamber by the respective valves 36, 35, 34.

The chambers 31, 32, 33 are cylindrical and the valves consist of simple circular washers guided in their movements by cylindrical parts 37 which slide along stationary cylinders 38 surrounding each of the cones 28, 29, 30.

It will be understood that the number in the series of truncated cones 28, 29, 30 has been made equal to 3 by way of example only and that the number may be made as large as desirable.

If the fluid mixture which flows through the delivery cone is not condensable or does not require to be condensed, the convergent cone will simply be extended by a divergent cone.

Assuming that steam flows through the nozzle 4 and that this steam carries with it steam flowing through the pipe 2 into the chamber 1, there will be a zone in which the mixture of steam, passing through the convergent cone will have a pressure equal to the tension of the vapor of the condensing water, which may be available. Assuming that this took place at the outlet of the cone 30, this outlet might be arranged at the middle of another cone 39; the annular space between these two cones communicating by

a pipe 40 with a source of condensing water. The condensation will take place either in the cone 39 or in the following cones 41, 42.

A rise in pressure in the cones 39, 41, 42 can be restricted as before and by the same means, that is to say by the use of valves 34, 43, 44, and atmospheric pressure will be finally attained at the outlet of a cone 45.

When condensing water under pressure is being used the preceding arrangement can only be started by adjusting the plug 26 in the nozzle 4. If this were not the case and if the condensation water had to be exhausted, it would be necessary that at the moment of starting the pressure of steam at the end of the cone 30 should be greater than the atmospheric pressure to such an extent that the discharge of steam might be capable of creating sufficient vacuum in the pipe 40 to insure the rise of the water. For this it would be necessary that the reservoir into which the pipe 2 opens should be capable of resisting a pressure considerably greater than atmospheric pressure, whereas in normal service, it should, on the contrary, be capable of resisting a vacuum. As this may have some disadvantages it will be preferable to cause the cone 45 to project into the delivery cone of a small steam ejector 46, exhausting into the atmosphere at 47 and supplied by steam under pressure through a pipe 48. This small ejector will serve simply to start the supply of water through the pipe 40 and it would be stopped as soon as the water flows out at 47.

The apparatus which I have described has been more especially designed for the purpose of producing, by means of a current of steam, a sufficiently large vacuum to insure not only the ebullition of water at 0° C., but also the formation of ice or the ebullition of water charged with salts which render it incongealable at temperatures below 0° C. But it is understood that my improved nozzle is applicable to every jet apparatus which is intended to pass a mixture of compressible fluids, but one part of which may be liquid from a reservoir at a certain pressure into a reservoir at a higher pressure, and that it can be employed to create a vacuum in a receiver or as a compressor.

What I claim is:

1. In an ejector, a fluid-supply nozzle, a fluid-controlling valve therefor, a receiving chamber communicating therewith, a series of axially aligned, truncated cone-shaped members arranged to form a converging fluid passage, which communicates with said receiving chamber and receives fluid therefrom, a chamber between adjacent members, a liquid admission port communicating with the outlet of the last member of said series and a second series of convergent members and intermediate communicating chambers cooperating with said first series.

2. In an ejector, a receiving chamber, a convergent and divergent nozzle communicating therewith, a convergent passage comprising a plurality of truncated cone-shaped members communicating with and receiving fluid from said receiving chamber, a chamber between adjacent members, a valve between adjacent members and the first of said chambers and said receiving chamber and a divergent nozzle communicating with the last of said chambers and receiving motive fluid from said converging passage.
3. In an ejector, the combination of a receiving chamber, a convergent and divergent fluid injector communicating therewith, a divergent fluid passage comprising a plurality of truncated cone-shaped members communicating with said receiving chamber and receiving fluid from said injector, a chamber between adjacent members, a valved ports connecting adjacent members, a valved port connecting the first of said chambers with said receiving chamber and a divergent nozzle communicating with the outlet of said divergent passage.
4. In combination with a receiving chamber, a fluid injector communicating therewith, a fluid passage comprising a plurality of axially-alined converging members communicating with said receiving chamber, pressure chambers between adjacent members, a valved opening between adjacent chambers and a divergent nozzle communicating with the last of said convergent members.
5. In combination with a receiving chamber, a fluid ejecting device communicating therewith and comprising a plurality of axially alined converging nozzle sections, a separate chamber communicating with the inlet end of each of said sections, and a valved passage establishing communication between the chambers of adjacent sections.
6. In combination with a receiving chamber, a convergent divergent nozzle communicating therewith and comprising a plurality of axially alined nozzle sections, a separate pressure chamber communicating with the inlet end of each section, and a valved passage establishing communication between chambers of adjacent sections.
7. In combination with a receiving chamber, a plurality of pressure chambers communicating therewith, a fluid nozzle and a passage between each two adjacent chambers, and a valve responsive to fluid pressure in one direction only, controlling the delivery of fluid through each of said passages.
8. In an ejector, a series of chambers, a fluid nozzle and a passage between each two adjacent chambers of said series, and a separate valve responsive to fluid pressure for controlling the delivery of fluid through each of said passages.
9. In an ejector, a series of pressure chambers, a fluid nozzle between each two adjacent chambers, and means for maintaining predetermined relative pressures between the chambers of said series.
10. In an ejector, a receiving chamber, a series of pressure chambers communicating therewith, a nozzle section, and a valved port establishing communication between each two adjacent chambers of said series.
11. In an ejector device adapted to be operated by elastic fluid for producing a vacuum, a motive fluid admission nozzle, a convergent nozzle into which the admission nozzle is adapted to discharge and means for automatically governing the pressure of the fluid in its passage through said convergent nozzle.
12. In an ejector device adapted to be operated by elastic fluid, an admission nozzle for the motive fluid, a convergent nozzle formed of a plurality of alined and separated sections and means for automatically controlling the fluid pressure between any two adjacent sections of said convergent nozzle.
13. In an ejector device adapted to be operated by elastic fluid, a receiving chamber, a motive fluid admission nozzle communicating with said chamber, a convergent nozzle communicating with said chamber and made up of a number of alined and separated nozzle sections and pressure operated means whereby the fluid pressure at the outlet of said sections is automatically controlled.
14. In an ejector device, a chamber for connection with the device to be evacuated, a convergent cone or nozzle communicating with said chamber and made up of a plurality of separated cone nozzle sections, a motive fluid admission nozzle arranged so as to discharge into the first of said sections and means operable by the pressure at the outlets of said sections for preventing the pressure in said convergent nozzle from exceeding a predetermined pressure.
15. In an ejector device for compressible fluids, a motive fluid admission nozzle, a convergent nozzle the outlet of which is arranged to receive the motive fluid and the fluid to be acted upon and which is made up of separated alined sections and means for automatically controlling the pressure at the outlet of each of such sections.
16. In an ejector device for compressible fluids, an admission nozzle for motive fluid, a mixing cone communicating with the source of fluid to be ejected and with said nozzle, and means for varying the effective length of said cone by discharging fluid therefrom at different points along its length.
17. In an ejector device for compressible fluids, an admission nozzle for motive fluid, a mixing cone communicating with the

source of compressible fluid to be ejected, and alined with said nozzle, and means for placing various points along the cone in communication with the inlet end of the cone, during the operation of starting the device.

18. In combination in an ejector, an admission nozzle for motive fluid, a mixing cone communicating therewith, and means for discharging fluid from said cone along its length during the operation of starting said ejector.

19. In combination in an ejector, an admission nozzle for motive fluid, a mixing cone communicating therewith, and means responsive to variations of fluid pressure within said cone for discharging fluid from said cone at points along its length during the operation of starting the ejector.

20. In combination in an ejector, an admission nozzle for motive fluid, a mixing cone communicating therewith and provided with apertures located at points along its length, and means for controlling the flow through the successive apertures during the operation of starting said ejector.

21. In combination in an ejector, an admission nozzle for motive fluid, a mixing cone provided with apertures located along its length, and valves operated by the fluid pressure within said cone for controlling the flow of the fluid through said apertures during the operation of starting said ejector.

22. In an ejector, an admission nozzle for motive fluid, a mixing cone communicating therewith and provided with a series of apertures arranged lengthwise the walls of the cone, and a corresponding series of normally closed non-return valves controlling the flow of the fluid through said apertures so that the pressure within said cone cannot exceed the pressure exterior thereto an appreciable amount.

23. In an ejector, an admission nozzle for motive fluid, means for entraining the fluid to be exhausted, a receiving chamber, a mixing cone located in said receiving chamber and provided with a series of apertures arranged along the cone, and a corresponding

series of normally closed non-return valves controlling the flow of the fluid through said apertures so that the pressure in the cone cannot exceed the pressure in the receiver chamber by any appreciable amount.

24. In an ejector operated by elastic fluid, an admission nozzle for operating fluid, means for entraining the fluid to be exhausted, a mixing cone communicating with said nozzle and comprising a series of truncated cones so arranged as to provide a clearance space between the outlet of one cone and the inlet of the next succeeding cone, and normally closed non-return valves controlling the delivery of fluid through said clearance spaces.

25. In an ejector operated by elastic fluid, an admission nozzle for operating fluid, means for entraining the fluid to be exhausted, a receiver chamber, a mixing cone located in said chamber and comprising a series of truncated cones so arranged as to provide a clearance space between the outlet of one cone and the inlet of the next succeeding cone, passages connecting said clearance space with the receiver chamber, and normally closed non-return valves controlling said passages so that the fluid can pass through said clearance space and passages into said receiver chamber when the pressure in said receiver chamber is appreciably less than the pressure in said mixing cone.

26. In an ejector device for compressible fluids, an admission nozzle for motive fluid, a combined convergent divergent tube communicating with the source of fluid to be ejected and having a discharge port intermediate the inlet and the outlet ends thereof, for discharging excess fluid traversing the tube during the operation of starting the ejector.

In testimony whereof I have hereunto subscribed my name this tenth day of July, 1906.

MAURICE LEBLANC.

Witnesses:

ALBERT DELAS,
HERNANDO DE SOTO.

It is hereby certified that in Letters Patent No. 1,137,767, granted May 4, 1915, upon the application of Maurice Leblanc, of Paris, France, for an improvement in "Ejectors," an error appears in the printed specification requiring correction as follows: Page 2, line 40, for the letter "*p*" read $\frac{p}{P}$; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 6th day of July, A. D., 1915.

[SEAL.]

R. F. WHITEHEAD,

Acting Commissioner of Patents.