R. S. PRINDLE.

APPARATUS FOR PRODUCING ARTIFICIAL RESPIRATION.

APPLICATION FILED FEB. 13, 1909.

1,169,996.

Patented Feb. 1, 1916.

3 SHEETS—SHEET 1.

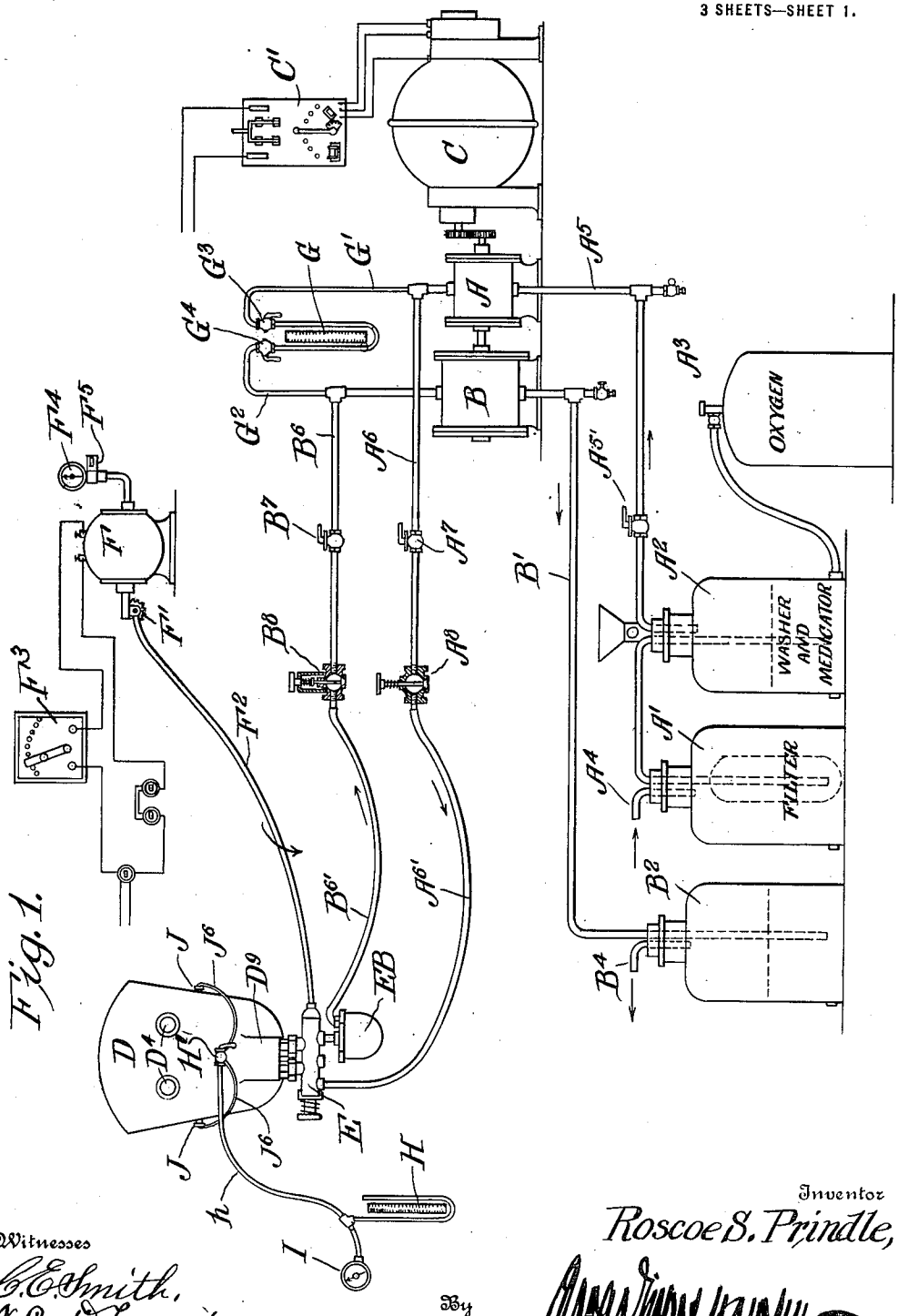


Fig. 1.

Witnesses

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3 SHEETS—SHEET 2.

Fig. 2.

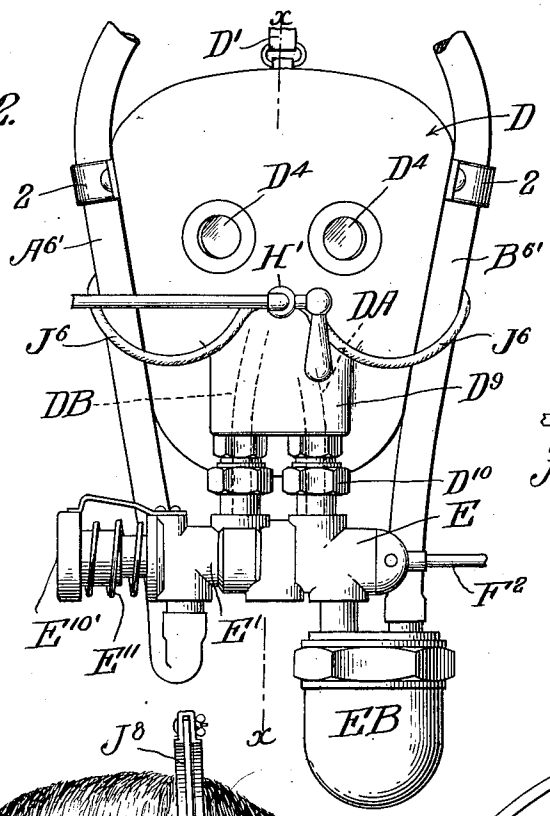


Fig. 7.

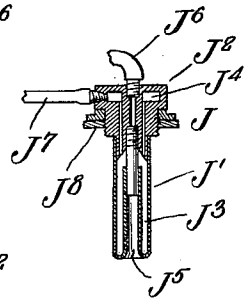


Fig. 3.

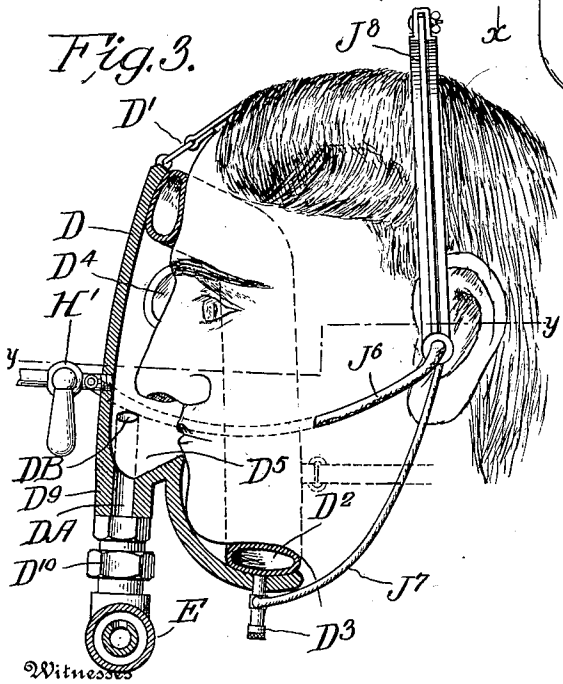
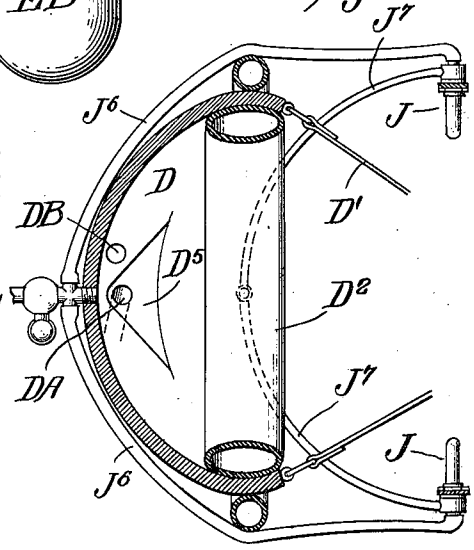


Fig. 4.



Witnesses

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3 SHEETS—SHEET 3.

Fig. 5.

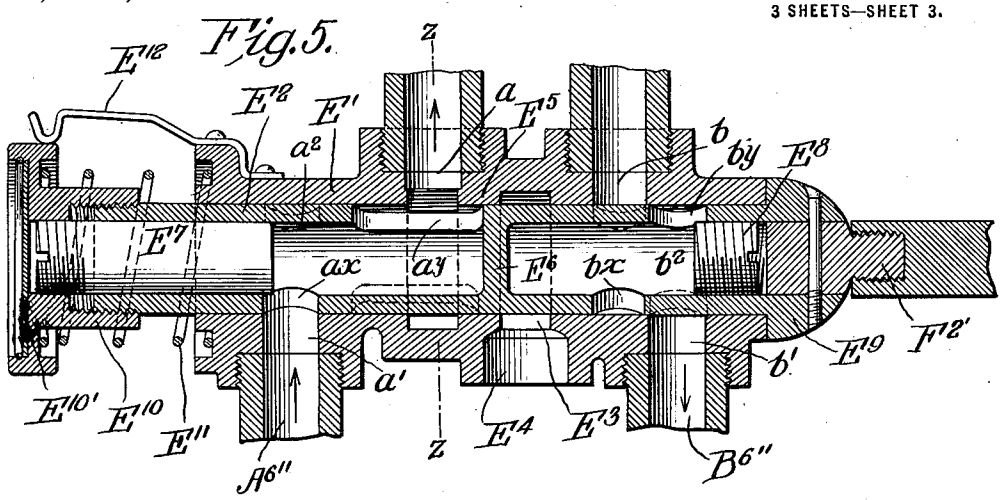


Fig. 6.

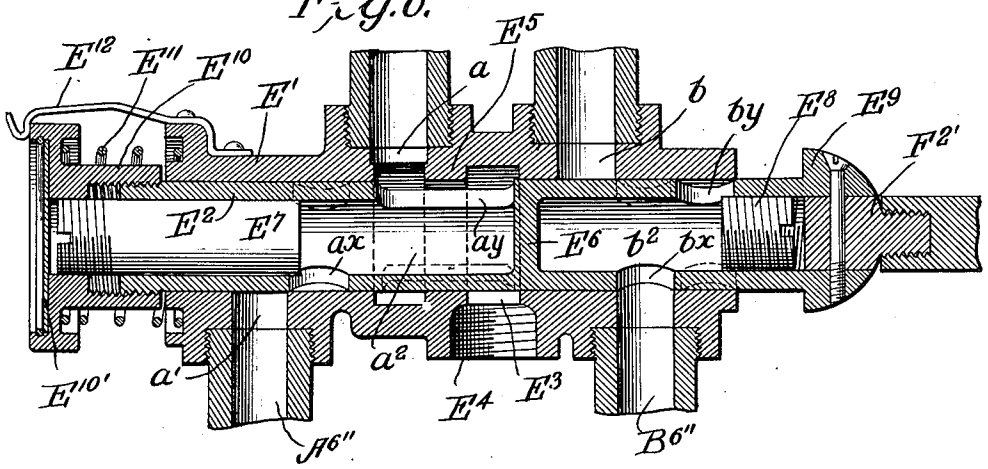
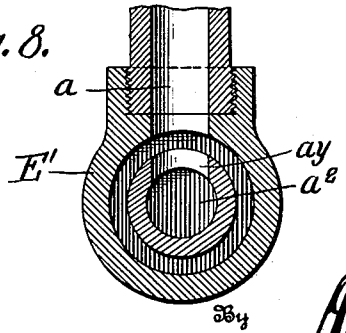


Fig. 8.



Witnesses

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UNITED STATES PATENT OFFICE.

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APPARATUS FOR PRODUCING ARTIFICIAL RESPIRATION.

1,169,996. Specification of Letters Patent. Patented Feb. 1, 1916.

Application filed February 13, 1909. Serial No. 477,484.

To all whom it may concern:

Be it known that I, ROSCOE S. PRINDLE, a citizen of the United States, residing at New York, in the borough of Manhattan and State of New York, have invented certain new and useful Improvements in Apparatus for Producing Artificial Respiration, of which the following is a specification.

Primarily my invention has to do with the production of artificial respiration and the cure of tubercular disease, but in a broader sense it relates to the purification of the blood in the human circulatory system and the rehabilitation of the tissue of the human body.

My improved apparatus for use in healing such diseases and disorders consists in means for substituting external forces for or superimposing external forces upon the habitual muscular movements of the patient's thorax or chest and for so gaging or controlling these forces as to inflate and deflate the lungs, first in rhythmic conformity with, and then in excess of, the patient's normal breathing. The forces referred to are those of gaseous pressure and a vacuum; and the aerating medium which I use is atmospheric air or mixtures of air and oxygen or other medicaments, as may best suit the condition and needs of the patient at times of treatment. In other words, my apparatus enables the physician or operator to supply compressed medicated or non-medicated air to the lungs of the patient and then exhaust the lungs, and, at the beginning of the treatments, to exactly reproduce the patient's breathing and afterward vary and increase the forces and thereby cleanse the lungs and readjust the factors of inspiration and expiration as rapidly as conditions safely permit.

My invention also consists in various novel constructions and combinations of parts, all as hereinafter described and particularly pointed out in the appended claims.

My invention will be most readily understood by reference to the accompanying drawings in which I have illustrated one of several forms of apparatus embodying the same.

In these drawings, which form a part of this specification, Figure 1 is a diagrammatic view of my novel apparatus for artificially producing, varying and controlling respiration. Fig. 2 is an enlarged view of the mask which is applied to the patient's face, together with the automatic controller or valve. Fig. 3 is a sectional view of the mask, on the line x, x of Fig. 2. Fig. 4 is a sectional view of the mask, on the line y, y of Fig. 3. Fig. 5 is an enlarged longitudinal section of the controller or valve, showing the parts in position to admit compressed air to the lungs of the patient. Fig. 6 is another sectional view showing how both the compressed air and the vacuum may be cut off and the patient supplied with atmospheric air at normal pressure. Fig. 7 is an enlarged longitudinal sectional view of one of the pneumatic ear stops; and Fig. 8 is a sectional view on the line z, z of Fig. 5.

I shall first describe the construction of the apparatus and will then describe the manner in which, and the purposes for which, it is used.

Referring now to Fig. 1 of the drawings, A represents a source of compressed air, here depicted as a rotary compression pump which is supplied with purified air, medicated air or oxygenated air from the bottles A′, A^2 and A^3. A^4 is the air inlet. The air is filtered in the bottle A′ and passes thence to the bottle A^2 which contains a quantity of liquid for washing, and, if desired, medicating, the air. When desired oxygen may be admixed with the air in the bottle A^2 by admission through the valved connection between the bottles A^2 and A^3, the latter being an oxygen tank. While further apparatus may be added for drying, heating, or cooling the aerating medium, if desired, such apparatus is not essential to the full understanding of my invention and it has not been thought necessary to illustrate it. The single pump A herein shown is merely representative; a different pump or several pumps may be substituted for it without departing from my invention. The air in either medicated or non-medicated condition passes from the bottle A^2 to the pump A through the pipe A^5 which contains the regulating valve $A^{5\prime}$. The valve $A^{5\prime}$ constitutes the admission valve of the pressure pump, and by operating the same the flow of air may be accurately adjusted. A second rotary pump B constitutes a source of vacuum, and B′ is the discharge pipe thereof. This pipe delivers the impure air from the lungs of

the patient to the washer or purifier B^2, wherein the air is cleansed before being discharged at the outlet B^4. The single pump B herein shown is merely representative; a different pump or several pumps may be substituted for it without departing from my invention. For driving the pumps A and B I preferably employ a single electric or other motor C of approximately two horse power. C′ represents a controller by which the speed of the motor and hence of the pumps may be widely varied and accurately controlled.

As before explained, I use my apparatus to successively inflate and deflate the lungs of the patient, and as the best means of connection with the sources of pressure and vacuum, I employ a mask D so constructed that it may be tightly bound upon or packed against the face of patient. This mask, more fully described hereinafter, is provided with inlet and outlet connections DA and DB, respectively joined to the pressure pipe A^6 of the pump A and the vacuum pipe B^6 of the vacuum pump B. For convenience the parts $B^{6'}$ and $A^{6'}$ of these pipes are made flexible. The rigid part of the pressure pipe A^6 contains a manual regulating valve A^7 and an automatic relief valve A^8. The corresponding part of the vacuum pipe B^6 contains a manual regulating valve B^7 and an automatic relief valve B^8. The valve A^8 is adapted to open outwardly, while the valve B^8 opens inwardly. Both valves are adjustable. By the use thereof constant pressure and vacuum in respective pipes is insured. In this connection it should be understood that the pumps are of somewhat greater capacity than actually required, and through the medium of the controller C′, the manual valves A^7, B^7 and the automatic valves A^8, B^8, the pressure and the vacuum at the mask may be regulated to any degree desired. The regulating valves are entirely independent and the conditions of vacuum or pressure existing in one pipe may be altered without changing the conditions in the other. It follows that the operator has direct and positive control; and may vary both the pressure and the vacuum at any time notwithstanding the fact that the two pumps are coupled to a single motor.

For the purpose of alternating the application of pressure and vacuum I interpose the controller E between the pipes A^6, B^6 and the mask D, and to avoid an air cushion between the two sources A and B and the lungs of the patient I place the controller directly upon the mask, making it a part thereof. The pipes A^6 and B^6 in a measure constitute reservoirs between the pumps and the controller, and if desired actual enlargements or reservoirs may be provided in the respective pipes, though in practice I secure the best results by limiting the capacities of the pipes to approximately the maximum requirements of a healthy person. A sputum cup EB is interposed between the controller E and the vacuum pipe B^6 for the purpose hereinafter described. The controller E as herein shown is of a rotary type and for actuating the same and for adjusting its rate of action to correspond with the natural respiration of the patient I employ a small electric or other motor F. The connection between the rotary member of the controller and the motor is established through the speed reducer F′ and the flexible driving shaft F^2.

F^3 represents the controller of the motor F by which the speed of the flexible shaft F^2 may be varied within the range of from five to fifty revolutions per minute.

An indicator F^4 and a counter F^5 enable the operator to exactly adjust the speed of the respiratory controller E.

For securing pressure and vacuum readings, I employ a U-shaped mercury tube G, of well known construction, coupled to the pipes A^6 and B^6 by small pipes G′ and G^2 and having selective valves G^3 and G^4. Slight variations of pressure take place between the regulating valves A^8, B^8 and the mask, and in order that the actual conditions within the mask may be known I preferably employ a second mercury column H, and a spirometer or volume meter I, connecting them, when required, to the mask by the flexible tube h, and the valve or cock H′, on the mask and communicating with the interior thereof. As hereinafter explained I also employ both the pressure meter H and the volume meter I, in determining the condition of the patient prior to and after treatment.

As shown in the drawings, the mask which I prefer to use, is approximately conformed to the face of a person and is of sufficient size to cover the forehead, cheeks and chin. This mask is usually secured to the head by straps D′, and as a convenient means of closing the joint between the mask and the face, I employ in the former a pneumatic tube or packing D^2. This tube extends around the rim of the mask and when the latter has been strapped upon the patient's head the packing tube is inflated, through the valve D^3, to the extent necessary to cause it to conform to the bony structure of the face and tightly close or seal the mask and prevent the escape of compressed air therefrom or the entrance of air at the rim of the mask when a partial vacuum is established therein. An advantage attaching to this particular formation and construction of the mask is that the chin, lips, nose and eyes of the patient are left free and circulation in the facial skin and muscles is not interfered with. Aside

from these mechanical features, my primary object in the use of the mask is to distribute the pressures and equalize the same upon the face of the patient and particularly the several ducts and organs which terminate in the mouth, nasal passages and eyes.

D^4, D^4 are eye glasses in the front of the mask through which the patient can see what is going on around him. That part of the mask which is opposite the lips contains a cavity or pocket D^5 to receive the sputum. The vacuum passage DA leads from the bottom of this cavity. The compressed air passage DB is arranged in, and opens through, the inner wall of the mask; at a point considerably above the pocket D^5, to prevent sputum from entering it. In some instances I employ pneumatic ear stops J connected to the mask and in communication therewith, the same flexibly joining the mask to the ears of the patient and having the effect of balancing the pressures in the Eustachian tubes. As shown in Figs. 3 and 4 a balancing device is provided for each ear, the same (see Fig. 7) comprising an annular bag J′-of a size to fit within the ear, carried by a small metal head or box J^2. The bag contains an annular cavity J^3 that communicates with the annular cavity J^4 in the head J^2. The central duct J^5 is continuous through both bag and head to admit air to the outer side of the ear drum. The air enters, and is exhausted from the duct J^5 through the flexible tube J^6 which is connected to the interior of the mask by being coupled to the valve fitting H′ between the valve and the mask. As a means of distending the bag within the patient's ear to make the connection air tight I connect the chamber J^4 of head J^2 with the valve stem D^3 of the packing D^2, using for the purpose a flexible tube J^7. As shown there are two ear stops, and these when once adjusted to the ears of the patient are rigidly held in position by the adjustable strap or yoke J^8 which passes over the head of the patient as shown in Fig. 3.

For convenience of illustration the controller E is shown below the mask, but I prefer to more closely assemble these parts, and in practice find it desirable to place the valve casing either directly in or against the lower part of the mask. As herein shown the offset portion D^9 of the mask, which contains the ducts DA and DB, is provided with nipples and union joints D^{10} for connecting them to the casing of the valve or controller.

The automatic admission and exhaust valve or controller E, best shown in Figs. 5, 6 and 8, comprises a cylindrical casing E′ and a cylindrical valve member or plug E^2. The top of the casing contains ports a and b which communicate with the ducts DB and DA respectively. The lower part of the casing contains ports a' and b' to which the pressure and vacuum pipes are respectively connected by the nipples $A^{6''}$ and $B^{6''}$, the latter being the connection of the sputum cup EB. The port a is preferably an annular groove in the inner wall of the casing, and parallel with this is another groove E^3, which communicates with the atmosphere through the hole E^4. The grooves or ports a and E^3 are separated by a narrow annular partition E^5. It will be noted that the ports a and a' are relatively staggered; this is true also of the ports b and b'. The valve proper or plug is divided into two chambers a^2 and b^2 by the middle partition E^6 and the end plugs E^7 and E^8. At the air entrance end, the part E^2 is provided with a small port a^x and also an elongated port a^y, which ports are relatively staggered, so that the port a^x co-acts only with the port a'. The port a^y is adapted to co-act with the port a and also with the port E^3, as hereinafter explained. At the vacuum end of the valve, the member E^2 contains the staggered ports b^x and b^y which co-act respectively with the ports b' and b. As shown the flexible shaft F^2, by means of a coupling $F^{2'}$, is joined to the outer end of the valve member E^2, and by means thereof the plug is rotated, to alternately open and close the air and vacuum passages. When the passage through a', a^x, a^2, a^y and a is open, the passage through b, b^y, b^2, b^x and b' is closed, and vice versa. Both passages are never open at once, though the interval between the opening of one and the closing of the other is comparatively short, the intervals conforming to the ratio of lapse and recovery in a person's breathing. The plugs E^7 and E^8 are longitudinally or revolubly adjustable in the valve member E^2, and by means thereof I am able to so change the shapes and dimensions of the ports a^x and b^y as to accomplish a definite and exact imitation of the cadences of a patient's breathing. It will be noted that these adjustments are wholly independent; this being necessitated by the fact that the cadences of inspiration and expiration are rarely the same. The coupling $F^{2'}$ and the plate $E^{10'}$ in the end of the valve member are both removable, to permit adjustments of respective cadence regulators or plugs E^8 and E^7. The valve member E^2 is longitudinally movable in the casing. Stops E^9 and E^{10} limit its movement. The latter is adjustable on the end of the member E^2 and is preferably in the form of a hand wheel by which the valve may be manually turned, for purposes of experiment. A spring E^{11} between the end of the casing and the stop E^{10} serves to hold the valve in the position shown in Fig. 5, but by pressing on the end of the valve either the operator or the patient may instantly shift the valve and open

direct communication with the atmosphere through the ports E^3, a^y and a, as shown in Fig. 6, at the same time closing both the air and vacuum passages. A latch E^{12} serves to hold the valve when thus shifted until it is desired to resume treatment.

As shown in Fig. 2 I usually carry the flexible pipes $A^{6'}$ and $B^{6'}$ up at the sides of the mask and attach them thereto by means of the clips 2, 2. These pipes may be suspended from a fixture above (not shown) or otherwise, and, incidentally, provide a flexible support for the mask, relieving the patient from its weight.

The use and operation of my apparatus is as follows: When a patient presents himself for treatment I first ascertain his general condition, particularly the state of his lungs, and carefully mark and determine the periodicity, cadences, volumes and pressures of the inspirations and expirations. The periodicity and the cadence may be mechanically determined by the use of suitable apparatus, but as the sounds of respiration are clearly perceptible, and as the respiratory apparatus herein shown emits like sounds, it is an easy matter to adjust the latter to correspond. This adjustment is secured, as to periodicity, by regulating the speed of the motor F; and, as to cadences of inspiration and expiration, by adjusting the valve ports a^x and b^y through the medium of the portage regulators or plugs E^7 and E^8. I employ the pressure meter H and the volume meter I in determining the pressure and the volume of the patient's breath, and then exactly reproduce these factors by regulating the speed of the pump motor C, the inlet and outlet valves of the pump, and the relief valves A^8 and B^8. Having then quite accurately adjusted the pumps and the several valves and the controller valve operating motor, I preferably subject the apparatus to a final test by closing the back of the mask and taking readings therefrom by connecting the meters I and H thereto. Having now adapted the apparatus to the exact or substantially exact reproduction of the patient's natural or normal respiration, I apply the mask. This may be done without stopping the apparatus if the valve E^2 is moved to the open atmosphere position shown in Fig. 6 of the drawings. Then the mask is first applied to the face of the patient and the packing D^2 is deflated. The straps are then adjusted and if their use is required the ear stops or balancing devices are adjusted and secured in position by means of the yoke J^8. These acts having been performed the operator by means of a small pump (not shown) applied to the valve stem D^3 inflates the packing D^2 to properly affix the mask. As the ear stops are connected with the valve stem D^3 the same pressure is exerted therein as in the packing D^2 causing them to expand or swell within the ear passages. It may be here explained that the central ducts J^5 of the ear stops are suitably strengthened to prevent the collapse thereof by pressure in the annular cavities J^3 of the plugs or stops. When the mask has been properly adjusted the treatment proceeds, being instituted by the restoration of the valve E^2 to working position; after which, each revolution of the valve causes the lungs of the patient to be successively inflated and deflated. It will be obvious that by thus alternately forcing aerating medium into the lungs of the patient and exhausting the lungs, he is relieved from both voluntary and involuntary muscular effort and is at once placed in a condition of rest. As the treatment proceeds the patient receives the benefits of a fuller and more regular oxygenation of the blood and the effective and regular exhaust and ejection of both accumulated and accumulating carbonic acid gas. The removal of the latter is final, reëntrance thereof to the lungs being absolutely prevented; which is rarely the case, even when breathing in an open atmosphere. The regular tides and impulses, which I am thus able to set up in the lungs of the patient, displace the obstructions therein and cause the fluid exudate to rise through the bronchial tubes, even during early treatment. As the patient's face is quite unhampered within the mask, he is able to readily eject fluids into the pocket D^5 provided therein, and they are instantly drawn away by the vacuum and deposited in the sputum cup of collector EB, that is connected to the controller E. As the treatments proceed, by means of the governing valves and the motor controller, I re-adjust the several factors of artificial respiration to accord with the patient's improved condition, and furthermore, by manipulating the controlling means, gradually increase the forces, namely, the pressure and vacuum, also the volume of air administered, and vary the periodicity and cadence, with a view to establishing greater lung capacity and better breathing conditions; to inculcate, also, the habit of deep breathing and the desire for purer air. At different times, when the accumulation of exudate in the lungs requires such treatment, to dislodge and eject it, I reduce the portage of the vacuum passage by means of the plug E^8, and increase the vacuum by adjustment of the valves B^8 and B^7, thereby increasing the force of expiration or deflation, but shortening its period or time, and thus produce repeated actions which are in the nature of coughing; by which the patient is effectually relieved of deleterious fluids as well as gases.

As various modifications of my invention will readily suggest themselves to those who

are skilled in the art, I do not limit nor confine my invention to the specific structures shown or described.

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

1. In respiratory apparatus the combination of a mask adapted to fit tightly over the nose and mouth of a patient and provided with passages, air forcing and air withdrawing means, a longitudinally adjustable rotary valve, pipes connecting said valve, said mask and said air forcing and air withdrawing devices together, and means for constantly rotating said valve, whereby air will be forced into said mask and withdrawn therefrom at intervals, substantially as described.

2. In respiratory apparatus, the combination with a mask adapted to fit tightly over a patient's nose and mouth, means for forcing air into said mask and withdrawing it therefrom, a valve casing provided with ports, piping connecting said mask and ports, a longitudinally adjustable rotary member in said casing adapted to control said ports, and means for continuously rotating said member.

3. In respiratory apparatus, the combination with a mask adapted to fit tightly over a patient's nose and mouth, of means for forcing air into said mask and withdrawing it therefrom, a valve casing provided with ports, and pipes connecting said ports and said mask, a port in said casing communicating with the atmosphere, a valve member rotatably mounted in said valve casing, controlling the inlet and exit of air to and from the mask, means for continuously rotating said member and means for confining said member in one position to establish communication between the interior of the mask and the atmosphere.

4. In respiratory apparatus, the combination with a mask, of a valve associated with said mask comprising a valve casing, a valve member slidably and rotatably mounted in said casing, said casing being provided with a port communicating with the atmosphere, a spring normally holding said member to maintain said port closed, means for holding said member in a position to open said port and means for continuously rotating said member.

5. In respiratory apparatus, the combination with a mask adapted to fit over a patient's face, of an air compressor, a vacuum pump, piping connecting said compressor and said pump with said mask, and a continuously rotating valve for regulating the intervals of supply to and exhaust from said mask, and means for controlling the quantity of air supplied and exhausted at each rotation of the valve.

6. In respiratory apparatus, the combination with a mask adapted to fit over a patient's face, of means for supplying air thereto and exhausting it therefrom, a continuously rotating controlling valve for governing the intervals of supply and exhaust, means for regulating the speed of said controlling valve, and means for controlling the quantity of air supplied and withdrawn at each rotation of the valve.

7. In respiratory apparatus, the combination with a mask adapted to fit over a patient's face, of an air compressor, a vacuum pump, piping connecting said compressor and said pump with said mask, and drainage devices and valves therefor connected to said compressor and vacuum pump whereby the apparatus may be sterilized and drained.

8. In respiratory apparatus, the combination of a mask adapted to fit tightly over the nose and mouth of a patient, means for fastening said mask around the patient's head, means for forcing air into said mask and withdrawing it therefrom at intervals, and devices whereby the patient or physician can throw the interior of said mask into communication with the atmosphere without removing the mask and without interrupting the action of the air forcing and withdrawing means, substantially as described.

9. In respiratory apparatus, the combination of a mask adapted to fit over the nose and mouth of a patient, straps for securing said mask to the patient's head, a flexible cushion between the mask and the patient's head, means for forcing air into said mask and withdrawing it therefrom at regular intervals, and means for establishing communication between the interior of said mask and open air without interrupting the action of the air forcing and withdrawing means, substantially as described.

10. In respiratory apparatus the combination with a mask adapted to fit tightly over the mouth and nose of a patient, of means for forcing air into said mask and withdrawing it therefrom at intervals, and a cavity in said mask to receive sputum whereby the patient may expectorate without removing the mask and without interfering with the forcing in and withdrawal of the air from the mask, said air withdrawal means being adapted to drain said sputum cavity, substantially as described.

11. In respiratory apparatus, the combination with a mask, an air compressor, a vacuum pump and suitable piping, of a valve casing connected with said piping and provided with ports, one of said ports communicating with the atmosphere and a valve slidably and rotatably mounted in said casing and provided with ports, substantially as described.

12. In respiratory apparatus the combination with a mask, an air pump, a vacu-

um pump and suitable piping, of a valve casing connected with said piping and provided with ports, one of said ports providing communication between the interior of the mask and the atmosphere, a valve provided with ports, said valve being slidably and rotatably mounted in said valve casing, a spring normally holding said valve so that the port leading to the atmosphere is closed, and means for fastening said valve so that said port communicating with the atmosphere is open after the valve has been moved against the tension of said spring, substantially as described.

13. In respiratory apparatus, the combination of a mask, a motor, an air compressor, a vacuum pump and suitable piping, a valve casing connected to said piping and provided with ports, a valve slidably and rotatably mounted in said casing, and a motor connected to said valve and rotating it continuously, substantially as described.

14. In respiratory apparatus, the combination of a mask adapted to fit over a patient's face, means for supplying air to said mask and exhausting it therefrom, and adjustable means automatically controlling the alternate duration of the intervals of supply and exhaust, substantially as described.

15. In respiratory apparatus the combination of a mask adapted to fit over a patient's face, means for supplying air thereto and withdrawing it therefrom at intervals, means for regulating the volume of air supplied and exhausted from said mask, and means for varying and controlling the intervals of supply and exhaust, substantially as described.

16. In respiratory apparatus, the combination of a mask adapted to fit over a patient's face, means for supplying air thereto and exhausting air therefrom, devices for controlling the volume and pressure of the air supplied to and withdrawn from said mask, and means for varying and controlling the intervals of the supply and exhaust, substantially as described.

17. In respiratory apparatus, the combination of a mask adapted to fit over a patient's face, an air compressor, a vacuum pump, piping connecting said compressor and said pump with said mask, means for operating said compressor and pump, and means whereby the interior of the mask can be thrown into communication with the atmosphere without interrupting the motion of the air compressor and the vaccuum pump, substantially as described.

18. In respiratory apparatus the combination with a mask adapted to fit over a patient's face, of means for supplying air thereto and withdrawing it therefrom, and means for automatically controlling the cadence of the air supplied and exhausted, substantially as described.

19. In a respiratory apparatus, the combination of a mask adapted to fit over a patient's face, means for supplying air thereto and exhausting it therefrom, continuously rotating means for controlling the intervals of supply and exhaust, and means for varying the speed of said controlling means, substantially as described.

In testimony whereof I affix my signature, in presence of two witnesses.

ROSCOE S. PRINDLE.

Witnesses:
CHARLES GILBERT HAWLEY,
N. CURTIS LAMMOND.