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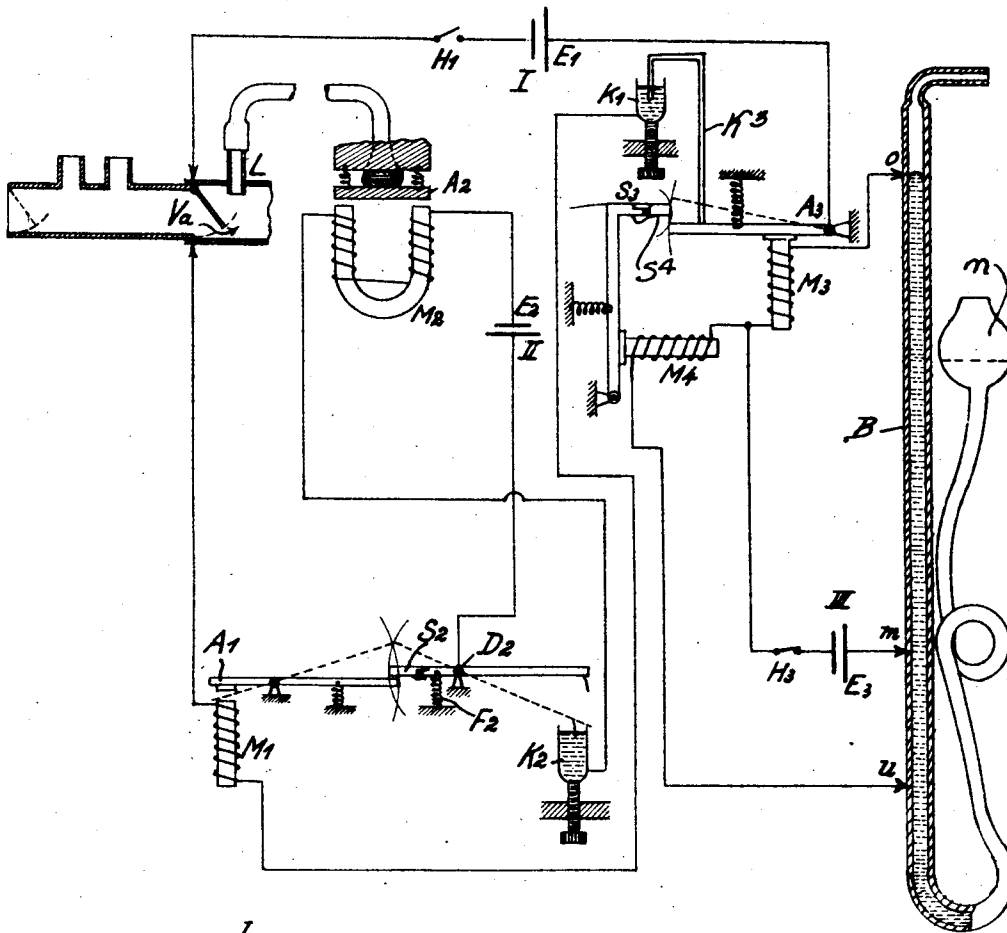
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APPARATUS FOR ANALYSING THE ALVEOLAR AIR FROM THE LUNGS

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Fig. 1.



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UNITED STATES PATENT OFFICE.

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APPARATUS FOR ANALYZING THE ALVEOLAR AIR FROM THE LUNGS.

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My invention relates to apparatus for analyzing the alveolar air from the lungs and it is an object of my invention to provide apparatus of the kind described in which such air is analyzed automatically.

To this end I provide means which are controlled by the flow of the air of respiration or by the rhythmic motion of the parts of the body which partake in respiration, and which toward the end of each respiration open and close a suction pipe connected with the respiratory organs until a measuring vessel, for instance a burette, has been filled with the desired quantity of alveolar air, operate an analyzing and registering apparatus and cause the vessel to be recharged with measuring liquid.

Any suitable means, and preferably an electromagnet control, may be provided for opening and closing the suction pipe, and the circuit of such control may be opened and broken by means of contacts which are bridged by the measuring liquid.

The variations in the percentage of carbonic acid or carbon dioxide and of oxygen contained in the blood are very important for many investigations of theoretical and practical medicine. The air on which such investigations are performed is that which is discharged from the lungs during the end of the respiration, its volume being about 10 cubic centimetres. This percentage of the total volume of respiration—which is the alveolar air referred to—is at balanced pressure with the blood flowing in the alveoles (Henry-Dalton rule) and therefore by analyzing this alveolar air as distinguished from the total volume involved in the respiration its content of carbon dioxide and oxygen will supply an indication of the composition of the gases in the blood which is substantially equal to an indirect analysis of the blood.

Apparatus for analyzing the alveolar air have already been proposed. Such apparatus may comprise a rubber tube or a glass pipe containing not less than 10 cubic centimetres. At the end of each expiration this tube or glass pipe is closed against the expiration opening by a valve or the like or the tongue of the patient and the portion of the tube or pipe at the rear of the expiration opening will contain exclusively alveolar air. A sample of this air is taken by a capillary tube in the vicinity of the expiration opening and delivering to a burette or the like whereupon it is analyzed for carbon dioxide or oxygen

as usual. Obviously, it is important with a view to obtaining pure alveolar air that this delivery to the burette should be effected immediately at the end of the expiration, or, in other words, immediately before the beginning of the following respiration.

Automatic means have also been proposed for effecting the sampling without the cooperation of the patient. A device for this purpose is the so-called nasal valve. This is a short glass pipe with minimum volume from which extend two pipes adapted to be inserted in the nostrils, and a light but tight-closing valve is provided at each end of the pipe. Both valves are check valves, one of them opening upon respiration but closing when expiration starts, and the other valve operating conversely, that is, closing at the beginning of respiration and opening at the beginning of expiration. The valve which opens at expiration delivers to the above-mentioned tube or pipe from which the sample of alveolar air is drawn into the burette.

Devices of this type involve the drawback that the operator is under the necessity of directing his attention exclusively to the analyzing operations which generally are effected within short intervals of time and this is all the more inconvenient as the observation often extends through a full day or night.

This drawback is overcome by my invention in which the samples are tested automatically and this has never been suggested nor practiced.

It is true that apparatus have already been proposed for automatically determining and indicating the percentage of carbon dioxide in furnace gases, and registering apparatus of this kind are also old, for instance the "Orsat".

The explanation why such apparatus have never been applied for the purpose of the present invention is that in the apparatus mentioned the total volume of exhaust gases for a given period is analyzed whereas in the present invention the object is to analyze a definite percentage of a periodically delivered volume, viz, the expired air, and only a fraction of this percentage, viz, the alveolar air. Therefore, the above-mentioned technical methods cannot be applied here without alteration.

The apparatus according to my invention is designed and operated on the following lines: When the expiration valve, that is, the check valve which closes upon inspiration, is

opened, connection to the burette is established at the same time so that a sample of alveolar air is drawn from the glass pipe by the liquid sinking in the burette. The mechanism for establishing the said connection is automatic and is so set that the opening period for sampling corresponds to the short pressure on a clip, and two or three cubic centimetres of alveolar air are drawn off. This opening and closing of the expiration valve is repeated until a definite volume, say 100 ccm., has been collected in the burette at any suitable pressure, preferably atmospheric.

When this volume has been collected, alveolar air is no longer tapped but the gases are analyzed automatically and after the analysis the operation of sampling is repeated, etc. The determination and registration of the percentage of gas may be effected by graphical means on a volumetric base or by photographic registration.

When the analysis has been completed, and the burette has been recharged with measuring liquid the mechanism is automatically set for another cycle of operations, that is, a sample of air is taken again and analyzed, registered etc.

My invention will be better understood by reference to the accompanying drawings in which an apparatus of the kind described is illustrated diagrammatically by way of example.

Figure 1 is a schematic representation of a device embodying my invention, and

Figure 2 is a fragmentary view of the expiration tube, illustrated diagrammatically.

The mechanism comprises three circuits, I, II, and III, which are operatively connected by a system of relays and locking means as required by their cooperation. Circuit No. I comprises a battery E_1 , a valve V^a , an electromagnet M_1 , and a contact K_1 . Circuit No. II comprises a battery E_2 , an electromagnet M_2 and a contact K_2 which is adapted to move about D_2 . The armature A_2 of the electromagnet M_2 is connected with a spring which normally, that is, when the magnet is not energized, compresses the rubber tube for drawing off the alveolar air against a fixed block.

In operation, the main switch H_1 is thrown in and the circuit I is closed by the closing of the valve V^a , and opened when the valve is opened at the beginning of the expiration. In order to connect the circuit No. I with the circuit No. II and thereby enabling the air to be drawn into the burette a short immersion of the contact K_2 is effected by the armature A_1 being attracted. As shown by way of example, an extension of the armature A_1 slides past an extension of contact support K_2 .

When the patient is breathing into the expiration tube T the valve V^a is open and consequently the circuit I is also open, and the air of expiration will pass through the expiration tube. At the end of the expiration, the valve

V^a will be closed by the beginning of the inspiration, thereby closing the circuit I. When the valve V^a closes, the last portion of the air of expiration, namely the alveolar air, is trapped in the expiration tube which is so formed that the air cannot readily or quickly escape therefrom.

When the circuit I is closed by the expiration valve, the magnet M_1 is energized and attracts the armature A_1 which pivots and moves the contact K_2 about the pivot D_2 and closes the circuit II, thereby energizing the magnet M_2 and releasing the clip A_2 from the rubber tube and allowing a portion of the alveolar air to be drawn from the expiration tube into the burette B. As the armature A_1 reaches the end of its movement the contact K_2 is released and the circuit II is opened, allowing the clip A_2 to close the rubber tube. The end of the contact K_2 is provided with a downwardly swinging spring pressed portion S_2 which is depressed by the armature A_1 on its return movement, thereby allowing the armature to move past the contact K_2 and be in position to raise the end of the contact when it is again attracted by the magnet M_1 .

It will be seen that the time during which the rubber tube is held open may be regulated by varying the depth to which the contact K_2 is immersed, or by any other time controlled means.

Circuit No. III is provided with the object of interrupting the operation of drawing in alveolar air during the analysis. The circuit is branched and comprises a battery E_3 , two contacts m and o in the burette at the highest and lowest level of the liquid in the burette the permanent contact u , and electromagnets M_3 and M_4 in each branch.

The magnet M_3 of one branch closes circuit No. I by attracting the spring pressed armature A_3 and immersing the end of the contact K_3 which is supported by the armature A_3 , in the contact K_2 . The armature A_3 is also held down by the end of the armature S_3 which is provided at its end by a spring pressed downwardly swinging catch S_4 , which allows the armature A_3 to pass on its downward motion. The armature S_3 is held in position by the magnet M_4 . When the liquid in the burette has fallen below the contact O , the branch of the circuit III containing the magnet M_3 is opened, and the armature A_3 released. The contact $K' K_3$ is not broken, however, as the catch S_4 still engages the armature A_3 and holds it down. When the liquid has fallen below the contact M , that is when the required quantity of air has collected in the burette, the branch of the circuit III containing the magnet M_4 is broken, releasing the catch S_4 and allowing the spring to raise the armature A_3 and remove the contact K_3 from the contact K_1 , thereby opening circuit No. I. From this time, the remaining alveolar air escapes into the atmosphere, as

none can be withdrawn with the circuit No. I open, and as this circuit is not closed until the liquid has risen to the contact O and the magnet has pulled the armature past the catch S₁. When the apparatus is in this position it is ready for the next cycle or operation.

For raising and lowering the liquid in the burette, I have illustrated diagrammatically, a leveling bottle N of the usual construction, although it will be obvious that any other arrangement for accomplishing this purpose may be utilized.

Instead of providing a valve V* in combination with a contact, and operating the valve by the varying pressure of the respiration, a part of the body which moves rhythmically in time with the respiration, may be used for controlling the mechanism. Obviously, any other means may be provided for closing the rubber tube instead of a clip. Instead of the illustrated time contact K₂, other means may be provided. Finally, the arrangement of circuits, contacts, and relays may be varied as desired without departing from the spirit of my invention.

I claim:

1. Apparatus for analyzing alveolar air comprising a burette, a pipe, a suction tube connecting said pipe and burette, a valve in said pipe, said valve being opened and closed by the air of respiration and means operated by the movement of said valve to open and close the suction tube to allow air to be conveyed to the burette.

2. Apparatus for analyzing alveolar air comprising a burette, a pipe adapted to receive the air of respiration, a suction tube connecting said pipe and burette and means to open and close the suction tube whereby the alveolar air will be drawn into the burette.

3. Apparatus for analyzing alveolar air comprising a burette, a pipe adapted to receive the air of respiration, a suction tube connecting the pipe and burette and means comprising an electromagnet, a time contact, and a member movable by the passage of the air of respiration through the pipe for opening

and closing the suction tube, to allow the alveolar air to be drawn into the burette for analyzing.

4. Apparatus for analyzing alveolar air comprising a burette, a pipe to receive the air of respiration, a suction tube connecting the burette and the pipe, means comprising an electromagnet, a time contact and a member moved by the passage of the air of respiration through the pipe for opening and closing the suction tube to allow the alveolar air to be drawn into the burette for analyzing, and means for recharging the burette with liquid after the analysis has been completed.

5. Apparatus for analyzing alveolar air comprising a burette, a pipe to receive the air of respiration, a suction tube connecting the burette and the pipe, a circuit including an electromagnet, a time contact and a contact moved by the passage of the air of respiration through the pipe for opening and closing the suction pipe, and means operated by the rise and fall of the liquid in the burette for making and breaking said circuit.

6. Apparatus for analyzing alveolar air comprising a burette, a pipe to receive the air of respiration, means connecting the pipe and burette, means timed to convey a portion of the alveolar air to the burette for analyzing and means to reset the apparatus for another cycle.

7. Apparatus for analyzing alveolar air comprising a burette, a pipe to receive the air of respiration, a suction tube connecting the pipe and burette, a circuit including an electromagnet and a time contact, means operated by the air of respiration in the pipe for operating the time contact to open and close the suction tube through the agency of the electromagnet, whereby the alveolar air will be conveyed to the burette for analyzing, and means controlled by the rise and fall of the liquid in the burette for making and breaking the circuit.

In testimony whereof I have signed my name to this specification.

HERMANN REGELSBERGER.