Nov. 25, 1941. C. M. HAMMOND 2,263,844

RESPIROMETER

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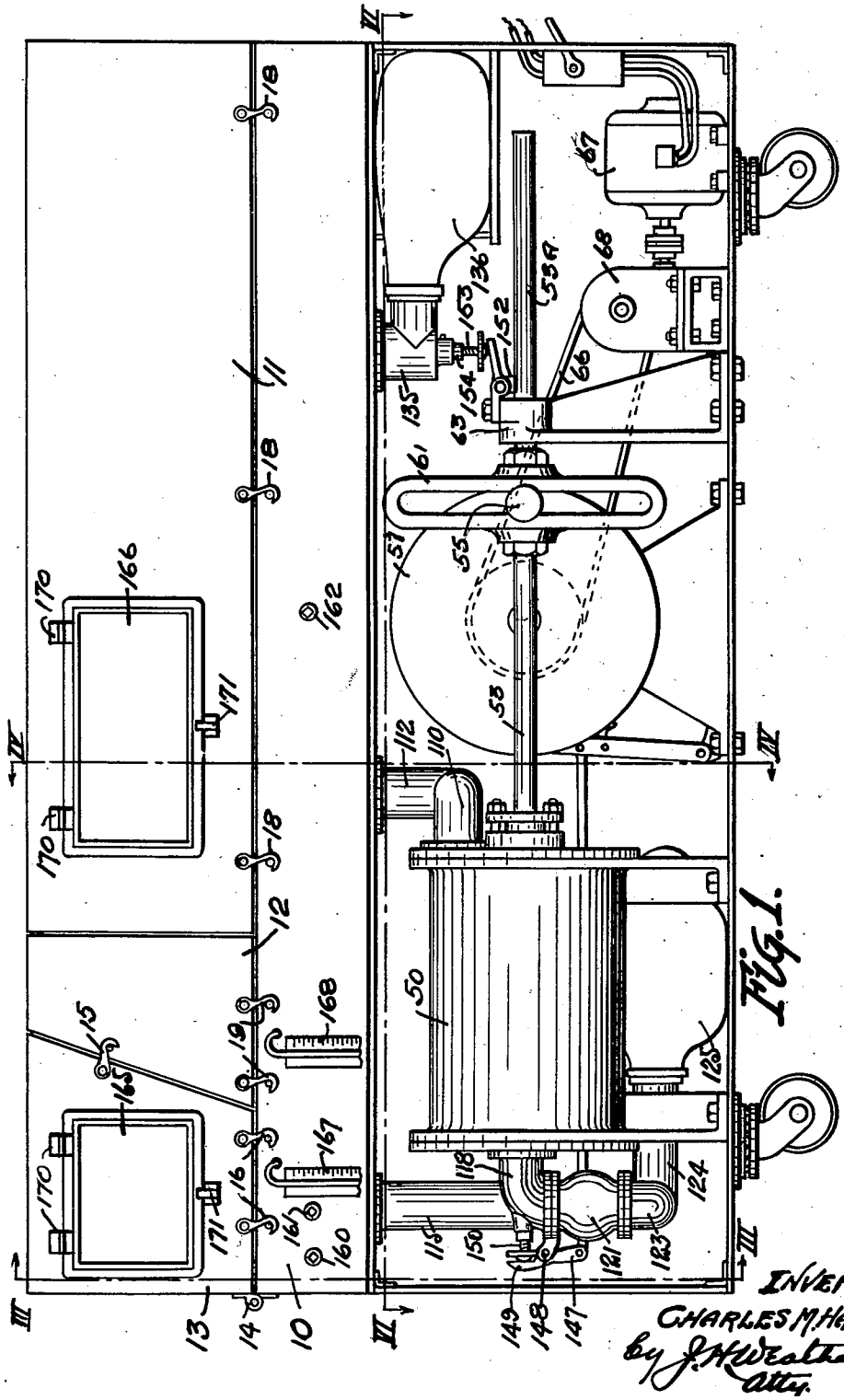


Fig. 1.

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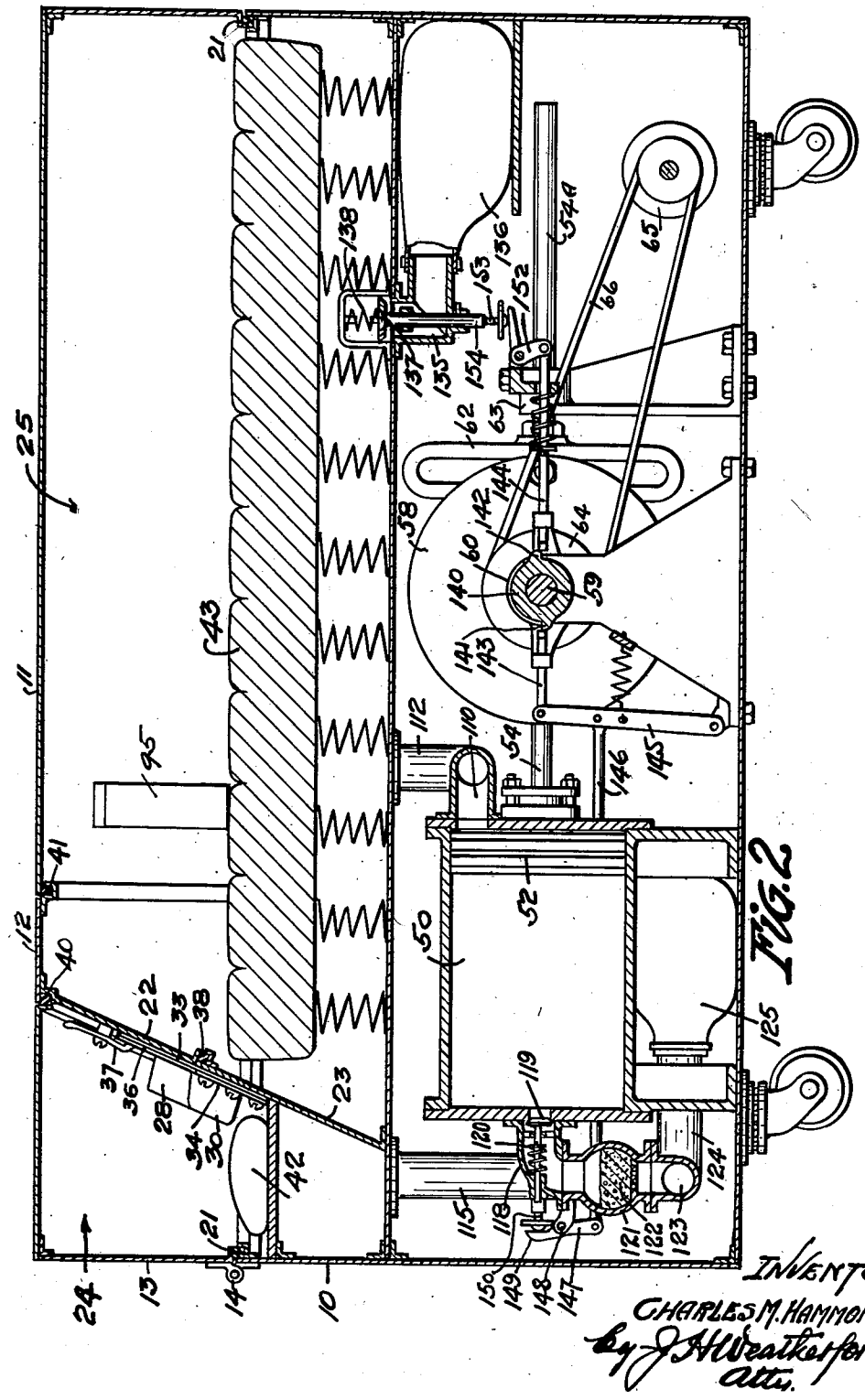


FIG. 2

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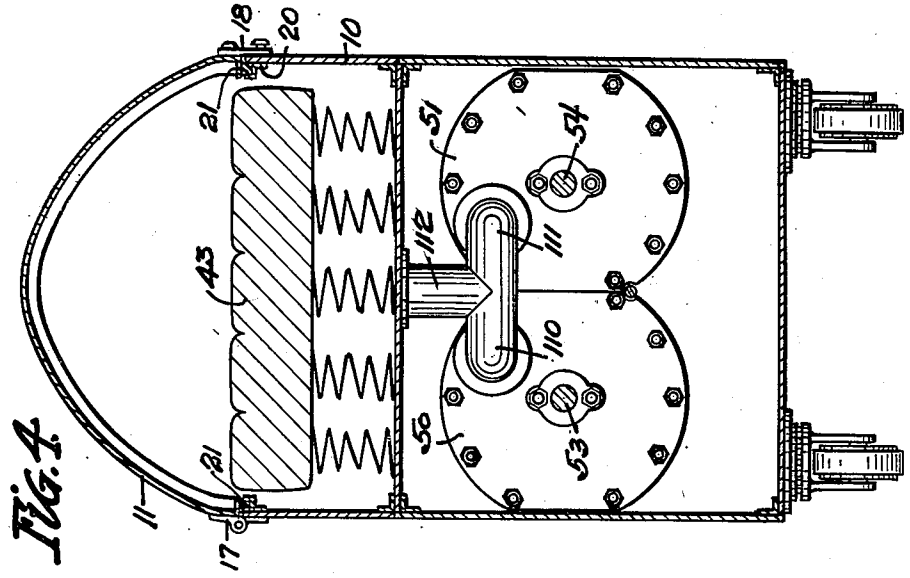


Fig. 4.

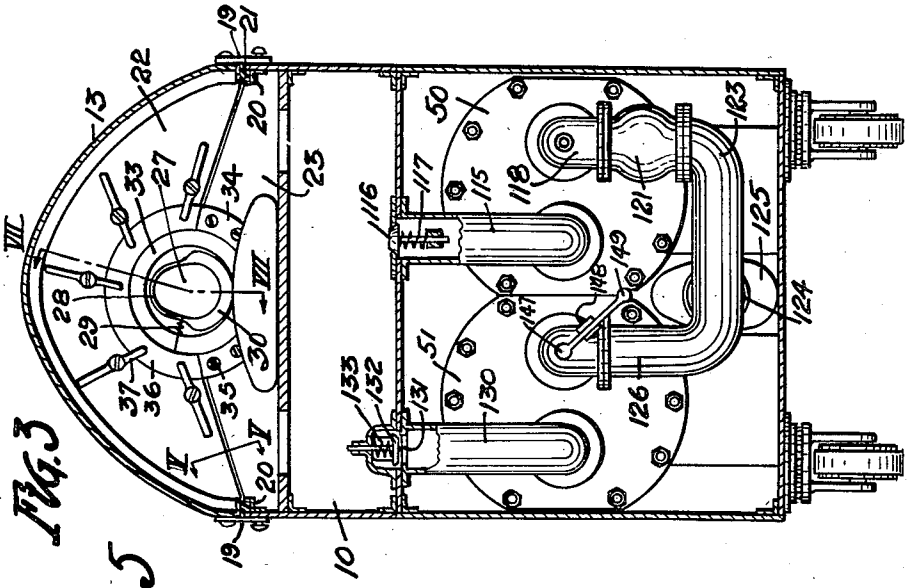


Fig. 3

Fig. 5

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RESPIROMETER

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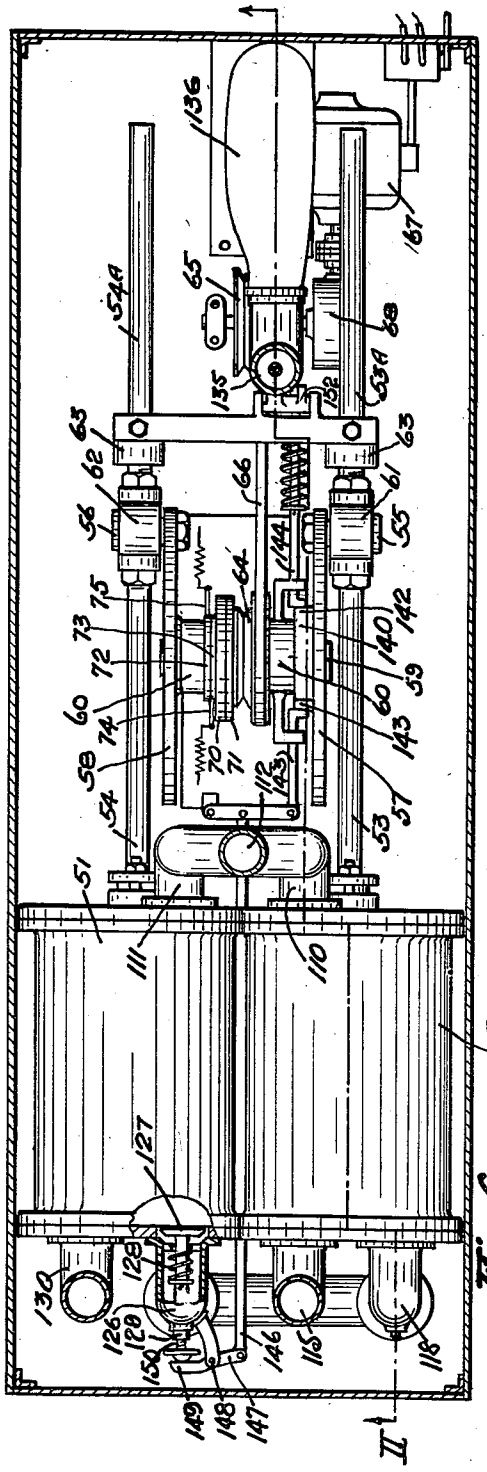


Fig. 6

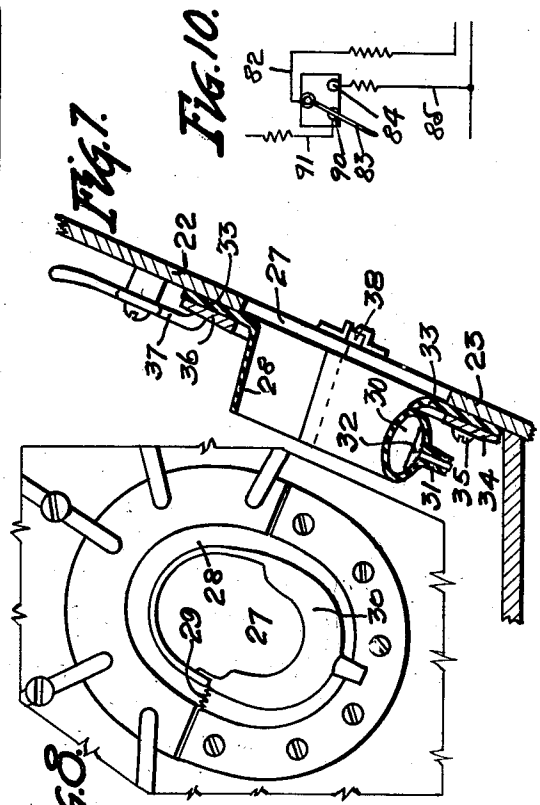


Fig. 7

Fig. 10.

Fig. 8.

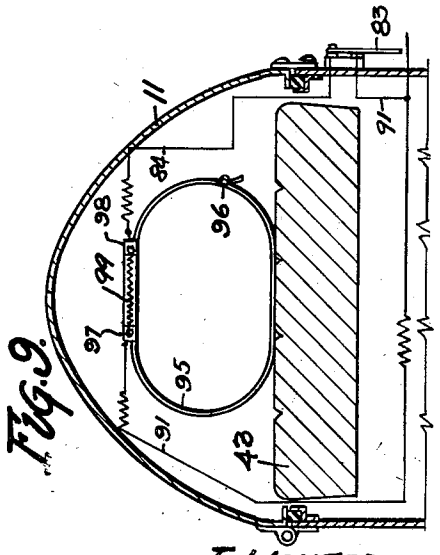


Fig. 9.

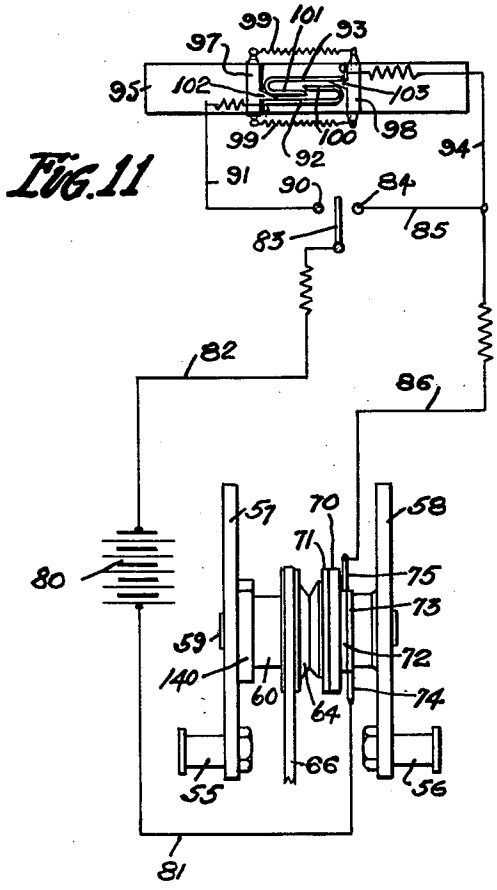
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RESPIROMETER

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FIG. 11



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UNITED STATES PATENT OFFICE

2,263,844

RESPIROMETER

Charles M. Hammond, Memphis, Tenn.

Application November 2, 1938, Serial No. 238,334

8 Claims. (Cl. 128—30)

This invention relates to devices for inducing respiration, particularly in the human body and especially to devices of this kind which mechanically induce and maintain respiration over a more or less extended period of time.

It further relates to a device of this kind in which the head and torso are separately but concurrently and reversely acted on, a partial vacuum and air pressure being alternately set up around the head whereby to artifically induce respiration and concurrently and reversely air pressure and partial vacuum are alternately set up around the torso whereby to assist in the establishment of the lung action.

The invention further relates to a device of this kind in which oxygen may be substituted in whole or in part for the air around the head and in which the air, or oxygen so substituted, may be cooled or heated as necessity may indicate.

The objects of the invention are:

To provide a casing which will completely enclose both the head and the body of the patient in separate compartments, and which may be hermetically sealed.

To provide as a portion of such casing a sectional top which may be fully opened to allow placing of the patient within the casing, and his or her subsequent removal therefrom.

To provide means for hermetically sealing the sections of the top together and of the top to the remaining portion of the casing.

To provide a sectional diaphragm cooperating with said casing including one of the sections of said top.

To provide means for sealing the diaphragm around the neck of the patient and the parts of the diaphragm together.

To provide means for alternately exhausting air from the head portion of the casing and establishing air pressure in such casing.

To provide means for alternately establishing air pressure in the body portion of said casing and exhausting air therefrom.

To provide means for synchronizing the action of such exhaust and pressure means whereby reduction of air pressure in the head portion of the casing is concurrent with increase of air pressure in the body portion of the casing, and following such action increase of air pressure in the head portion of the casing is concurrent with reduction of air pressure in the body portion of the casing, such actions being serially repeated.

To provide means whereby air delivered to the casing may be heated or cooled.

To provide means whereby oxygen may be substituted in whole or in part for the air delivered to the head portion of the casing; and

To provide indicating means whereby the pressures and vacuums set up in the device are visually shown.

The means by which the foregoing and other objects are accomplished, and the manner of their accomplishment will readily be understood from the following specification on reference to the accompanying drawings, in which:

Fig. 1 is a side elevation of the respirometer.

Fig. 2 is a sectional side elevation taken on the broken line II—II of Fig. 6.

Figs. 3 and 4 are transverse sectional elevations taken respectively on the lines III—III and IV—IV of Fig. 1.

Fig. 5 is a fragmentary section taken on the line V—V of Fig. 3 showing an enlarged detail of the sealing structures used.

Fig. 6 is a sectional plan taken on the line VI—VI of Fig. 1.

Fig. 7 is a fragmentary longitudinal section taken on the line VII—VII of Fig. 3; and

Fig. 8 a fragmentary elevation looking in the direction of the arrow 8 of Fig. 7.

Fig. 9 is a fragmentary section corresponding to Fig. 4 showing a current control belt adapted to encircle the body of the patient.

Fig. 10 is a fragmentary diagrammatic sketch of the switch shown in Fig. 9; and

Fig. 11 is a diagrammatic sketch of the mechanism and wiring controlled by the belt of Fig. 9.

Referring now to the drawings in which the various parts are indicated by numerals:

The respirometer includes an elongated casing to receive the patient, this casing including a substantially rectangular base portion 10 to which is hingedly secured a torso cover 11, a diaphragm cover 12 and a head cover 13. Suitable hinges 14 secure the end of the head cover to the base section 10, and latches 15, 16 secure the head cover to the diaphragm cover 12, and to the base portion 10 respectively, when the head cover is closed. Similar hinges 17 along one longitudinal edge of the torso covers 11 and diaphragms 12, hinge these covers to the base portion 10 and latches 18 and 19 complete the attachment of these covers respectively when they are closed.

The base portion 10 is provided around its entire periphery with a member 20 which forms, with the upper edges of the side and end walls, a groove adapted to receive a resilient sealing

strip 21 against which the various top sections are clamped by the hinge and latch actions.

22, 23 are upper and lower portions of a diaphragm which divides the casing into head and torso chambers 24, 25 respectively. The upper portion of the diaphragm is integrally secured to the diaphragm cover 12 and the lower portion of the diaphragm to the base 10. An opening 27 is made through the diaphragm, part of this opening being in the upper and part in the lower portion, which opening is adapted to receive the neck of a patient. 28 is a collar of resilient material which is adapted to surround the neck of the patient in an air-tight manner. This collar is cut in two along one side so that it may be placed around the patient's neck and is provided with a zipper 29 or other means whereby it may be secured together and the secured edges sealed. A portion 30 also of the collar, preferably that which underlies the back of the patient's neck is of tubular form and is provided with a suitable inlet tube 31 and a closure valve 32 whereby it may be inflated and caused to conform closely to the contour of the neck surface. The base of the collar has a flange 33 extending laterally outward that seats against the diaphragm 22, 23. This flange is, like collar portion, cut in two at one side so that both collar portion and base portion may be open to receive the patient's neck and the lower left is permanently held against the diaphragm section 23 by an arcuate ring section 34 secured as by screws 35, the other half being adapted to be secured to the diaphragm section 22 by a complementary ring portion 36 which is secured in place by camming members 37. The two sections 22, 23 of the diaphragm are provided along their meeting edges with sealing strips 38 (Fig. 5).

40 is a sealing strip forming a joint between the head cover 13 and the diaphragm cover 12 along the periphery of the upper diaphragm 22. 41 is a similar sealing strip which seals the joint between the torso cover 11 and the diaphragm cover 12. 42 indicates a pillow and 43 a mattress.

Disposed below the casing thus formed is an air compressing mechanism. This mechanism comprises two double acting cylinders 50, 51, each cylinder having a piston therein, the piston 52 of the cylinder 50 being shown. 53, 54 are the piston rods of the cylinders 50, 51 respectively. These piston rods are reciprocated in unison as by crank pins 55, 56 respectively, which pins are carried by crank discs 57, 58, these discs being rigidly secured on a joint shaft 59 which is journalled in suitably supported bearings 60. 61, 62 are slotted crossheads carried by the piston rods 53, 54 respectively and in which the pins 55, 56 are respectively operatively disposed. Extensions 54—A, 55—A of the piston rods are supported and reciprocate in guide bearings 63.

Mounted on the shaft 59 between the bearings 60, is a pulley 64, here shown as a grooved pulley having two steps, which pulley is driven from a complementary pulley 65 through a belt 66, the belt 66 being shiftable from one set of grooves or steps of the two pulleys to the other set to vary operating speeds. 67 is a variable speed motor which is connected through an usual speed reduction mechanism 68 to the pulley 65.

70, 71 are complementary discs of a magnetic clutch such as may be bought in the open market, this clutch having one disc 70 secured to the shaft 59 and the other disc 71 to the pulley 64. The clutch has the usual collecting rings 72, 73 and contact brushes 74, 75 through which current is delivered to the clutch, no attempt having been made to show the insulation or other detail of these parts.

In Fig. 11, 80 is a source of current, here indicated as a battery, which has one lead 81 to the clutch contact brush 74, and the other lead 82 to a control switch 83, by which it may be cut off should it be so desired. The switch is ordinarily closed through the pole 84 and leads 85, 86 directly to the opposite brush 75 of the clutch to establish operative engagement of the clutch discs 70, 71. Optionally the switch 83 may be shifted to the pole 90 and through lead 91 to a contact member 92. 93 is a complementary contact member and 94 a lead from this complementary contact member to the lead 86. 95 is a belt adapted to be placed around and partially encircle the body of the patient in such position as to respond to the breathing of the patient, the belt being provided with securing means 96 through which it may be adjusted to the individual patient. The ends of this belt are spaced apart and have blocks 97, 98 of insulating material, such as hard rubber or Bakelite, secured respectively thereto, the blocks being urged together as by tension springs 99.

The contact members 92, 93 are preferably substantially of U shape with one short leg each, the longer legs being respectively secured to the blocks 97, 98. These contact members extend into over-lapping relation, with their shorter legs 100, 101 making sliding contact as breath enters the patient's lungs and expands the body, and remaining in such contact as breath is expelled from the lungs and the body responsively collapses, this contact continuing almost to the completion of breath exhalation, but at this point the ends of the contact members separate and the contact is broken. 102, 103 are blocks of insulating material secured respectively to the blocks 97, 98 which insure separation of the short leg of one U from the long leg of the other U at such time, such insulation obviously being extendable along the entire length of the U leg if so desired.

The inner ends of the cylinders 50, 51 are connected by passageways 110, 111 and a joint passageway 112 with the interior of the torso chamber of the device, these passageways being unobstructedly open. At its outer end the cylinder 50 has an intake passageway 115 which leads from the head end of the casing into the cylinder. This flow from the casing is through a valve 116 which opens against pressure of a spring 117 and is reseated by such spring to prevent return flow to the casing. 118 is a discharge passageway from the cylinder 50, flow through this passageway from the cylinder being permitted by a valve 119 which is held seated by a spring 120, this valve preventing return flow through the passageway to the cylinder. The passageway 118 discharges through a chamber 121 having a perforate bottom, in which chambers a chemical 122, such as soda-lime, adapted to absorb carbon dioxide is contained, and through which chemical the air discharged from the cylinder must pass. From the chamber 121 a passageway 123 continues. This passageway has a branch 124 which leads to an inflatable bag 125 adapted to receive and temporarily store the discharge from the cylinder 50. The pas-

sageway also has a second branch 126 which leads into the cylinder 51. 127 is a valve, held seated by a spring 128, which permits discharge of air through the passageway 126 into the cylinder 51, but prevents return flow therefrom. The stem 129 of the valve 127 extends through the wall of the passageway 126 and is controlled additionally in a manner to be hereinafter described. 130 is a discharge passageway from the outer end of the cylinder 51, this passageway discharging through an opening 131 into the head chamber of the casing. 132 is a valve normally held seated by a spring 133 to close the opening 131, this valve opening against the spring action to permit discharge from the passageway 130.

135 is a passageway leading from the torso chamber to an expandable bag 136, flow to this bag being controlled by a valve 137, normally held closed by a spring 138, this valve seating in the direction of flow from the torso chamber so that it must necessarily be mechanically raised to permit such flow.

Mounted on and secured to the shaft 59 is a cam 140 having oppositely disposed lift portions 141, 142, both having abrupt rises, which respectively engage oppositely disposed rods 143, 144 respectively. The rod 143 is connected through an arm 145 to a rod 146 which extends beyond the cylinders and contacts one end of an arm 147 pivotally supported as by a bracket-carried pin 148. The opposite end 149 of the arm engages the stem 129 of the valve 127, engagement being made through a threaded extension 150, which extension may be adjusted outward to increase the throw of the valve, or inward, to decrease same even to the extent of entirely cancelling opening movement.

The rod 144 extends oppositely to a pin connection with a bell crank lever 152 through which thrust of the rod 144 is transmitted through an adjustable, threaded member 153 to the stem 154 of valve 137, adjustment of the threaded member here again increasing the throw of the valve, or decreasing the same to the point of cut-off.

160, 161 are caps which may be removed to uncover openings into the head chamber, and 162 a similar cap closing an opening into the torso chamber. These caps when removed permitting the insertion of tubes for introducing oxygen into the head chamber or samples of the air content of that chamber either singly or concurrently and for introducing tubes into the torso chamber as for blood transfusions or other intravenous injections.

165, 166 are windows through which the head and body of a patient may be observed. 167, 168 are manometers. Windows 165, 166 are preferably provided with hinges 170, and latches 171 so that they be opened when and if necessary.

In using the device the latches 15 and 16 are released and the head cover 13 is opened about the hinges 14. The latches 18 are released and the torso cover 11 is turned back about the hinges 17; the latches 19 are released and the diaphragm cover 12 is turned back about its hinges, this secondary torso cover carrying with it the attached upper half 25 of the diaphragm and leaving the mattress 43 and the pillow 42 fully accessible and the collar 28 similarly accessible. The closure 29 is released and the upper half of the collar 28 turned back.

The patient may then be placed in the apparatus and the collar closed and fastened. The upper portion of the collar so closed comes around the patient's chin and along the opposite sides of the lower jaw, the inflatable portion 30 which has previously been collapsed underlying the back of the patient's neck. Air is introduced through the valve 32 causing the collar to conform itself closely to and seal around the neck, and drawing the upper portion into sealing contact with the jaw and chin. The secondary torso cover 12 is closed and latched, the upper half 25 of the diaphragm seating on the sealing strips 38. The ring section 36 is placed against the upper half of the collar flange 33 and is clamped thereagainst by the camming members 37 to complete the sealing of the diaphragm separating the head and body sections of the apparatus. The main torso cover 12 and the head cover 11 are then closed and secured by their respective latches and the apparatus is ready for use.

The clutch control switch 83 is shifted to neutral position, disconnecting the clutch discs 70, 71 and current is turned on to the motor 67. When the motor 67 has reached running speed the clutch control switch 83 is shifted, preferably to the pole 90, and through the contacts 92, 93, to energize the clutch and start up the air pumping mechanism. Before throwing in the clutch the patient's breathing is observed through the windows 165, 166 and the position of the pump pistons and their direction of movement is checked in order to start the operation of this mechanism as nearly in synchronism with the patient's breathing as possible, except that it is desirable to so start the mechanism that the operation will slightly lead the corresponding breathing of the patient. With the clutch cut in, the mechanism starts functioning approximately in step with the patient's breathing completing such portion of the inhalation and exhalation breathing cycle as may remain, the mechanism starting the inhalation portion of the next cycle, slightly before exhalation is completed by the patient. Unless, however, the patient's breathing instantaneously responds to this lead of the mechanism, completion of exhalation by the patient disconnects the contact 92, 93 and cuts off the magnetic clutch 70, 71 until such time as the patient's breathing again closes the contacts 92, 93 and re-establishes clutch action and the mechanical cycle.

Should the mechanism speed be greater than the patient's breathing speed the same cut-out action will occur at the end of this breathing cycle, and each succeeding breathing cycle until regulation of the motor speed is made to synchronize the apparatus speed with the patient's breathing cycle. If the mechanism speed is slower than the patient's breathing the same condition will occur except that cut-out of the clutch will throw the apparatus still further out of step and in such case it is advisable to cut off the clutch entirely and speed up the motor to a speed approximately slightly greater than that of the patient's breathing and again cut in the clutch through the control contacts 92, 93 and regulate as before. When the mechanism has been synchronized with the patient's breathing, the switch 83 preferably is shifted to the pole 84 and steady operation of the mechanism carried on. After such steady operation is effected, if the patient's breathing is slower than it should be, the motor may be very slowly advanced in speed, gradually speeding up the patient's breathing in desired manner, or if too fast, the motor may be slowed down lengthening both the inhalation and ex-

halation periods, but primarily by lengthening the inhalation period, slowing the patient's breathing to a more desirable rate.

During operation of the mechanism, as the piston in cylinder 50, is drawn away from the outer head of the cylinder, air is drawn from the head section of the casing through the passageway 115 into the cylinder, this action by reducing the pressure in the head chamber assisting the patient in exhaling. The air thus drawn into the cylinder 50 is forced out of the cylinder through the passageway 118 and through the soda-lime 121 in the chamber 119, and through passageways 123, 124 into the bag 125 in which it is temporarily stored. Return of air to the head chamber during this cycle is prevented by the valve 116, and return of air from the passageway 118 to the cylinder by the valve 119.

The piston in cylinder 51 moves concurrently with the above described movement of piston 52. On the instroke this piston draws in air from the bag 125 through passageways 124, 126 past the non-return valve 127 into the cylinder, and on the out stroke delivers this air through passageway 130 past non-return valve 132 into the head section, from which it is withdrawn into cylinder 50 as described above during the next succeeding cycle.

As the pistons in cylinders 50 and 51 move inward, as above described, they force air through the passageways 110, 111, 112 into the torso section of the casing, and on the return stroke withdraw the same amount of air therefrom, thus building up pressure in the torso chamber as pressure is reduced in the head chamber and reducing this pressure as pressure is increased in the head chamber.

As the pistons approach the inner end of the stroke the lift portion 141 of the cam 140 rather abruptly shifts the rod 143 and through the arm 145, rod 146 and arm 147—149, opens the valve 127 establishing connection to the bag 125 permitting equalization of the pressures therebetween. Concurrently the lift portion 142 of the cam, acting similarly through the rod 144, and bell crank lever 152, opens the valve 137 and permits equalization of the pressure in the torso chamber with the bag 136. The lift portions 141, 142 of the cam, being 180 degrees apart, accomplish the identical valve openings at the opposite ends of the piston strokes so that at the completion of both the exhaust and pressure strokes in the head chamber and the concurrent completion of the pressure and exhaust strokes in the torso chamber, the pressures in these chambers are re-established substantially at atmospheric pressure as in normal breathing.

Should it be found desirable, one of the caps 160 or 161 may be removed, and usual and well known apparatus for supplying oxygen may be connected through the opening left by the removal of the cap to enrich the air being supplied to the patient, such oxygen apparatus forming no part of the present invention, not being here shown. The outer cap may be removed and air withdrawn from the head chamber for testing CO_2 and oxygen content, or other purposes. Either of the caps may be removed for either of the above purposes, two however are preferably supplied as shown in order that both oxygen supply and test connection may be made at the same time should this be desirable. The cap 163 on the torso section may from time to time be removed and tubes introduced, as for intravenous feeding, blood transfusion or the like. In such cases the body cover 11 is temporarily opened while connection of the needle into the patient's vein is being made, and after such connection, closed during the transfusion or intravenous feeding.

Observation of the patient within the casing may be made through the windows 164, 165 provided in the head and torso covers respectively.

I claim:

1. In a respirometer including a casing divided into complementary sealed head and body chambers, means for alternately increasing and reducing pressure in one of said chambers, and synchronously alternately reducing and increasing pressure in the other thereof.

2. In a respirometer including a sealable casing divided into complementary head and body chambers, means for alternately increasing and reducing pressure above and below atmospheric pressure in one of said chambers and synchronously alternately similarly reducing and increasing pressure in the other thereof, and synchronized means for re-establishing atmospheric pressure at the completion of each cycle.

3. In a respirometer comprising a sealable casing divided into complementary head and body chambers, means for alternately increasing and reducing pressure above and below atmospheric pressure in one of said chambers and synchronously alternately similarly reducing and increasing pressure in the other thereof, and synchronized means for re-establishing atmospheric pressure at each pressure reversal.

4. In a respirometer comprising a casing divided into complementary chambers, adapted respectively to enclose the head and body of a patient, means for alternately increasing and reducing pressure in one of said chambers, and synchronously alternately reducing and increasing pressure in the other thereof, said means including an electric motor drive, a magnetic clutch for transmitting power therefrom, and clutch control means including a source of electric current, a circuit therefrom to said clutch, said circuit including a switch; and means responsive to breathing of said patient for opening and reclosing said switch at a predetermined point in the breathing of said patient.

5. In a respirometer comprising a casing, adapted to enclose the head and body of a patient, and means for alternately increasing and reducing pressure on the body of said patient, said means including an electric motor drive, a magnetic clutch for transmitting power therefrom, and clutch control means including a source of electric current, a circuit including a switch leading from said source to said clutch; and means responsive to expansion and contraction of said body during breathing for opening said switch at a predetermined point in the breathing of said patient.

6. In a respirometer comprising a casing, adapted to enclose the head and body of a patient, means for alternately increasing and reducing pressure on said body to increase breathing action thereof, said means including an electric motor drive, a magnetic clutch for transmitting power therefrom, and clutch control means including a source of electric current, a circuit therefrom to said clutch, said circuit including a switch; and means responsive to breathing of said patient for opening said switch at a predetermined point in the breathing of said patient.

7. In a respirometer including a sealable head chamber, pumping mechanisms respectively for

withdrawing air from and for introducing air into said chamber, and actuating means for said mechanisms, a passageway adapted to permit flow from said chamber to said withdrawing mechanism, means for preventing return flow through said passageway, an expansible and collapsible air repository, a second passageway leading from said withdrawing mechanism to said repository, means for preventing return flow to said withdrawing mechanism, a third passageway leading from said second passageway into said introduction mechanism, means for preventing return flow therethrough, an additional passageway for permitting flow from said introduction mechanism into said chamber, means for preventing return flow from said chamber through the last said passageway, and means for opening said return flow-preventing means, between said chamber and said introducing mechanism, concurrently with completion of each introduction and each withdrawing movement.

8. In a respirometer including a sealable head chamber, pumping mechanism respectively for withdrawing air from and for introducing air into said chamber, and actuating means for said mechanisms, a passageway adapted to permit flow from said chamber to said withdrawing mechanism, means for preventing return flow through said passageway, an expansible and collapsible air repository, a second passageway leading from said withdrawing mechanism to said repository, means for preventing return flow to said withdrawing mechanism, a third passageway leading from said second passageway into said introduction mechanism, means for preventing return flow therethrough, an additional passageway for permitting flow from said introduction mechanism into said chamber, means for preventing return flow from said chamber through the last said passageway, and cooperative means for temporarily establishing direct flow between said chamber and said repository concurrently with completion of each air introduction and each air withdrawal.

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