

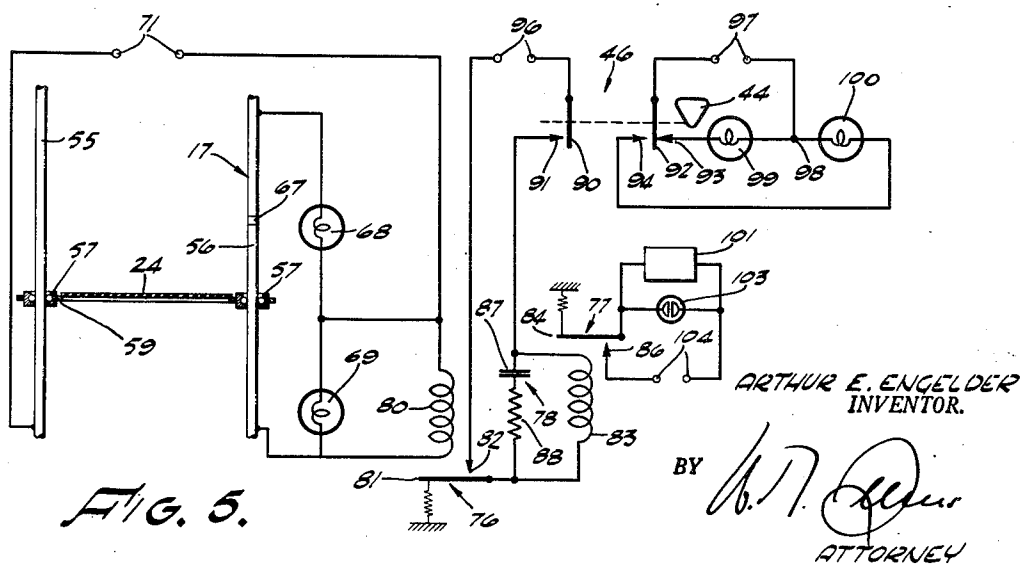
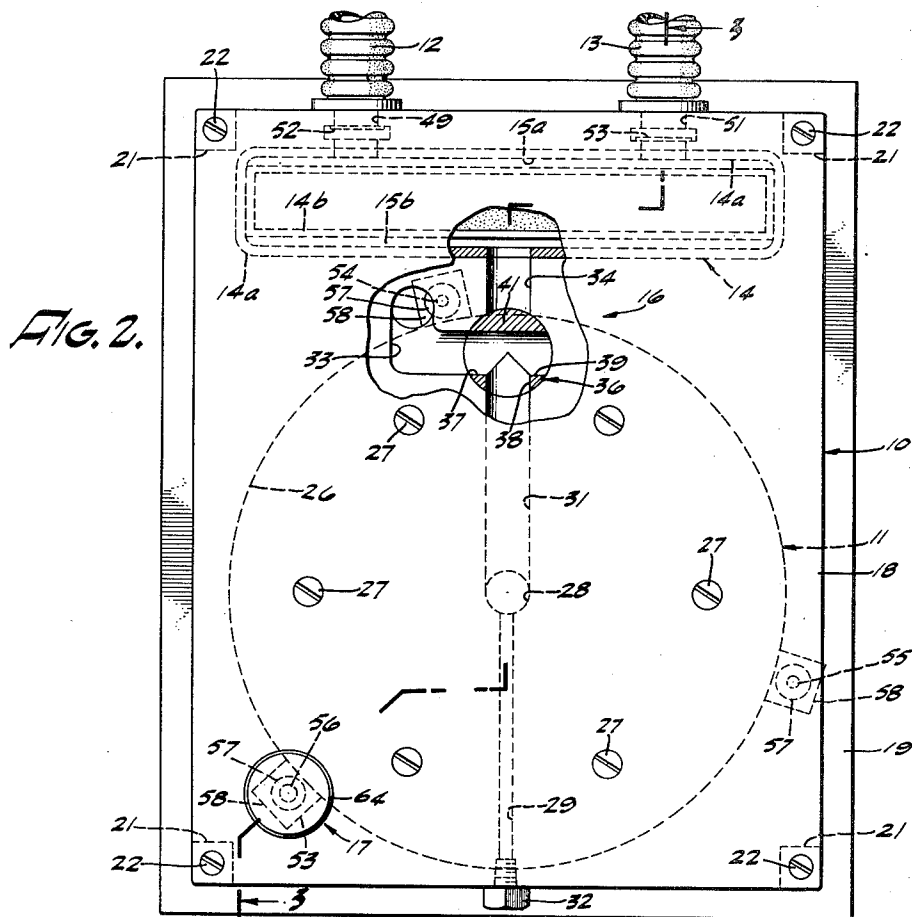
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BREATHING RESERVOIR

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1

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BREATHING RESERVOIR

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15 Claims. (Cl. 128—2.07)

This invention relates to a breathing reservoir or spirometer for use with apparatus for determining metabolic rates, anesthesia machines, and like equipment. More specifically, the invention relates to a device for determining the length of time required by a test subject to absorb into his lungs a predetermined mass of oxygen.

In various types of clinical testing it is important to determine the exact moment when a standard quantity of a gas has been absorbed by the lungs of a patient. One such type of clinical testing is performed with the apparatus for determining metabolic rates disclosed in my co-pending patent application Serial No. 348,259, filed April 13, 1953. Application Serial No. 348,259 describes a method and apparatus for determining metabolic rates by placing a predetermined charge or mass of oxygen into a breathing reservoir and causing the subject to inhale oxygen from the reservoir until the entire oxygen charge is consumed. Oxygen not absorbed by the lungs of the subject during a given breathing cycle is returned to the reservoir and recycled, and the exhaled water vapor and carbon dioxide are absorbed by suitable chemical agents.

It is common experience that patients subjected to such metabolism tests frequently complain of difficulty in breathing and may, due to a momentary panic, resort to gasping for air. This is particularly undesirable since a metabolic rate determination is only accurate if the patient is in a completely relaxed condition and is breathing regularly. The above difficulty results from the fact that conventional spirometers are constructed with a base on which is supported a relatively heavy oxygen container, the upper wall of which moves downwardly when oxygen is inhaled and upwardly upon exhalation. Such spirometers inherently create a substantial back pressure tending to prevent the subject from exhaling, and are unsound physiologically since it is known that the exhalation phase of the respiratory cycle is a passive or recoil phase as distinguished from the inhalation phase in which energy is supplied by the intrinsic and extrinsic muscles of respiration.

To reduce the objectionable back pressure during exhalation, all conventional vertical spirometers are counterbalanced with a relatively heavy weight acting over a pulley system. Although the static back pressure produced by the reservoir may thus be reduced, the relatively large mass of the parts provides a substantial inertia, which, with the friction of the moving system, interferes with normal quiet respiration.

In view of the foregoing disadvantages inherent in the construction of conventional spirometers, it is an object of the present invention to provide a breathing reservoir of minimum weight and inertia, fewer moving parts, and relatively little friction, and in which the expiratory phase of respiration is aided and not impeded by the effect of gravity acting on the movable reservoir.

Another object of the invention is to provide a spirometer or breathing reservoir constructed so that the movable horizontal reservoir wall travels upwardly during inhalation and downwardly during exhalation.

Another object of the invention is to provide improved means to indicate the consumption of a specific charge of oxygen.

These and other objects and advantages of the invention will be more fully appreciated upon a reading of the following specification and claims considered in connection with the attached drawings to which they relate.

2

In the drawings:

Figure 1 is a perspective view of the spirometer constructed in accordance with the present invention;

Figure 2 is a top plan view of the spirometer, with portions broken away to better illustrate the valve and passage elements;

Figure 3 is a compound vertical section upon the broken line 3—3 of Figure 2;

Figure 4 is a detail view illustrating the construction of the adjustable reference rod; and

Figure 5 is a schematic diagram of the electrical means for indicating the consumption of a specific charge of oxygen.

Referring to the drawings, the breathing reservoir or spirometer may be seen to comprise a frame or supporting structure denoted generally by the reference character 10, a bellows 11 mounted in dependent relation on the frame 10, inlet and outlet breathing tubes 12 and 13 communicating with bellows 11 and with a mask, not shown, on the face of the subject being tested, and a filter canister 14 interposed between the bellows and the breathing tubes to absorb normally exhaled substances such as carbon dioxide and water vapor. The spirometer further comprises a valve means 16 for starting and stopping the test, and reference level means 17 which are associated with electric circuit and signal elements to indicate the time required by the subject to consume a predetermined mass of gas.

The frame or support structure 10 comprises upper and lower horizontal walls 18 and 19 maintained in parallel spaced relation by four vertical corner posts 21 to which they are secured by suitable screws 22 shown in Figure 2. To facilitate the inclusion of various passages connecting breathing tubes 12 and 13 with bellows 11, the upper wall 18 of the frame is illustrated as formed of two abutting plates or sheets of material. It is to be understood, however, that it may be formed of a single piece of material, preferably an insulating plastic, and that the other elements of the frame may be integral or formed of various interconnected component parts in accordance with economy and design considerations.

Bellows 11 is preferably cylindrical in shape, and is formed with a corrugated side wall 23 and an integral horizontal bottom wall 24. The upper edge of the bellows is mounted in tightly sealed relationship on the underside of upper frame wall 18 by a suitable disc 26 which is itself secured by arcuately spaced screws 27 in a corresponding recess in the underside of the wall. As shown in Figures 2 and 3, the only means of communication with the interior of bellows 11 comprises a downwardly opening port 28 formed in the central portion of wall 18 and communicating with a pair of passages 29 and 31. Passage 29 is illustrated as being relatively small and extends within wall 18 for communication at its end with a fitting 32 adapted to be connected to a suitable source, not shown, of oxygen or other gas. Passage 31 extends within wall 18 to the valve means 16 and there communicates, depending upon the position of the valve, either with a passage 33 (Figure 2) leading to the underside of wall 18 outwardly of the bellows, or with a passage 34 also positioned within wall 18 and which connects to the canister 14. The various passages 28, 31, 33 and 34, as well as breathing tubes 12 and 13, are sufficiently large to permit gas to flow therethrough without objectionable frictional resistance to the end that the breathing of a test subject will be without difficulty.

The valve element 16 controlling flow in passages 31, 33 and 34 comprises a vertically disposed cylinder 36 mounted in a corresponding cylindrical bore in the upper part of frame wall 18. Cylinder 36 has three communicating radial passages 37, 38 and 39 formed in it at ninety-degree angles, there being a solid wall portion 41 opposite passage 38. To provide for the manual rotation of cylinder 36 to its various positions, an upwardly extending shaft 42 is formed integral with the cylinder and has a suitable turning knob 43 mounted at its end. Mounted centrally on shaft 42 above top wall 18 is a cam 44 adapted to actuate a switch 46 (Figures 3 and 5). The relationship between the cam and switch, which will be described in detail subsequently, is such that switch 46

3

is shifted when valve 16 is turned to the test position. Switch 46 is mounted on a retaining ring 47 carried by top wall 18, the ring encircling shaft 42 and overlying valve cylinder 36 to retain the latter against vertical displacement.

The filter canister 14 is illustrated as being rectangular in shape and is suitably mounted in dependent relation relative to upper frame wall 18. A body of filtering material 48 adapted to absorb carbon dioxide, water vapor, etc., is provided in the canister 14. This filter material, which may be soda-lime, assures that gas passing between reservoir 11 and breathing tubes 12 and 13 will be substantially pure oxygen and nitrogen, from which carbon dioxide has been removed. Referring to Figures 2 and 3, the connection between canister 14 and breathing tubes 12 and 13 is seen to comprise passages 49 and 51 in which are mounted, respectively, suitable flutter valves 52 and 53. The flutter valves 52 and 53 may be of conventional construction permitting free gas flow in one direction but effectively blocking the flow in the reverse direction. Flutter valve 52, in passage 49 between exhalation tube 12 and canister 14, is adapted to permit inward flow of air from tube 12 to the canister but to prevent return flow. Flutter valve 53 operates in the reverse manner to permit only outward gas flow to inhalation tube 13.

Referring to Figures 2 and 3, it will be noted that the canister 14 is formed with an outer casing 14a and an inner casing 14b, the latter containing the filter material 48. The four edges of inner casing 14b are disposed to abut the outer casing and the upper frame wall 18, so that no air may pass therearound, and the side walls of inner casing 14b are spaced inwardly from the corresponding outer casing side walls to provide outer and inner chambers 15a and 15b. In addition, a horizontal row of perforations or ports 15c are provided in the upper edge of the outer wall of inner casing 14b, adjacent the passages 49 and 51, and a corresponding row of perforations 15d are formed in the inner wall of casing 14b but at its lower instead of its upper edge. With such an arrangement, the inhalation and exhalation gas will pass upwardly or downwardly for the full height of canister 14 to provide the maximum filtering action. To illustrate, let it be assumed that the subject is inhaling, and that gas will flow from reservoir 11 to chamber 15b between the inner side walls of casings 14a and 14b. The air in chamber 15b will flow downwardly and through perforations 15d, after which it will flow upwardly through the full height of the filter material 48 to outlet perforations 15c. From perforations 15c the air flows laterally through the upper portion of chamber 15a and to passage 51, flutter valve 53, and tube 13 leading to the subject.

In the operation of the elements thus far described, let it be assumed that it is desired to employ the spirometer in connection with an apparatus for determining metabolic rates. When the spirometer is used for this purpose, the face mask connected to tubes 12 and 13 is first positioned on the subject whose metabolic rate is to be determined, and the valve knob 43 is rotated until valve passage 38 is registered with passage 34. A free path is thus completed from passage 34 to the passage 33 leading to the atmosphere, but the passage 31 to the bellows is effectively blocked by the solid portion 41 of the valve cylinder. The subject is then breathing atmospheric air admitted from passage 33 and through valve passages 39 and 38 to canister 14, thence through the respective breathing tubes 12 and 13. In this manner the subject becomes accustomed to breathing through the face mask, tubes and canister, and after a certain time is completely relaxed as is necessary for an accurate metabolic rate determination.

Either before or after the face mask is positioned on the subject, oxygen is admitted into bellows 11 from a small capsule (not shown) containing a standard mass or weight of oxygen at a relatively high pressure. This is accomplished by connecting the capsule to fitting 32 and then causing the oxygen to expand into passage 29, passage 28, and bellows 11. The volume of the bellows then increases, through lowering of bottom bellows wall 24, by an amount equal to the volume of the admitted oxygen at room temperature and pressure. It is then possible to determine, by use of the reference level means 17 and associated circuits to be described subsequently, the exact time when bellows wall 24 returns to its initial level,

4

which means that the bellows volume is the same as it was prior to charging with oxygen and that the oxygen charge has been consumed.

To start the test, after charging the reservoir with oxygen as described, valve knob 43 is manually rotated until valve passages 37 and 39 are registered, respectively, with frame passages 31 and 34, valve portion 41 then blocking the passage 33 to the atmosphere. This is done immediately subsequent to an exhalation and prior to the next inhalation. The next inhalation will therefore draw oxygen from bellows 11 through frame passages 28 and 31, valve passages 37 and 39, frame passage 34, canister 14, flutter valve 53, passage 51, and tube 13 to the face mask. As previously indicated, inhalation through tube 12 is blocked by flutter valve 52. The volume of bellows 11 will then be decreased by an amount equal to the tidal volume of the subject's lungs, normally approximately 500 cc., and lower bellows wall 24 will move upwardly a corresponding amount. The next exhalation will then pass through tube 12, passage 49, flutter valve 52, and canister 14 to bellows 11, the flutter valve 51 preventing exhalation through tube 13. The material 48 in canister 14 effectively absorbs the carbon dioxide, water vapor and other impurities from the exhaled breath. It follows that an amount of oxygen, equal to the amount inhaled minus the amount (normally 10 to 15 cc.) absorbed by the lungs of the subject, will be returned to bellows 11 to cause it to increase in volume through lowering of wall 24.

The lower wall 24 of the bellows thus oscillates up and down with each inhalation and exhalation, and in addition has an overall upward movement caused by absorption of oxygen by the lungs of the subject and consequent decrease of the oxygen in the bellows. As distinguished from previous spirometers which were constructed with the movable bellows wall above the stationary wall, the weight of bellows walls 23 and 24 tends to aid the exhalation portion of the respiration cycle as is highly desirable since exhalation is a passive function. The inhalation phase of the respiratory cycle, which is sustained by the muscles of respiration, is utilized to elevate bellows wall 24 against gravity. It is a feature of the invention that the bellows is formed of very thin rubber, plastic, or other light material, so that it has very small mass which the subject in his breathing must overcome. This is to be distinguished from conventional counterweighted structures in which the transition from inhalation to exhalation may be noticeably disturbing to the subject because of the inertia and friction of the spirometer system.

When the bellows wall 24 returns to its initial level, indicating that the oxygen charge has been consumed, the operator rotates the valve 16 to again cause the subject to breathe atmospheric air. In addition, the elapsed time between starting and stopping of the test is manually or automatically recorded. This time interval, as well as the weight or mass of the oxygen charge, may then be entered into the computation of the subject's metabolic rate.

Proceeding now with a description of the remaining portions of the spirometer, and particularly the reference level means 17 and associated circuits, three cylindrical metal rods 54, 55 and 56 are vertically mounted at 120-degree angles between upper and lower frame walls 18 and 19 exteriorly of bellows wall 23. The rods 54-56 operate to guide suitable electrically conductive bearings 57 which are mounted on ears or lugs 58 formed integral with a guide ring 59. Ring 59, in turn, is mounted on the undersurface of bellows 24 by means of arcuately spaced expandable nipples 61 formed integral with the bellows and extending downwardly through corresponding holes in the guide ring. The bearings 57 are preferably of the relatively frictionless ball bearing type, and completely surround the respective guide rods to effectively prevent any twisting of the bellows. As in the case of the bellows 11, the guide ring 59 and associated parts are extremely light in weight to facilitate the breathing process. The ring 59, for example, is formed of a light plastic which is of the electrically conductive variety to permit it to act as a component of the electric circuits associated with the reference level means.

To form the reference level means 17, guide rod 56 is provided at its upper end with a threaded portion 63 which passes through a tapped electrically conductive bushing 63a in upper frame wall 18 and terminates in an adjustment knob 64. At its lower end, rod 56 is slid-

5

ably inserted in an electrically conductive bushing 66 mounted in a base block 66a, so that rotation of knob 64 operates either to raise or lower the rod depending upon the direction of turning. In this manner an insulating segment or spacer 67, which is provided in rod 56 as best shown in Figure 4, may be vertically adjusted until it registers with the corresponding bearing 57 prior to the admission of any oxygen into the bellows.

Referring to Figure 5, the upper and lower portions of rod 56, separated by insulating element 67, are electrically connected to each other through two pilot or signal lights 68 and 69. For this purpose suitable terminal lugs 66b are mounted on bushings 63a and 66. The portion of the circuit between pilot lights 68 and 69 is then connected to one side of a suitable current source 71, the other side of which is connected to guide rod 55 through a metal bushing 75 (Figure 1) at the lower end. When guide ring 59 and lower bellows wall 24 are below insulating element 67, an electric circuit is completed from source 71 through rod 55, bearing 57 on rod 55, retaining ring 59, bearing 57 on rod 56, the lower portion of rod 56, and pilot light 69 back to current source 71. Conversely, when bellows wall 24 and ring 59 are above the insulating element 67, a similar circuit is completed through the upper portion of rod 56 to energize light 68. The lights 68 and 69 therefore indicate whether the bellows wall 24 is below or above insulating element 67, and in addition show the operator when the bellows wall is registered with the insulating element since neither of the lights is on at this time.

In the operation of the reference level means, the reference knob 64 is turned, prior to the admission of any oxygen into the bellows, until insulating segment 67 registers with the corresponding bearing 57. This position is readily determined since neither of the signal lights 68 and 69 is then lit. Oxygen is then admitted and the test commenced as previously described, the bellows and guide ring 59 then expanding downwardly to cause lighting of pilot light 69. With each succeeding inhalation and exhalation of oxygen, the bellows wall 24 will move upwardly and downwardly as previously described, but this motion will not be sufficient to elevate wall 24 to the level of spacer 67. However, as the amount of oxygen in bellows 11 is consumed, guide ring 59 will first register with insulating element 67 on each upswing of the lower bellows wall to cause flashing or blinking of pilot light 69. As the oxygen supply is further diminished, the lights 68 and 69 will alternately blink or flash as guide ring 59 alternately passes above and below the insulating element. The end of the test arrives at the instant when signal 69 no longer lights at the exhalation or downswing of bellows wall 24 and guide ring 59, it then being known that the entire charge of oxygen has been absorbed by the lungs of the subject. At this end point of the test, pilot 68 will be lighted continuously or else both pilots 68 and 69 will be extinguished.

Through observance of the pilot lights 68 and 69 in the manner above described, the amount of time required by the test subject to consume the standard mass of oxygen, that is to say the elapsed time between turning of valve 16 to the "test" position and the instant when signal light 69 no longer lights on the downswing of bottom bellows wall 24, may be readily determined. The present invention further provides novel relay means for automatically measuring and recording the test time, and these means will next be described.

Referring to Figure 5, these means comprise an A. C. relay indicated generally at 76, a D. C. relay indicated generally at 77, and time delay means 78 associated with relay 77 and adapted to prevent its operation until the lower spirometer wall 24 is at or above insulating segment 67 for a period of time longer than a normal breathing cycle. The relays 76 and 77 are associated not only with the electric circuits comprising rods 55 and 56 but with the switch 46 which is operated by cam 44 on valve 16 as previously indicated. The turning of valve knob 43 to the "test" position is utilized, as will be described, to start the operation of timer or indicator elements, while the associated D. C. relay 77 and time delay means 78 are adapted to stop the timer or indicator means at the end of the test.

More specifically, the relay 76 comprises a coil 80 connected in parallel with pilot 69, the coil being adapted when energized to attract its armature 81 and thus close

6

normally open contact 82. Relay 77 comprises a coil 83 adapted to attract an armature 84 to close normally open contact 86, the opening of contact 86 upon deenergization of coil 83 being delayed by the time delay means 78 which are connected in shunt with coil 83 and comprise a capacitor 87 in series with a resistor 88. The switch 46 comprises a single-throw arm 90 adapted to engage the contact 91, and a double-throw arm 92 movable to engage either of contacts 93 or 94. Arms 90 and 92 are simultaneously operated by cam 44 on the shaft 42 of valve 16. The relationship between these elements is such that when the valve 16 is in other than the "test" position the switch 46 is in the position illustrated, that is to say with arm 90 out of engagement with contact 91 and with arm 92 in engagement with contact 93. When, however, the valve 16 is turned to the "test" position, with valve passage 39 registering with passage 34, and with valve passage 37 registering with passage 31, the arms 90 and 92 are respectively shifted into engagement with contacts 91 and 94.

The electrical circuits and power sources associated with the above elements include a D. C. power source 96 connected between arm 90 of switch 46 and contact 82 of relay 76. The energization of coil 83 is thus controlled both by relay 76 and by switch 46, since coil 83 is connected between armature 81 and contact 91. A second power source 97, which is preferably A. C. and may be the same as source 71, is connected across switch arm 92 and a circuit point 98 between two pilots 99 and 100, the pilot being series connected across the switch contacts 93 and 94. To complete the illustrated circuits, a timer 101 and cycling pilot 103 are parallel connected across a power source 104 in series with contact 86 and the associated arm 84, so that the energization of timer 101 and pilot 103 is controlled by the relay 77.

In the specific values of the components of the circuits of Figure 5, the power sources 71 and 97 may be five volts A. C. from a transformer, the power source 95 may be thirty-three volts D. C., and source 104 one hundred ten volts A. C. The resistor 88 of time delay means 78 may be, for example, 6500 ohms, and the capacitor 87 may be a sixty microfarad dry electrolytic type. The D. C. relay 77 is adapted to pick up at thirty-three volts and drop out at nine volts, but the drop out is delayed for a period of several seconds due to the stored charge in capacitor 87 acting through resistor 88. All of the pilots 68, 69, 99, and 101 may be of the filament type, and the cycling pilot 103 may be neon or argon. The timer 101 may be any standard timer, for example incorporating a synchronous motor, and is adapted to be reset at the end of each test. Timer 101 is preferably of the self-starting type, and may be eliminated if desired since cycling pilot 103 will visually indicate the duration of the test period.

In the operation of the spirometer together with the reference means and circuits of Figure 5, let it be assumed that the switches are initially in the positions shown in Figure 5 and that oxygen has been admitted to the bellows 11. Wall 24 is then depressed a substantial distance beneath insulating segment 67, the elevation of the latter having been adjusted, as previously described, by rotating the knob 64. The valve 16 is then in the position at which the subject is breathing room air through the face mask and tubes 13 and 12, and a circuit is completed from source 97 and through arm 92 and contact 93 to pilot 99. The lighted condition of pilot 99 therefore indicates to the operator that the valve 16 is not in the "test" position at which the subject is breathing oxygen from reservoir 11. The lowering of bellows wall 24, due to admission of oxygen into the bellows, completes a circuit from power source 71 to light the pilot 69, so that relay coil 80 in parallel therewith will also be energized. The energized coil 80 will then attract arm 81 and close contact 82 of relay 76, and a circuit from power source 96 will be set up for energization of coil 83 of relay 77 when valve 16 is turned to the "test" position. When valve 16 is thus turned, the cam 44 operates to shift arms 90 and 92 of switch 46 into engagement with contacts 91 and 94, this action occurring immediately subsequent to an exhalation and prior to the next inhalation as previously indicated. When arm 90 closes to contact 91 the circuit from D. C. source 96 to relay 77 is completed, so that arm 84 immediately closes with contact 86 to effect energiza-

7

tion of timer 101 and cycling pilot 103 by power source 104. The closing of switch arm 92 to contact 94 effects deenergization of pilot light 99 and energization of pilot 101, the latter pilot then indicating that the subject is breathing oxygen.

The test will then continue and the subject will consume the oxygen from bellows 11 as previously described, until the periodic blinking of pilot 69, and of pilot 68, will indicate that the end of the test is approaching. As the bottom bellows wall 24 and ring 59 come into registry with insulating segment 67 to effect the periodic blinking of pilot 69, the coil 80 of relay 76 will be momentarily de-energized and its contacts will open, but this will not effect opening of the contacts of relay 77 since the time delay means 78 prevent this action as previously indicated. However, as soon as the lower bellows wall 24 and ring 59 no longer come into registry with the lower portion of rod 56, so that pilot 69 and relay coil 80 are no longer energized upon the downswing of the lower bellows wall, the capacitor 87 will lose its charge and no longer maintain the energization of coil 83. Arm 84 of relay 77 will then be permitted to return to its normal position and its contact 86 will be opened to effect de-energization of cycling pilot 103 and timer 101. The duration of the test is thus accurately timed by the timer 101, and visually indicated by cycling pilot 103 so that the operator may turn the valve 16 to the room air position which will be indicated by lighting of pilot 99. The test is thus concluded and the interval of oxygen consumption accurately recorded.

While the particular apparatus herein shown and described in detail is fully capable of attaining the objects and providing the advantages hereinbefore stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as defined in the appended claims.

I claim:

1. A breathing reservoir, comprising a support, a bellows mounted on said support in dependent relation relative thereto, said bellows having a bottom portion adapted to move upwardly and downwardly to vary the volume of the chamber defined by said bellows, means to charge said bellows with gas, and means to conduct said gas in both directions between said bellows and a subject, said arrangement utilizing the effect of gravity on said bottom bellows portion to aid in the exhalation of gas by said subject into said bellows.

2. The breathing reservoir as claimed in claim 1, wherein said bellows is formed of an extremely light, flexible material to minimize the inertia tending to disturb the transition between the exhalation and inhalation portions of the respiratory cycle of said subject.

3. A breathing reservoir for use with apparatus for determining the metabolic rate of a subject, which comprises a frame having a horizontal wall, a bellows mounted on said horizontal frame wall and adapted to be charged with oxygen to be consumed by said subject, a canister mounted on said frame and containing material adapted to absorb water vapor and carbon dioxide from the breath of said subject, inhalation and exhalation tubes communicating with said canister and adapted to be connected to a face mask on said subject, one-way valve means to prevent inhalation by said subject through said exhalation tube and exhalation through said inhalation tube, a valve mounted in said horizontal frame wall, and separate passage means in said frame wall between said valve and said bellows, said canister, and the atmosphere; said valve being adapted when in one position to connect said canister and the atmosphere for breathing of atmospheric air by said subject, and when in another position to connect said canister and bellows for breathing of oxygen by said subject.

4. The invention as claimed in claim 3, wherein said horizontal frame wall is the upper of two vertically spaced parallel walls, and said bellows is disposed between said walls in dependent relation relative to said upper wall.

5. The invention as claimed in claim 3, wherein said canister comprises an inner casing containing said absorbent material, and an outer casing enclosing said inner casing, said outer and inner casings being formed with chamber and port means adapted to effect flow of gas

8

into contact with substantially all of said absorbent material.

6. In an apparatus for determining the length of time required by a subject to consume a predetermined charge of gas from an expansible and contractible breathing reservoir, a pair of electrically conductive members mounted along the path of expansion and contraction of said reservoir, said electrically conductive members being spaced from each other to form an insulating gap, means to adjust the locations of said members to register said gap with the initial position of said reservoir prior to the admission of said charge of gas, and electric circuit means connected to said electrically conductive members to indicate the return of said reservoir to said initial position after consumption of said charge of gas by said subject.

7. In an apparatus for determining the length of time required by a subject to consume a predetermined charge of gas, a breathing reservoir adapted to contain said gas charge and having an end wall movable in a direction increasing the volume of said reservoir upon admission of said charge of gas and in the reverse direction decreasing the reservoir volume as the charge is absorbed by the lungs of said subject, reference means disposed along the path of movement of said end wall, said reference means being formed with two electrically conductive components separated by an insulating spacer, electric contact means mounted on said end wall to engage said reference means; a first electric circuit comprising said contact means, one of said conductive reference components, and a first signal; a second electric circuit comprising said contact means, the other of said conductive reference components, and a second signal; and means to adjust said reference means to register said insulating spacer with said contact means prior to the charging of said reservoir with gas, whereby one of said signals is operated upon charging of said reservoir and the end of the test is indicated by failure of said one signal to operate for a period longer than the breathing cycle of said subject.

8. A breathing reservoir, comprising a supporting frame having a horizontal upper wall, a cylindrical bellows formed of flexible material and mounted on said upper frame wall in dependent relation relative thereto, said bellows having a horizontal bottom wall spaced a substantial distance beneath said upper frame wall and adapted to move upwardly and downwardly to vary the volume of the chamber defined by said bellows, valve and passage means to admit a predetermined charge of oxygen into said bellows and to connect said bellows to breathing tube means leading to a subject whose metabolic rate is to be determined, first and second electrically conductive vertical guide rods provided on said frame adjacent said bellows, said first guide rod being formed with an insulating spacer separating its upper and lower portions, first and second electrically conductive bearings mounted on said bottom wall of said bellows for travel along the respective guide rods, a pair of pilot indicator circuits both including said second guide rod and both of said bearings, one of said circuits including said upper portion of said first guide rod and operating a signal when said bottom bellows wall is above said insulating spacer, the other of said circuits including said lower portion of said first guide rod and operating a second signal when said bottom bellows wall is below said insulating spacer, and means vertically to adjust said first guide rod prior to the charging of said reservoir until said insulating spacer registers with said first bearing and neither of said signals is operated.

9. The invention as claimed in claim 8, wherein a guide ring is provided peripherally of said bottom bellows wall to support said bearings, said guide ring being formed of electrically conductive plastic to electrically connect said first and second bearings.

10. A breathing reservoir apparatus, comprising a bellows adapted to be charged with gas for consumption by a subject, conduit means leading from said bellows for connection with said subject, valve means in said conduit means and adapted when in one position to establish communication between said subject and bellows and when in a second position to establish communication between said subject and the atmosphere, first switch means associated with said valve means for operation during shifting thereof between said one position and said second position, second switch means associated

with said bellows to indicate the return thereof to an initial unexpanded condition after consumption of said gas charge by said subject, and electric circuit means of the time delay type associating said first switch means, said second switch means, and a timing means, said elements being so constructed and arranged that said timing means records the elapsed time between shifting of said valve means to said one position and subsequent return of said bellows to said unexpanded condition.

11. The invention as claimed in claim 10, wherein said electric circuit means includes a time delay relay to prevent the ending of the recorded interval until said bellows is in said unexpanded condition for a period of time longer than a normal respiratory cycle.

12. An apparatus for determining the length of time required by a test subject to consume a predetermined charge of oxygen, which comprises a breathing reservoir adapted to contain said charge and having an end portion adapted to move from an initial inner position to an outer position upon admission of said charge, conduit means leading from said reservoir for connection with said subject, valve means in said conduit means and adapted when in one position to establish communication between said subject and the atmosphere and when in a second position to establish communication between said subject and said reservoir, a switch adapted to be closed upon movement of said valve means from said one position to said second position, an electrical contact element provided on said end portion of said reservoir, an electrically conductive reference element disposed to be engaged by said contact element when said end portion is between said initial and outer positions,

said contact element moving out of engagement with said reference element upon movement of said end portion to the side of said initial position remote from said outer position, a normally open relay, and electric circuit means associating said switch, contact element, reference element, and the coil of said relay to effect energization of said coil and consequent closing of the contacts of said relay when said contact element and reference element are in engagement and said valve means is in said second position.

13. The invention as claimed in claim 12, wherein said relay contacts are adapted when in closed condition to effect running of a timer, and means are provided to prevent opening of said contacts and consequent stopping of said timer until said contact element is out of engagement with said reference element for a period of time longer than a normal breathing cycle.

14. The invention as claimed in claim 12, wherein means are provided to adjust said reference element in accordance with the position of said end portion of said reservoir prior to the admission of said charge.

15. The invention as claimed in claim 12, wherein said reservoir is dependent from the upper wall of a frame, said upper wall being adapted to contain a portion of said conduit means and to provide a mounting for said valve means and switch.

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