BREATHING INDICATOR AND VENTILATOR

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ABSTRACT

The device indicates the instantaneous volume of gases being breathed by a medical patient, and provides a means for "ventilating" the patient; i.e. causing the patient to breathe artificially. A pair of bellows is provided. The first bellows is pneumatically connected to the patient's respiratory system. The first bellows expands when the patient exhales in a closed system, contracts when the patient inhales or gases are forced into the patient's lungs. The second bellows is mechanically coupled to but pneumatically isolated from the first bellows. The second bellows preferably is connected to a manual resuscitation squeeze-bag which can be used to expand the second bellows and thereby compress the first bellows and force gases into the patient's lungs, thus ventilating the patient. An automatic non-rebreathing valve is used to ensure independent operation of the second bellows and the bag. The bellows are mounted so as to expand and contract along an arcuate path. An indicator indicates the excursions of the first bellows, and thus indicates the instantaneous volume of flow. Movement of the bellows along an arcuate path provides mechanical amplification of the movement of the indicator, thus giving improved resolution and accuracy. A disposable liner is provided for the first bellows so that the bellows itself will remain isolated from the gases breathed by the patient, and will be relatively easy to keep clean. Preferably, the second bellows has a cross-sectional area considerably smaller than that of the first, so that only a relatively small flow of gas from the squeeze-bag is effective to force a substantially greater volume of gas into the patient's lungs. Thus, the double-bellows arrangement serves as an amplifier for the squeeze-bag. In one embodiment of the invention, the movement of the bellows is in a vertical plane, and in another embodiment the movement is in a horizontal plane. An accumulator is used to indicate the total flow of gas breathed by the patient, and a timing device is used to indicate the "minute volume" of ventilation, i.e., the flow rate. An especially advantageous bellows construction is used.

15 Claims, 9 Drawing Figures
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BREATHING INDICATOR AND VENTILATOR

This invention relates to breathing indicator devices and ventilator systems for assisting medical patients in breathing.

Prior breathing indicators, such as that shown in my U.S. Pat. No. 3,256,878, are in need of improvement. One of the problems with such prior devices is that the bellows which expands and contracts in order to indicate the breathing of the patient must be cleaned and sterilized before it can be used by a new patient, and the bellows is difficult to clean or sterilize. Another problem is that the indication of volume of breathing or ventilation is not given with sufficient resolution. Also, means for indicating the total flow and flow rate of gas breathed by the patient is needed. Also needed is means for pre-setting the inflation volume for each breath.

Accordingly, it is an object of this invention to provide a breathing indicator device and ventilator in which it is relatively easy to maintain sterility, which indicates the instantaneous and total volume of breathing of the patient with a relatively high degree of resolution, and which is relatively easy to operate manually or by a mechanical automatic cycling ventilator. Also, it is an object of the invention to provide such a device in which the inflation volume can be pre-set and maintained without the continuous attention of an operator.

In accordance with the present invention, the foregoing objects are met by the provision of a breathing indicator system in which the bellows which indicates the breathing of the patient is provided with a disposable plastic liner which is easy to change so that sterility can be maintained from one patient to the next without the necessity of cleaning or sterilization of the bellows. Preferably, two bellows are used instead of the one previously used. The second bellows is mechanically coupled to the first so as to elongate when the first bellows contracts, and vice-versa. The bellows preferably move along an arcuate path. The second bellows is operated either by an automatic breathing machine or by a manual squeeze-bag. The second bellows preferably has a cross-sectional area which is relatively smaller than the cross-sectional area of the first bellows. The result is that the movement of gas by means of the squeeze-bag is greatly amplified, and the patient's lungs can be ventilated more easily. Moreover, the volume differential between the first and second bellows reduces the energy losses of gas compression and elastic expansion of the second bellows. The use of two bellows which are pneumatically isolated but mechanically coupled avoids the need for an air-tight housing with its inherent large gas volume, thus simplifying and reducing the cost of the housing for the indicator unit. An indicator moves with the bellows. The arcuate path of movement gives amplification of the indicator movement, thus improving resolution of the indicator reading. A non-rebreathing valve is used to facilitate the operation of the device as a ventilator with a manual resuscitation type squeeze-bag. An adjustable stop is used to pre-set the inflation volume. The double-bellows construction of the device makes it possible to use a relatively simple stop structure. Further, an accumulator device and timer device are provided to indicate the total volume for about 5 minutes, i.e. the flow rate of the gas breathed by or inflated into the patient.

The foregoing and other objects and advantages of the invention will be explained in or apparent from the following description and drawings.

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IN THE DRAWINGS

FIG. 1 is a perspective, partially cut-away view of a breathing indicator device constructed in accordance with the present invention:

FIG. 2 is a cross-sectional view taken along line 2—2 of FIG. 1, and includes the portion of the breathing system omitted from FIG. 1;

FIG. 3 is a cross-sectional view of a portion of one of the bellows of the device shown in FIGS. 1 and 2;

FIGS. 4 and 7 are perspective views of further embodiments of the invention;

FIG. 8 is an elevation view of a component for use with the system of FIG. 7; and

FIG. 9 is a schematic view of a component of FIGS. 3, 4 and 7.

FIG. 1 shows the breathing indicator device 10 of the present invention. The device includes a housing with a bottom wall 10, side walls 12 and 14, a rear wall 18 and a cover 16 (FIG. 2) which is fastened to the rear wall 18 by means of a hinge 62. The cover 16 is omitted from FIG. 1 in order to show more clearly some of the internal components of the device 10. The walls preferably are made of a transparent plastic material such as "Lucite". A transparent front wall also is provided.

Referring now to FIG. 2, mounted inside the housing is a pair of bellows 20 and 22. The first bellows 20 is a breathing bellows which accepts and releases gases breathed in and out by the patient. The second ("power") bellows 22 drives the breathing bellows during ventilation.

In accordance with one aspect of the invention, the breathing bellows 20 contains a flexible thin-wall plastic bag 30 which is secured to the inner end of a tube 32 which passes through the wall of the housing and is secured in an opening in a hinged door 34. The tube 32 leads to a Y-shaped check-valve unit 42 of conventional construction. Connected to the check-valve unit 42 are flexible tubes 44 and 46. Tube 44 leads to a carbon dioxide absorber 48. Another flexible tube 47 leads the absorber 48 to one branch of a second Y-shaped check-valve unit 50. The other tube 46 leads to the other branch of the unit 50. At the outlet of the unit 50 is a tracheal tube 52 which conducts gases to and from the trachea of the patient. Alternatively, a face mask such as is shown in my above-mentioned patent can be used instead of the tracheal tube 52.

As it is well known in the prior art, each of the check-valve units 42 and 50 has a pair of check-valves which direct the flow of gases in a closed circuit path indicated by the arrows next to the flexible tubes 44, 46 and 47. That is, when the patient inhales, or gas is forced into his lungs during ventilation, the check-valves allow the gas to flow through the tube 46 but not through the tubes 44 or 47. Natural inhalation by the patient causes the bag 30 to collapse, and the slight resilient bias of the bellows causes the breathing bellows 20 to contract and the driving bellows 22 to expand. When the patient exhales, the check-valves reverse their open or closed conditions, and the gas flows through the tube 47 to the carbon dioxide absorber 48 where carbon dioxide is removed from the gases exhaled by the patient. The gas then goes through tube 44 and the unit 42, and into the plastic bag 30. This ex-

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pands the plastic bag and the bellows 20 and folds up the driving bellows 22.

Anesthetic gas and/or oxygen is supplied to the gas flow conduit through a tube 58 from a source 54. Its flow is metered by means of a manually operated valve 56.

A relief valve 60 is provided to vent the gas to the atmosphere if the pressure in the system rises too high.

Ventilation is accomplished by means of manually operated resuscitation-type squeeze-bag 24 whose outlet communicates with the interior of the driving bellows 22 through an automatic non-breathing valve 26. When the bag 24 is squeezed as shown in FIG. 2, the driving bellows is expanded and collapses the breathing bellows 20 and the bag 30, forcing air into the patient's lungs. When the bag 24 is released, the bag 24 re-fills itself through a check-valve 27, and the bellows 22 exhausts its gases to the atmosphere through the valve 26.

The structure of the bag 24 and valves 26 and 27 is shown schematically in FIG. 9. The bag 24 is resilient so that it tends to return to its full or expanded shape as shown in FIGS. 1 and 9. When it is squeezed, a flexible rubber flap 29 which normally covers the bag outlet, is forced off of that seat and against the end 35 of an exhaust conduit 33. The valve 26 includes a housing 31 around the end 35 of tube 33 and the flap 29. The housing 31 has an outlet 37 which is connected to the interior of the driving bellows 22, as it is shown in FIG. 2. Air squeezed out of the bag flows through the outlet 37 and into the bellows, while the vent 33 is closed.

When the bag 24 is released, gas enters the bag from the atmosphere through the check-valve 27 while the flap 29 is seated over the outlet opening of the bag. At the same time, the exhalation by the patient compresses the bellows 22. The air forced out of the bellows 22 is vented to the atmosphere through the vent 33, which now is open. This arrangement ensures that a full charge of air will be present in the bag 24 for each ventilation stroke, and also ensures that the patient will not have to expend extra effort which might be required to fill the bag while he is exhaling if the valve 26 were not used.

Conventional automatic non-rebreathing valves such as the "Ambu Valve," "Puritan-Bennett," "Bird," "Fink" and "Sierra" valves, also can be used as the valve 26. These valves also will prevent interaction between the bellows 22 and the squeeze-bag between lung inflations.

If desired, of course, an automatic positive-pressure ventilation machine can be used in place of the manual squeeze-bag.

The excitations of the breathing bellows 20 are indicated by a "septum" 28 which is attached to the right end of the bellows 20 and the left end of the bellows 22. The septum 28 is pivoted to the bottom wall 10 of the housing by means of a hinge 64. The upper end 68 of the septum serves as a pointer. It moves just behind a transparent scale 66 where the volume of gas flow is indicated in liters. The bellows 20 moves in an arcurate path. Accordingly, the scale 66 is arcurate. This arrangement provides improved resolution of reading of the scale 66 because the distance moved by the pointer 68 is greater than that of the bellows.

The hinged door 34 on the left side wall 14 of the housing greatly facilitates the maintenance of sanitary conditions in the breathing indicator unit. The door 34 is hinged to the wall 14 along its bottom edge by means of a hinge 38, and is held tightly in place by means of three manual latches 36. As is shown in FIG. 2, a continuous gasket 40 is provided to provide an air-tight seal between the door 34 and the wall 14. The left end of the breathing bellows 20 is secured to the side wall 14 by adhesives or the like so that the seal between the bellows 20 and the wall 14 also is air-tight.

The disposable liner-bag 30 preferably is made of polyethylene because that material does not absorb any substantial amount of ethylene oxide gas (used for sterilization) or halothanes used as anesthetics. The end of the bag 30 has an opening which is slightly smaller than the external diameter of the inner end of tube 32 so that when the bag opening is fitted over the tube an air-tight seal is formed by the natural resiliency of the bag material.

The construction of the bellows 22 is substantially the same as that of the bellows 20. However, the cross-sectional area of the bellows 22 is substantially less than that of the breathing bellows 20. This arrangement provides a substantial amount of mechanical leverage for the person operating the squeeze-bag 24. Depending upon the relative cross-sectional areas of the bellows 20 and 22, squeezing a given amount of gases out of the bag 24 into the bellows 22 extends the bellows 22 by a greater distance than it would the larger bellows 20. Thus, a greater volume of gas is expelled from the bellows 20 to the patient than otherwise would be possible by means of the same manipulation of the bag 24. This mechanical advantage makes the ventilation of a patient's lungs substantially easier than in the past. In particular, it is believed that the female anesthetist with small hands is able to accomplish manual compression of the bag with less hand fatigue.

The volume scale 66 is formed on one edge of an arcurate canopy 70 with a centrally located slot 80. The pointer 68 extends upwardly from the septum 28 through the slot 80. An adjustable stop member 72 is provided to prevent the pointer 68 from going beyond a certain desired point. This has the purpose of setting the volume of ventilation of the patient's lungs. A thumb-screw 74 is provided as shown in FIG. 2 to adjust the position of the stop member 72.

BELLOWS CONSTRUCTION

The bellows preferably is constructed as shown in FIGS. 3, 5 and 6. A strong but relatively thin flexible sheet 76 of polyvinyl chloride ("PVC") is reinforced with trapezoidal PVC plates 78 which are substantially thicker and more rigid than the sheet 76. The plates 78 are fastened to the sheet 76 by means of an adhesive.

The plates 78 are arranged in the double-reversing pattern shown in FIG. 6. The pattern is called "double reversing" because the alignment of the alternate plates reverses both in the Y direction and in the X direction shown in FIG. 6. The assembly then is folded at lines 79, 81 and 83, and the lower edge 77 of the sheet 76 is folded over the upper edge and attached by means of an adhesive, thus forming the tubular construction shown in FIG. 5.

Polynyl chloride is a preferred material for the bellows because it is relatively easy to work with in fabrication processes and it can be fabricated with readily available adhesives or heat-sealed. Although polyvinyl chloride readily absorbs halothane or ethylene oxide and normally would require time-consuming and expensive washing procedures in order to remove the ab-
sorbed gases, this is not a disadvantage in the present invention because the polyethylene bag 30 is disposable and does not need washing. Furthermore, it would not need purging because polyethylene does not absorb halothane or ethylene oxide and thus does not require the expensive soaking procedures necessary with polyvinyl chloride.

ALTERNATIVE EMBODIMENTS

FIG. 4 shows a simplified version of the device shown in FIGS. 1 and 2. The parts which are the same in FIGS. 1, 2 and 4 have the same reference numerals.

The FIG. 4 device has no removable bag liner 30 for the bellows 20. Instead, the bellows is made easily removable for washing. The bellows 20 can be made of polyethylene instead of PVC in order to make it easier to clean and sterilize. The tube 32 communicates directly with the interior of bellows 20 through a tube 88.

Two additional walls 84 and 86 from a 90° angle with one another. The ends of the bellows are attached to these walls. The hinge 64 is at the junction of the walls 84 and 86.

The scale 96 is on the top cover 16 of the housing, and not on the curved front panel 90. Also, a slot 92 is made in the top cover 16 instead of the curved panel 70 with its slot 80 as in FIG. 1. A second immovable stop 94, in addition to the movable stop 72, is provided for the pointer 68 to limit the ventilation volume per stroke. The stops 72 and 94 are adjacent the slot 92.

The breathing indicator and ventilator shown in FIG. 7 is the same as that of FIGS. 1 and 6 except that the bellows move in a horizontal plane rather than a vertical plane. The bellows are secured to plates 98, 99 and 100, which are supported on a base plate 102. An adjustable stop 114 is securable at a desired position in an arcuate slot 112 to set the volume per ventilation stroke.

An accumulator mechanism 105 is provided to accumulate and indicate the total flow of gases during breathing. The accumulator includes a toothed wheel 106, and a double pawl 108 mounted on a base 110 attached to the septum 28. The ratchet and pawl arrangement thus formed causes the wheel 106 to be driven in the direction of arrow 107 around a pivot 104 which is co-axial with the hinge 64. The distance traveled by the wheel 106 during each expiratory gas movement is directly proportional to the volume of the breath. Thus, the relative position of the wheel 106 indicates the total volume of flow over a period of time. The double-pawl structure 108 increases the resolution possible in the use of the accumulator.

FIG. 8 shows a stop clock or timer 116 which is calibrated to give the minute volume of flow of gas from the patient. The clock is started by means of a control 120 and is stopped when the wheel 106 completes one revolution. The rate in liters per minute is indicated by the pointer 118.

In addition to the alternative embodiments mentioned above, it is possible to utilize the invention in other ways. For example, if it is desirable to use only the breathing bellows 20 and eliminate the driving bellows 22, this can be done by making the housing air-tight, such as by using an air-tight front cover 23, which is shown partially in FIG. 1. Then the gas from the squeeze-bag 24 or the automatic breathing system enters the housing and, by changing the pressure in the housing, causes the bellows 20 to contract. The bellows 22 are shown in dashed outline in FIG. 2 to indicate that they have been removed to form this embodiment of the invention.

In another alternative embodiment, the breathing indicator unit 10 can be made to provide a visual recording of its output in the following manner: Referring to FIG. 1, a marking device such as a pen 69 can be attached to the pointer 68 of FIGS. 1 and 2. Graph paper 71 formed into an arc can be made to move in a direction 73 perpendicular to the centerline of the slot 80 in a plane such that the excursions of the pen 69 leave a trace on the paper. The graph paper 71 and pen 69 are shown in dashed outline to indicate this alternative embodiment.

It should be understood that the closed breathing circuit or circular breathing circuit shown in FIG. 2 is not the only type of circuit with which the invention can be used. It is possible to use a non-rebreathing circuit in which none of the gas exhaled by the patient is breathed again, or a partial rebreathing circuit in which part of the gases exhaled by the patient are exhausted and part are rebreathed.

The above description of the invention is intended to be illustrative and not limiting. Various changes or modifications in the embodiments described may occur to those skilled in the art and these can be made without departing from the spirit or scope of the invention. For example, when the invention is used in a ventilator, resiliency of the bellows is not required to collapse the bellows 20 because the ventilation pressure will do the job automatically. However, it may be desirable to provide a resilient bias in the bellows or a spring or the like (not shown) to assist the patient in returning the bellows 20 and 22 during exhalation. Also, the angles of the bellows can be adjusted and/or guides can be used to prevent bowing outwardly by the bellows. The adjustment can be accomplished, for example, by means of wedges such as wedge 122 in FIG. 7, or by angular adjustment of the mounting plate 99. Guides (not shown) can be positioned, for example, between the slot 112 and the bellows 22 in FIG. 7.

We claim:

1. A breathing responsive device comprising a first bellows, a first conduit means for conducting a first quantity of gas between said first bellows and a patient, a second bellows, mounting means for mounting said first and second bellows in mechanically coupled relationship to one another, said second bellows being pneumatically isolated from said first bellows, second conduit means for conducting a second quantity of gas to said second bellows, and indicating means associated with said first bellows for indicating the relative extent thereof.

2. A device as in claim 1 in which said second bellows has a cross-sectional area which is different from that of said first bellows by a predetermined amount.

3. A device as in claim 1 in which said bellows comprise a flexible air-tight outer sleeve with relatively stiff slats forming the walls of the folds in said bellows.

4. A device as in claim 1 including a ventilator connected to said second conduit.

5. A device as in claim 1 in which said indicating means comprises a transverse projection from the end of said first bellows to which said second bellows is attached.
6. A device as in claim 1 in which said first and second bellows extend and contract in a generally horizontal direction along a generally arcuate path.

7. A device as in claim 4 in which said ventilator comprises a resilient squeeze-bag and a non-rebreathing valve interconnecting the outlet of said squeeze-bag with said second conduit.

8. A device as in claim 1 including accumulator means connected to said indicating means to accumulate the movements in one direction by said first bellows.

9. A device as in claim 8 in which said accumulator means includes a wheel with ratchet teeth on its periphery, a pawl device mounted on said indicator means to move therewith and engage said ratchet teeth to drive said wheel.

10. A device as in claim 1 including a removable flexible liner held within said first bellows.

11. A device as in claim 10 in which said first bellows is made of a material which is relatively absorptive to anesthetic gases, and said liner is made of a material which is relatively non-absorptive to anesthetic gases.

12. A device as in claim 11 in which said first bellows comprise a flexible air-tight outer sleeve with relatively stiff slats forming the walls of the folds in said bellows, said liner being made of polyethylene, and said sleeve being made of polyvinyl chloride.

13. A breathing-responsive ventilator device comprising a bellows, means for connecting the interior of said bellows with the breathing tract of a patient, a ventilator pump, means for communicating the positive pressure of said pump to the exterior of said bellows to compress said bellows, said communicating means including a non-rebreathing valve connected to vent gas from said communicating means when said patient exhales said non-rebreathing valve including a housing defining a vent, an outlet communicating with the exterior of said bellows, an inlet communicating with said pump and valve means for closing said inlet and opening said vent upon the application of negative pressure between said inlet and outlet, and for opening said inlet and closing said vent upon the application of positive pressure between said inlet and outlet, and indicating means associated with said bellows for indicating the relative extent thereof.

14. A device as in claim 13 in which said ventilator pump comprises a manual squeeze-bag with a check-valve for permitting re-filling of the bag.

15. In a breathing-responsive device, a bellows and means for connecting said bellows to the breathing tract of a medical patient, said bellows including a thin-wall plastic tube with trapezoidal slats on the tube surface, said slats being arranged in four rows and forming a double-reversing pattern, with folds between adjacent rows.