United States Patent [19]

Tysk et al.

[11] **3,875,626**

[45] **Apr. 8, 1975**

[54] **DEVICE FOR MEASURING THE TIDAL GAS VOLUME IN A LUNG VENTILATOR**

[75] Inventors: **Jan Tysk**, Ekero; **Goran Sjoberg**, Kungsangen; **Sven Olofsson**, Skalby, all of Sweden

[73] Assignee: **Jungner Instrument AB**, Solna, Sweden

[22] Filed: **Dec. 11, 1973**

[21] Appl. No.: **423,789**

[30] **Foreign Application Priority Data**

Dec. 12, 1972 Sweden 16188/72

[52] **U.S. Cl.** **128/208**; 73/223

[51] **Int. Cl.** **A61b 5/08**

[58] **Field of Search** 128/2.08, 2.07; 73/23, 73/223

[56] **References Cited**

UNITED STATES PATENTS

3,467,078	9/1969	Bird	128/2.08
3,659,590	5/1972	Jones	128/2.08
3,718,044	2/1973	Joyce	73/223

Primary Examiner—Richard A. Gaudet
Assistant Examiner—G. F. Dunne
Attorney, Agent, or Firm—Waters, Roditi, Schwartz & Nissen

[57] **ABSTRACT**

A device in a lung ventilator for measuring the tidal volume for exhaled gas volume, comprising a rigid container divided in two separate compartments by a flexible, substantially freely movable, internal partition wall so that the sum of the volumes of the two compartments is always constant and independent of the position of the partition wall. One compartment is connected to a conduit leading to the respiratory ways of the patient during the exhalation phase of the ventilation cycle of the ventilator so as to receive the gas being exhaled by the patient and to the ambient atmosphere during the inhalation phase of the ventilation cycle. The other compartment in the container is connected to a device for injecting a predetermined constant gas flow into this other compartment. The injection of this constant gas flow is started at the end of the exhalation phase of the ventilator, when the communication between the first compartment in the container and the conduit leading to the respiratory ways of the patient is interrupted, and is automatically interrupted when said first compartment has attained its smallest possible volume, that is when it has been emptied of all exhaled gas. The device for injecting the constant gas flow in the second compartment of the container is preferably controlled from a pressure transducer sensing the gas pressure in said second compartment. The duration of the constant gas flow injected in the second compartment of the container is measured; this duration being directly proportional to the gas volume exhaled by the patient during the preceding exhalation phase.

2 Claims, 4 Drawing Figures

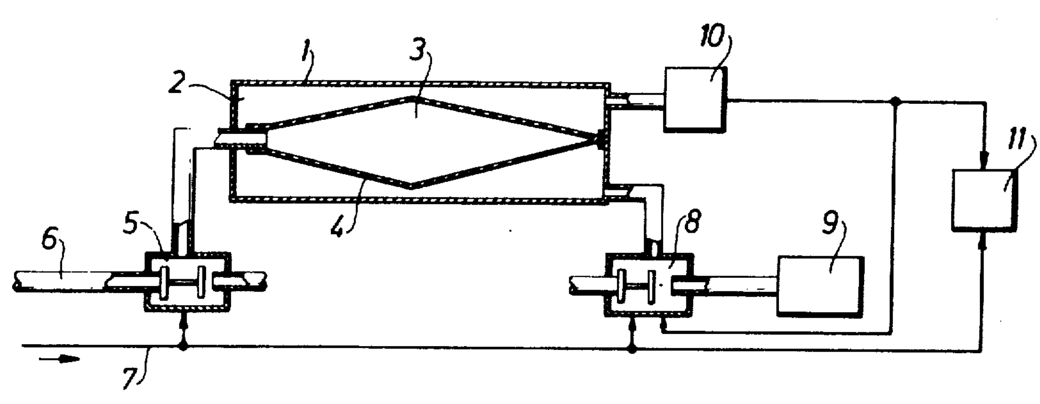


Fig.1

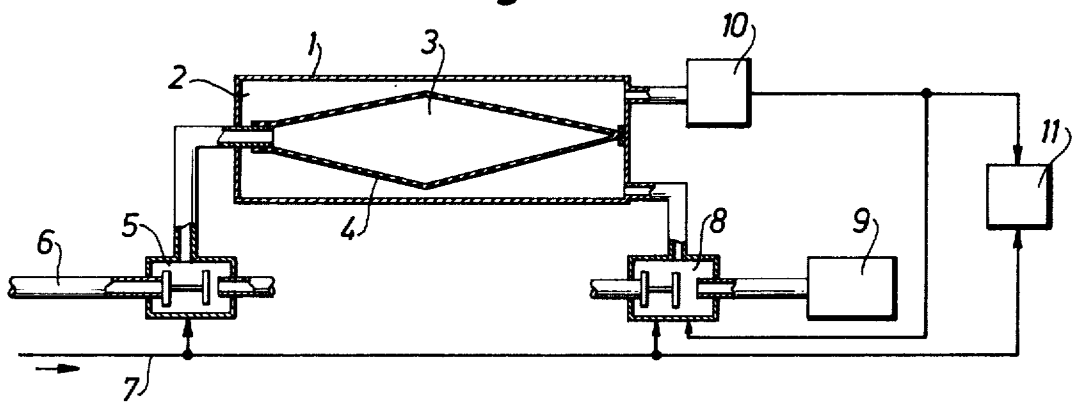


Fig. 2

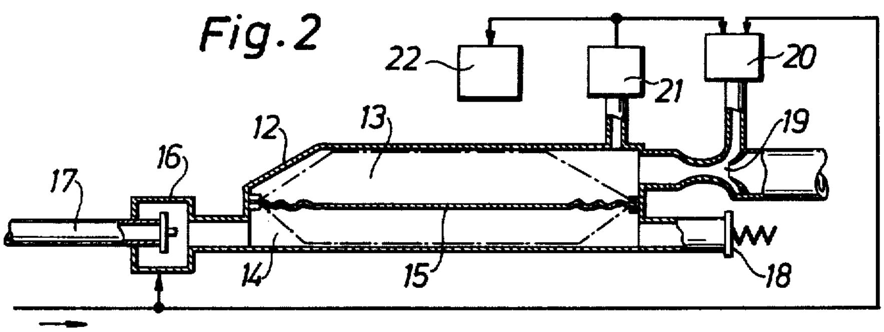


Fig.3

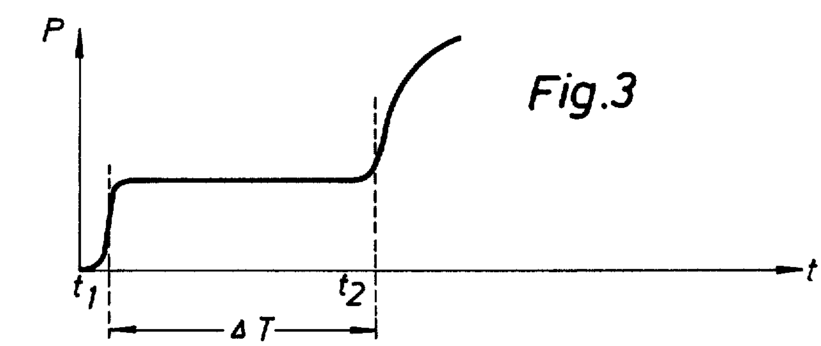
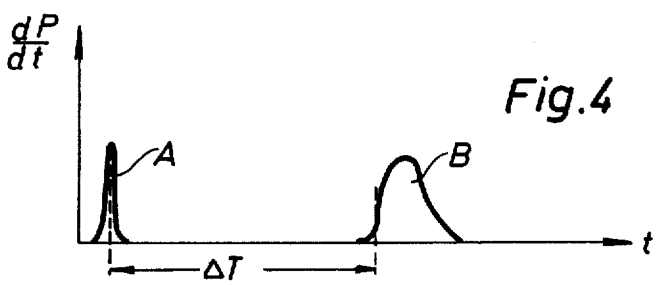


Fig.4



DEVICE FOR MEASURING THE TIDAL GAS VOLUME IN A LUNG VENTILATOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a device in lung ventilators for measuring the so called tidal volume, that is the gas volume exhaled by the patient.

2. Description of the Prior Art

It is a very important and well known requirement in connection with lung ventilators that the gas volume exhaled by the patient can be measured as accurately as possible, as this gas volume corresponds exactly to the volume of gas actually supplied to the patient, provided that no leaks exist in the exhalation pipe from the patient to the measuring device. Devices of various designs for measuring the exhaled gas volume in lung ventilators are known in the prior art. These prior art devices can in the main be regarded as belonging to two different types, namely on the one hand continuously operating meters as for instance various types of rotor meters, and on the other hand intermittently operating meters, in which the exhaled gas from one or possibly several successive exhalation phases is collected in an expansible or inflatable container, as for instance a gas bell or a bellows, the expansion of which is measured for determining the volume of the exhaled gas and which is subsequently emptied before its next filling with exhaled gas. However, all prior art devices have as a common disadvantage that they are comparatively complicated and thus expensive and sensitive to disturbances and/or that they have an unsatisfactory measuring accuracy, in particular for small tidal volumes.

SUMMARY OF THE INVENTION

The object of the invention is therefore to provide an improved device for measuring the exhaled gas volume in lung ventilators.

For this object the invention provides a device for measuring the exhaled gas volume in a lung ventilator, which comprises a rigid container provided with an internal, freely movable partition wall dividing the interior of the container in first and second separate compartments in such a manner that the sum of the volumes of said first and second compartments remains constant and independent of the actual position of the partition wall and that any change in the position of the partition wall results in equally large but opposite changes in the volumes of said first and second compartments, valve means for putting said first compartment in communication with a conduit leading to the respiratory ways of the patient during the exhalation phase of the ventilation cycle of the lung ventilator and in communication with the ambient atmosphere during the inhalation phase of the ventilation cycle, means for injecting a predetermined constant gas flow into said second compartment, means for activating said gas flow injecting means to start said constant gas flow when at the end of the exhalation phase the communication between said first compartment and said conduit leading to the respiratory ways of the patient is interrupted, pressure transducer means responsive to the gas pressure in said second compartment for initiating said gas flow injecting means to interrupt said constant gas flow and instead put said second compartment in communication with the ambient atmosphere when said first compartment attains its minimum value and as a result thereof the pressure in said second compartment rises momentarily, and means for measuring the duration of said constant gas flow.

In a preferred embodiment of the invention the pressure transducer means responsive to the gas pressure in the second compartment of the container are designed to produce an electric signal representing said gas pressure and the time measuring means are responsive to this electric signal so as to start the time measuring process in response to the pressure rise resulting from the starting of the constant gas flow and to interrupt the time measuring process in response to the pressure rise appearing when said second compartment of the container attains its maximum volume.

The device according to the invention has a comparatively simple structural design and is therefore inexpensive and reliable. Further, the device according to the invention makes it possible to measure large tidal volumes, as the expansible compartment, in which the exhaled gas is collected, is emptied positively during the following inhalation phase, and has at the same time a good accuracy also for small tidal volumes, as the volume measurement can be based on an electronic time measurement. Further, the accuracy of the device according to the invention is not dependent on any accurate tolerances in the design of the container and its internal partition wall or the accuracy of the movements of the partition wall as is the case in many prior art devices, where the measurement is based on observation of the movements of the partition wall.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be further described with reference to the accompanying drawings, which illustrate by way of example some embodiments of a device according to the invention. In the drawings:

FIG. 1 illustrates schematically a first embodiment of a device according to the invention;

FIG. 2 illustrates schematically a second embodiment of a device according to the invention;

FIG. 3 is a diagram illustrating the pressure as a function of time during the emptying of the inflatable compartment used for collecting the exhaled gas in the device illustrated in FIG. 2; and

FIG. 4 is a diagram illustrating the time derivative of the pressure signal in FIG. 3.

In FIGS. 1 and 2 electric signal connections are indicated by solid lines provided with arrows indicating the direction of signal transfer. In FIG. 1 as well as FIG. 2 only the device according to the invention is shown, whereas all other parts of the lung ventilator, with which the devices according to the invention is associated, are omitted, as these other parts of the lung ventilator can be of any conventional type already well known in the art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The device according to the invention illustrated schematically and by way of example in FIG. 1 comprises a rigid container **1**, the interior of which is divided in two separate compartments **2** and **3** by a flexible, substantially freely inflatable bag **4**, which thus forms a partition wall between the two compartments **2** and **3**. It is appreciated that the sum of the volumes of the two compartments **2** and **3** is always constant and that any change in the volume of one of these compartments results in an equally large but opposite change in the volume of the other compartment.

The compartment 3 inside the bag 4 can by means of a valve device 5 be put into communication alternatively with a pipe conduit 6 leading to the respiratory ways of the patient or with the ambient atmosphere. As schematically indicated with an electric signal connection 7, the valve device 5 is controlled from the control unit of the lung ventilator in such a manner that the interior 3 of the bag 4 communicates with the pipe conduit 6 leading to the respiratory ways of the patient during the exhalation phase of the ventilation cycle of the ventilator, whereas it communicates with the ambient atmosphere during the inhalation phase of the ventilation cycle.

The compartment 2 in the container 1 outside the bag 4 can through a valve device 8 be connected either to a device 9 for injecting a predetermined, constant gas flow into the compartment 2 or to the ambient atmosphere. The device 9 can be of any suitable conventional design, for instance consisting of a pressurized gas source with predetermined constant pressure and a restriction determining the rate of the gas flow. The valve device 8 is normally in the position, in which the compartment 2 in the container 1 is communicating with the ambient atmosphere, but is operated from the control unit of the lung ventilator in such a manner that at the end of the exhalation phase of the ventilation cycle the valve device interrupts the communication between the ambient atmosphere and the compartment 2 and instead opens the communication between the compartment 2 and the device 9 so that a constant gas flow from the device 9 is injected into the compartment 2. The valve device 8 is returned to its normal position in response to a control signal from a pressure transducer 10 connected to the compartment 2 in the container 1, as will be described more in detail in the following.

Further, the device comprises a time measuring device 11, which is started by the control unit of the lung ventilator at the end of the exhalation phase of a ventilation cycle and is stopped again in response to the signal from the pressure transducer 10 at the same time as the constant gas flow from the device 9 into the compartment 2 of the container 1 is interrupted.

The device illustrated in FIG. 1 operates in the following manner. During the exhalation phase of a ventilation cycle of the ventilator the two valve devices 5 and 8 are in positions opposite to those illustrated in the drawing, wherefore the compartment 3 inside the bag 4 communicates with the pipe conduit 6 leading to the respiratory ways of the patient, whereas the compartment 2 outside the bag 4 communicates with the ambient atmosphere. The gas volume exhaled by the patient flows consequently into the interior 3 of the bag 4, which is thus inflated to a corresponding degree at the same time as the volume of the compartment 2 is reduced. At the end of the exhalation phase the two valve devices 5 and 8 are returned in response to the control unit of the ventilator to the positions illustrated in the drawing, whereby the interior 3 of the bag 4 is put into direct communication with the ambient atmosphere, whereas the compartment 2 outside the bag 4 is connected to the device 9, which starts to inject a constant gas flow into the compartment 2. At the same time the time measuring device 11 is also started. Under the effect of the constant gas flow injected into the compartment 2 outside the bag 4 from the device 9 the bag 4 is emptied through the valve device 5 to the ambient atmosphere. It is appreciated that the rate of emptying the bag 4 will be constant and directly proportional to the rate of the gas flow from the device 9, wherefore the time for a complete emptying of the bag 4, that is until the compartment 3 within the bag 4 attains its smallest possible volume, will be directly proportional to the gas volume exhaled by the patient during the preceding exhalation phase, as this gas volume was collected in the bag 4.

When the bag 4 has been completely emptied as described above and thus the compartment 3 has attained its smallest possible volume, the pressure in the compartment 3 will rise steeply due to the gas flow from the device 9. This steep and large pressure rise is sensed by the pressure transducer 10, which produce's a corresponding output signal, which on the one hand stops the time measuring device 11 and on the other hand returns the valve device 8 to its other position so that the gas flow from the device 9 into the compartment 2 of the container 1 is interrupted and the compartment 2 is instead put into communication with the ambient atmosphere.

From the above description of the operation of the device it is appreciated that the time interval measured by the time measuring device 11 will be directly proportional to the gas volume which is expelled from the interior 3 of the bag 4 and thus to the gas volume exhaled by the patient during the preceding exhalation phase. A direct measure of this gas volume is obtained by multiplying the time measured by the time measuring device 11 and the rate of the constant gas flow from the device 9.

The device according to the invention illustrated in FIG. 1 has obviously a gas consumption - from the device 9 - which is equal to the gas volume exhaled by the patient. This comparatively large gas consumption may be a disadvantage, particularly if the lung ventilator is driven from its own compressor. FIG. 2 in the drawings shows schematically a device according to the invention, which constitutes an improvement in this respect and which is also simplified in some other respects.

The device according to the invention shown in FIG. 2 comprises also a rigid container 12, the interior of which is divided in two separate compartments 13 and 14 by a flexible, substantially freely movable diaphragm 15, which can move between the two extreme positions indicated with dotted lines.

The compartment 14 can be put into communication with the pipe conduit 17 leading to the respiratory ways of the patient through a valve 16 operated from the control unit of the lung ventilator and with the ambient atmosphere through a biased check valve 18. The valve 16 is operated from the control unit of the ventilator in such a manner that it is closed during the inhalation phase and open during the exhalation phase of the ventilation cycle of the ventilator. Consequently, the gas volume exhaled by the patient during the exhalation phase flows into the compartment 14 of the container 12 resulting in an increase of the volume of the compartment 14 and a corresponding reduction of the volume of the compartment 13. The biassing of the check valve 18 is such that the valve does not open under the influence of the pressure arising in the compartment 14 during the exhalation phase but only for a predetermined higher pressure.

The compartment **13** in the container **12** communicates with the ambient atmosphere through an ejector device **19**, which is connected to a device **20** producing a drive gas flow for the ejector **19** having a predetermined constant flow rate and pressure, whereby the ejector device **19** will under the influence of this drive gas flow inject a predetermined constant gas flow into the compartment **13** of the container **12**. The major portion of this gas flow is of course taken from the ambient atmosphere. By proper design of the ejector device **19** it is possible to achieve that at least 90 percent of the gas flow injected into the compartment **13** is taken from the ambient atmosphere. It is appreciated that in the absence of a drive gas flow from the device **20** to the ejector device **19** the compartment **13** of the container **12** is communicating directly with the ambient atmosphere through the ejector device. The device **20** can be of any suitable conventional type and for instance consist of a source of pressurized gas with predetermined constant pressure and a restriction for determining the rate of the gas flow; the drive gas flow to the ejector **19** being started and interrupted respectively by means of any suitable valve device.

The device **20** is started to supply the necessary drive gas flow to the ejector **19**, whereby a constant gas flow is injected into the compartment **13** of the container **12**, by actuation from the control unit of the ventilator at the end of the exhalation phase simultaneously with the closing of the valve **16**. The injection of the constant gas flow in the compartment **13** results in a very rapid increase of the pressure in the compartment **13** up to the opening pressure for the check valve **18**, as shown at the time t_1 in the pressure diagram in FIG. **3**. This pressure rise is sensed by the pressure transducer **21** connected to the compartment **13**. The pressure signal from the pressure transducer **21** is preferably differentiated so that a corresponding signal pulse A is produced, as shown in the diagram in FIG. **4**. This signal pulse starts a time measuring device **22**.

After the opening of the check valve **18** at the time t_1, the constant gas flow from the ejector **19** into the compartment **13** will cause a corresponding emptying of the compartment **14** to the ambient atmosphere through the check valve **18**. When the compartment **14** is completely emptied, that is has attained its smallest possible volume, the pressure in the compartment **13** will once again rise steeply, as illustrated at the time t_2 in the pressure diagram in FIG. **3**. Also this pressure rise is sensed by the pressure transducer **21** and its differentiated pressure signal will consequently display a signal pulse B, as shown in the diagram in FIG. **4**. In response to this signal pulse B the time measuring device **22** is stopped and the device **20** is actuated to interrupt the drive gas flow to the ejector **19**. Consequently, the injection of a constant gas flow into the compartment **13** of the container **12** is interrupted and this compartment **13** is instead put into direct and free communication with the ambient atmosphere through the non-operating ejector **19**.

It is realized that also in this case the time interval Δt in FIGS. **3** and **4** as measured by the time measuring device **22** will be directly proportional to the gas volume expelled from the compartment **14** to the ambient atmosphere and thus also directly proportional to the gas volume exhaled by the patient during the preceding exhalation phase.

What we claim is:

1. A device in a lung ventilator for measuring the gas volume exhaled by a patient, comprising a rigid container provided with an internal freely movable partition wall dividing the interior of the container into a first and a second compartment in such a way that the sum of the volumes of said first and second compartments is constant and independent of the position of said partition wall and any change of the position of said partition wall results in equally large but opposite changes in the volumes of said first and second compartments; valve means for putting said first compartment into communication with a gas conduit leading to the respiratory ways of the patient during the exhalation phase of the ventilation cycle of the ventilator and in communication with the ambient atmosphere during the inhalation phase of the ventilation cycle; means for producing a predetermined constant gas flow and injecting this constant gas flow into said second compartment; means for activating said gas flow producing means to start the injection of said constant gas flow into said second compartment when at the end of the exhalation phase the communication between said first compartment and said conduit leading to the respiratory ways of the patient is interrupted; pressure transducer means responsive to the gas pressure in said second compartment for actuating said gas flow producing means to interrupt the injection of said constant gas flow into said second compartment and instead putting said second compartment into communication with the ambient atmosphere when said first compartment attains its smallest possible volume and the pressure in said second compartment thus rises momentarily; and time measuring means for measuring the duration of said constant gas flow.

2. A device as claimed in claim **1**, wherein said pressure transducer means provides an electric output signal representing the gas pressure in said second compartment and said time measuring means is controlled by said electric output signal so as to start its time measuring process in response to the pressure rise caused by the starting of said constant gas flow and to interrupt its time measuring process in response to the pressure rise produced when said second compartment attains its maximum possible volume.

* * * * *