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SPIROMETER APPARATUS FOR DETERMINING THE CHARACTERISTIC OF METABOLISM

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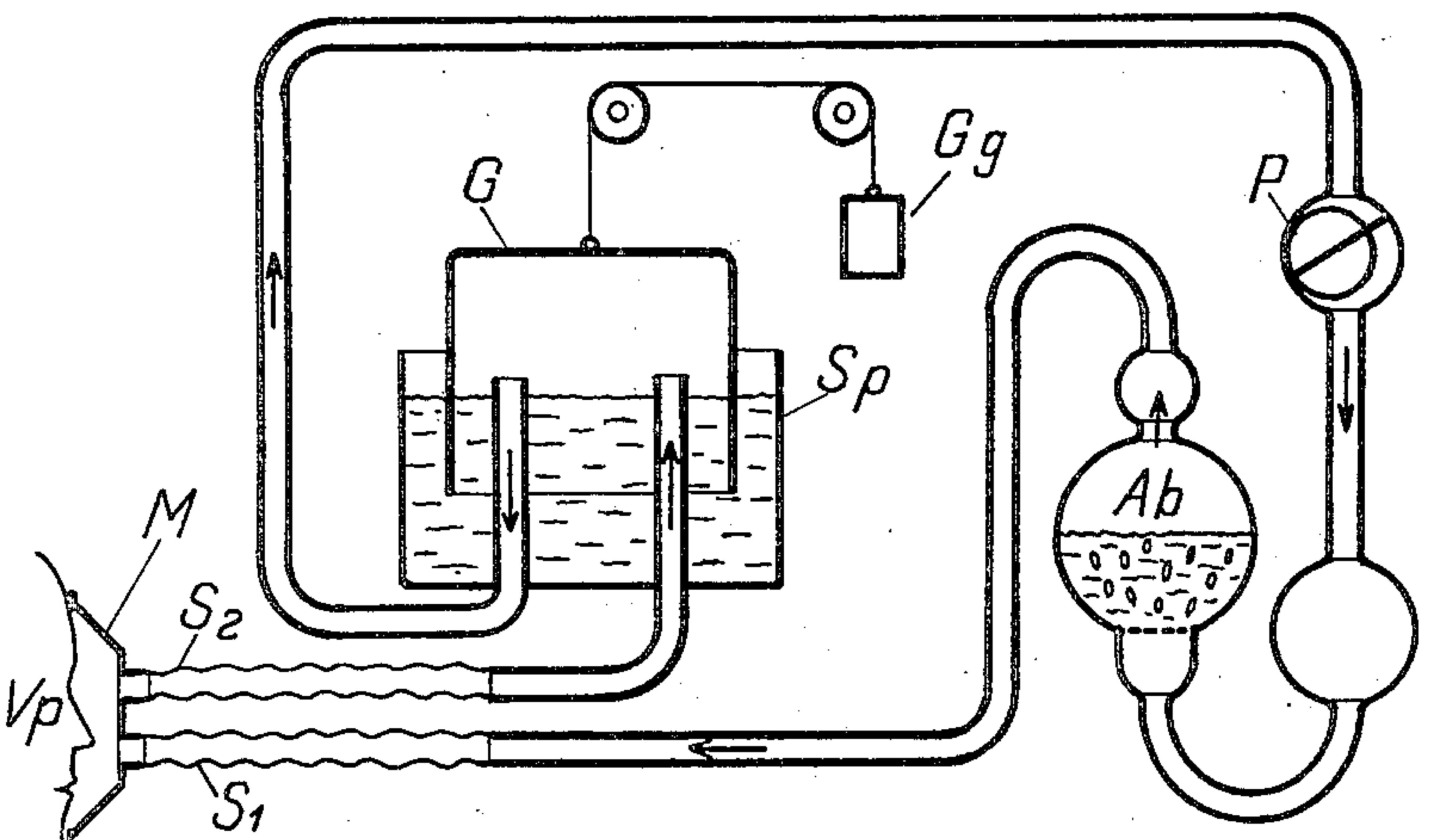


FIG. 1

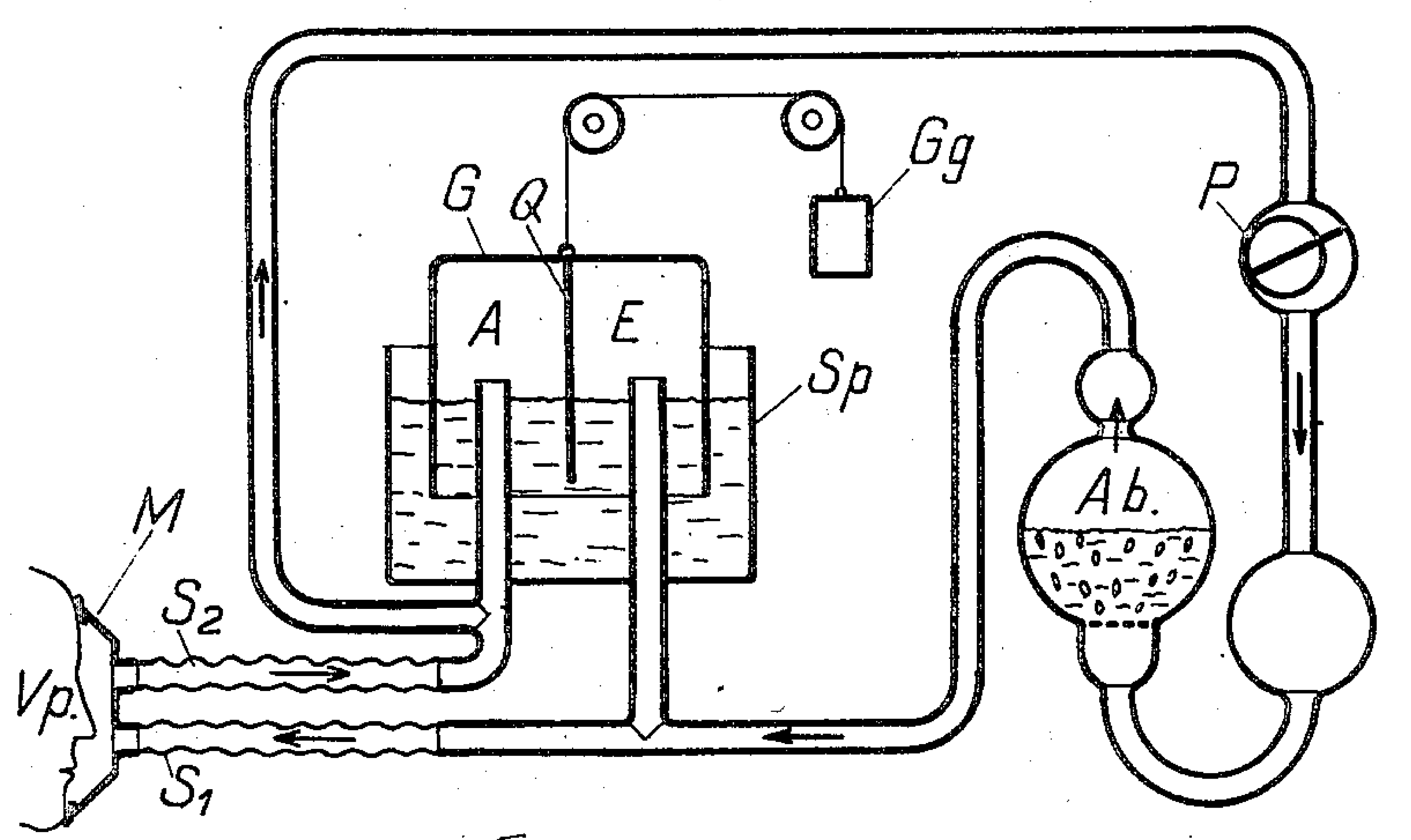
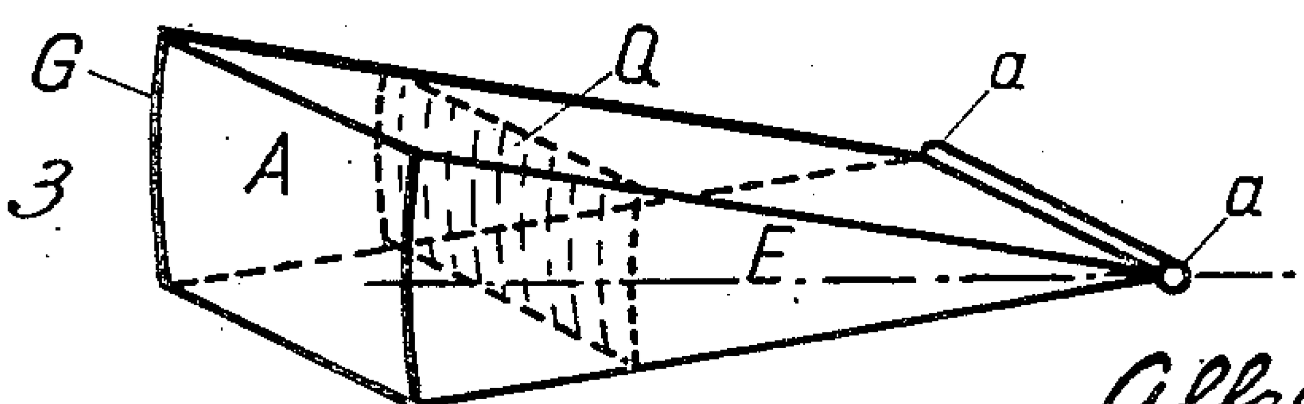


FIG. 2

FIG. 3



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SPIROMETER APPARATUS FOR DETERMINING THE CHARACTERISTIC OF METABOLISM

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My present invention relates to improvements in spirometers as used in apparatus for determining the characteristic of metabolism, and the objects of my improvements are, first, to afford facilities which permit of positively freeing the air cycled through the apparatus of carbon dioxide, and, second, to provide means which permit of substantially reducing the velocity and thus the friction head of the said air.

For determining the characteristic of metabolism for humans and animals, usually the consumption of oxygen is ascertained, which permits of determining the characteristic of metabolism in calories by a simple conversion. The quantitative determination of the consumption of oxygen, therefore, is very frequently practiced for physiological examinations as well as for clinical diagnostic purposes. The method used generally is as follows:

A rubber mask M is mounted airtightly on the face of the test person *Vp* (Fig. 1, which shows a conventional form of spirometer apparatus). A current of air continuously passes through the said mask and flows, driven by means of the air pump P, through the absorption vessel *Ab* which is supplied with a potassium hydroxide solution, in order to be freed of the exhaled carbon dioxide. Such air, further, flows through the corrugated hose S_1 into the mask M, and further through the corrugated hose S_2 into the spirometer *Sp* and thence back into pump P.

The air breathed by the test person is superposed onto the airflow maintained by the pump. During inhaling, a portion or the entire volume of air flowing into the mask is absorbed by the lungs so that a lesser volume or no air at all flows through hose S_2 into spirometer *Sp*. Since, however, the aspiration of air from spirometer *Sp* through pump P is constant, the spirometer bell G, the weight of which is compensated by the counterweight *Gg*, sinks. Upon exhaling, the exhaled air which flows through hose S_2 into spirometer *Sp* and raises the spirometer bell G, is added to the constant air current of the pump. The oxygen originally present in spirometer *Sp*, gradually is consumed by the test person *Vp*, and the consumption of oxygen is computed from the gradual sinking of the vertically reciprocating bell G.

The rate of air flow produced by pump P has to be at least as great as the maximum rate of flow of the breathing air in order that all the inhaled air may be taken from hose S_1 at the maximum rate of inhaling and that no previously exhaled air has to be inhaled from spirometer *Sp* through hose S_2. Reinhaling of the same exhaled air leads to an accumulation of carbon dioxide in the lungs and in the blood and thus to difficulties of breathing.

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When a person is working physically hard, the maximum rates of flow of the breathing air attain values, which correspond to the inhaled and exhaled volume of 4 lts/sec., for example or more. The pump P, therefore, also has to supply at least 4 lts/sec.

Such high volume of supply from the pump has the following disadvantages:

First, one does not succeed, with the aid of the conventional absorption vessels for carbon dioxide (in form of wash-bottles filled with a potassium hydroxide solution) to entirely free the quickly passing air of carbon dioxide, so that the circulating air still contains up to 1% of CO_2.

Second, the resistance encountered by the flowing air is considerable. An undesirable factor, above all, is the friction head of the air flow in hose S_2 upon exhaling. The 4 lts/sec. of exhaled air are added to the 4 lts/sec. discharge from pump P so that 8 lts/sec. flow through hose S_2. The pressure in mask M, therefore, is materially increased, hindering the exhalation and frequently lifting the mask M from the face of the test person *Vp* so that the entire determination of the consumption of oxygen is falsified and rendered useless due to leakage. It has to be borne in mind that the air flow through the entire system is turbulent so that, when the rate of flow is doubled, the friction head is increased approximately four times.

My present invention eliminates these disadvantages. It consists in subdividing the measuring instrument or spirometer into two chambers, one of which is the inspiratory chamber, which is connected through the inhaling-air line to the pump and the absorption vessel on one hand, and to the mask on the other hand. The other or expiratory chamber through the exhaling-air line communicates with the air pump on one hand and with the mask on the other hand.

A preferred form of the present invention, together with three modifications thereof, and a known form of spirometer apparatus are schematically illustrated in the accompanying drawing, in which—

Fig. 1 shows diagrammatically an apparatus known in the art;

Figure 2 shows diagrammatically a preferred form of the present invention;

Figure 3 shows diagrammatically a first modification of such preferred form.

Fig. 2 illustrates one form of this invention. The hollow body of the spirometer *Sp*, adapted as a bell G for example, has a partition Q which divides its hollow space into two equal chambers A and E. The expiratory chamber A receives the exhaled air, and the person inhales from the inspiratory chamber E. The conduit leading into the inspiratory chamber E is tapped from the inhaling-air line upstream from its entrance into mask M which envelopes the outer respiratory organs of the test person *Vp*. The exhaling-air line which leads from the elastic mask M (which, for example is made of rubber) is tapped upstream from its entrance into the expiratory chamber A and the branch line is by-passed about chamber A to connect with the air pump P.

The mode of operation of the apparatus according to my present invention, as shown in Fig. 2, is as follows: when the test person is holding his or her breath, the air flows from pump P through the absorption vessel *Ab*, thence, by-passing the inspiratory chamber E, through line S_1 directly into mask M, thence, by-passing the expiratory chamber A, back into the pump. Let it be assumed first that the rate of flow produced by the air pump P, is 2 lts/sec., i. e. only half of that assumed in connection with the conventional method illustrated in Fig. 1. The maximum velocities of the air of breathing, however, also correspond to a rate of 4 lts/sec. as in the case of Fig. 1. Such arrangement during breathing operates as follows:

Let it be further assumed that the test person breathes at a rate of 4 lts/sec. The inhaling air is introduced through hose S_1 into mask M. Since the pump supplies only 2 lts/sec., the difference, i. e., 2 lts/sec., is sucked from chamber E, and the bell G thus gradually drops and decreases the content of chamber E by 2 lts/sec. During such inhaling of 4 lts/sec., there is no flow through hose S_2, i. e. there is no re-inhaling therethrough. The pump, however, sucks 2 lts/sec. from chamber A so that the content thereof decreases at the same rate as that of chamber E.

Upon exhaling, the air flows at a rate of 4 lts/sec. through hose S_2. Since, however, the pump P draws off 2 lts/sec., space A is increased by only $4-2=2$ lts/sec. At the same time, the pump supplies 2 lts/sec. into the space E which is increased, by the rise of bell G, by two lts/sec., since no air then flows through S_1 into mask M.

A comparison of the normal or conventional spirometer (Fig. 1) with the inventive "coupled double-spirometer" (Fig. 2) furnishes the following data:

	Normal spirometer, lts/sec.	Coupled double spirometer, lts/sec.
At a rate of flow through pump P of	4	2
the max. rate of inhaling of the test person is	4	4
the rate of flow in hose S_1	4	4
and the rate of flow in hose S_2	0	0
At a max. rate of exhaling of the test person of	4	4
the rate of flow in hose S_1 is	4	0
and the rate of flow in hose S_2	8	4

The arrangement according to my present invention has the following advantages over the arrangement comprising a conventional spirometer: the pump has to deliver only half the volume. Nevertheless, the requirement is fulfilled that no exhaled air be re-inhaled. The maximum rate of flow in the exhaling hose is only half of that in a conventional spirometer in spite of a like intensity of breathing, thus bringing about a substantial reduction of the friction head in the

apparatus and of the size of the pressure fluctuations in the mask.

Since the pressure in the inspiratory chamber E of the spirometer according to the present invention is higher than in the expiratory chamber A, due to line leakage, the bell G, in case of a bell spirometer, is set askew. Such inconvenience may be compensated by guiding the bell or by one-sided loading or by means of two cylindrical bells telescoped into each other or, finally, by means of a tiltable spirometer such as is schematically shown in Fig. 3. In the latter, the spirometer bell G rocking about the axis *a—a*, is lengthwise subdivided by the partition into two chambers A and E, which are of equal volume. In such an arrangement, bell G is not twisted nor set askew.

The hollow body G also could be subdivided by its partition Q into two chambers of different volumes. Again, two separate air-filled hollow bodies also could be provided for, which are sealed against the ambient air and mechanically coupled to each other, one of which encloses the inspiratory chamber and the other the expiratory chamber. The hollow body or bodies also could be sealed against the ambient air by means of movable diaphragms.

What I claim as new, and desire to secure by Letters Patent, is:

1. An apparatus for determining metabolism, comprising a rubber mask adapted to be fit airtight onto the face of the test person, an inhaling line and an exhaling line running into and from the said mask respectively, the said lines forming a closed air-filled circuit which includes an air pump for forcing the air therethrough and a CO_2 absorption vessel, a second vessel partly filled with a liquid, a bell submerged with its open end into the said liquid and having a partition to form an inspiratory chamber and an expiratory chamber, means for guiding the said bell during its vertical oscillations and descent so as to prevent a relative rotation and tilting thereof, a measured amount of fresh air trapped in the said bell, a riser tube extending from the said inhaling line into the said inspiratory chamber and a riser tube extending from the said exhaling line into the said expiratory chamber.

2. An apparatus according to claim 1, in which the two chambers in the said bell are of equal volume.

3. An apparatus set out in claim 1, in which the said bell is secured tiltable to the said second vessel to rock about a horizontal axis.

4. An apparatus set out in claim 1, in which the weight of the said bell is balanced by means of a counterweight.

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