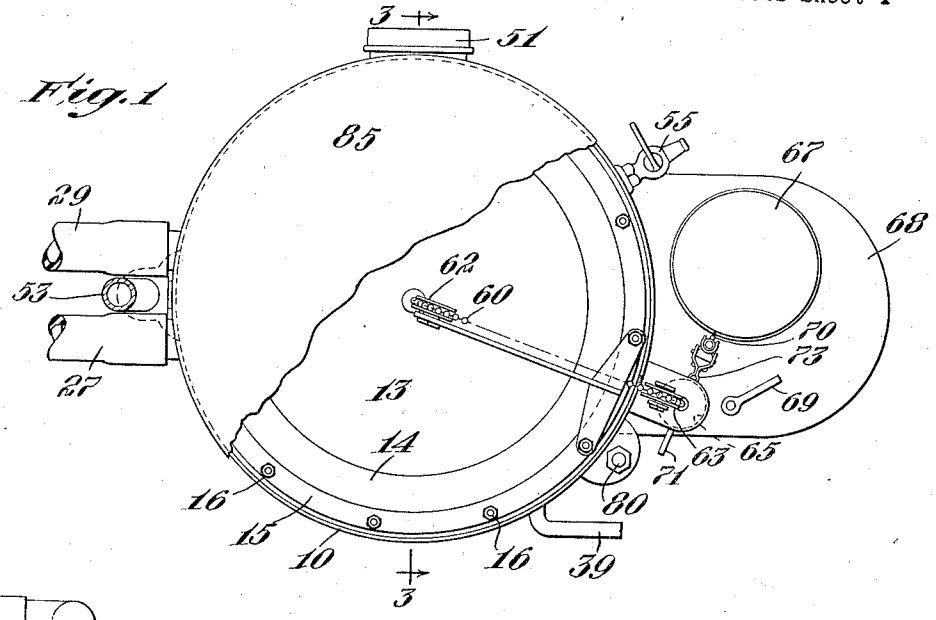
April 23, 1940. H. P. ROTH 2,198,230

SPIROMETER

Filed May 20, 1938 2 Sheets-Sheet 1

Fig. 1



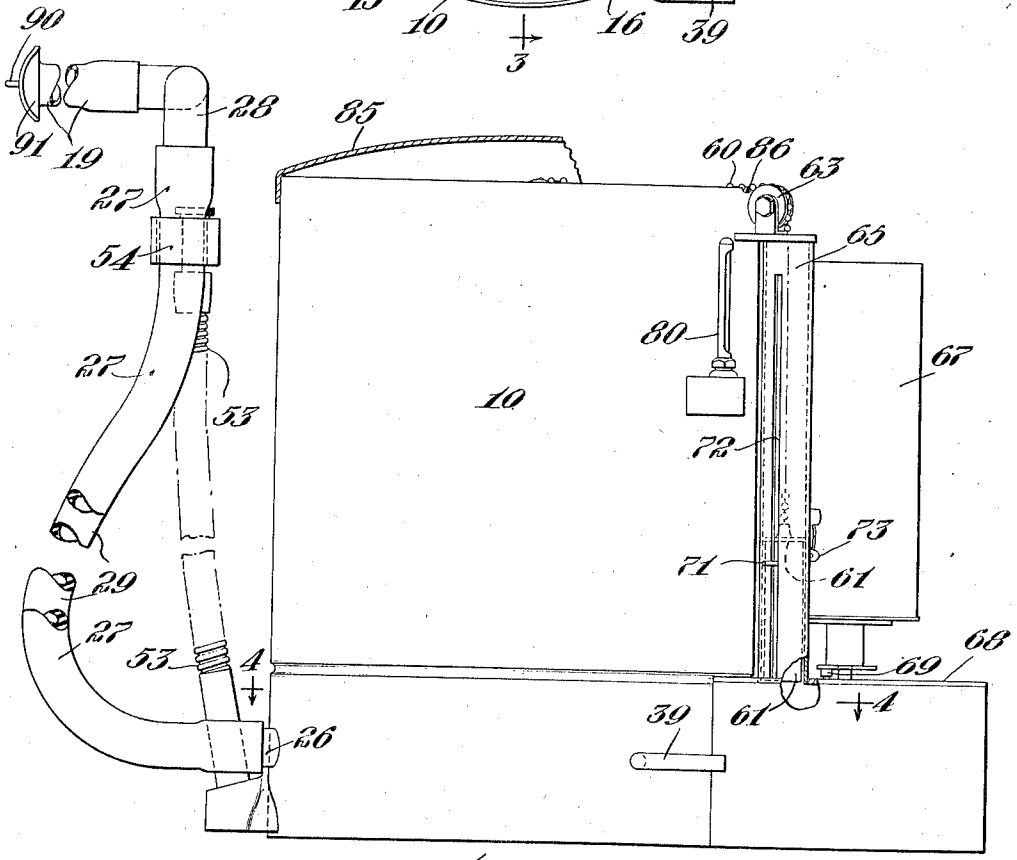


Fig. 2

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April 23, 1940. H. P. ROTH 2,198,230

SPIROMETER

Filed May 20, 1938 2 Sheets-Sheet 2

Fig. 3

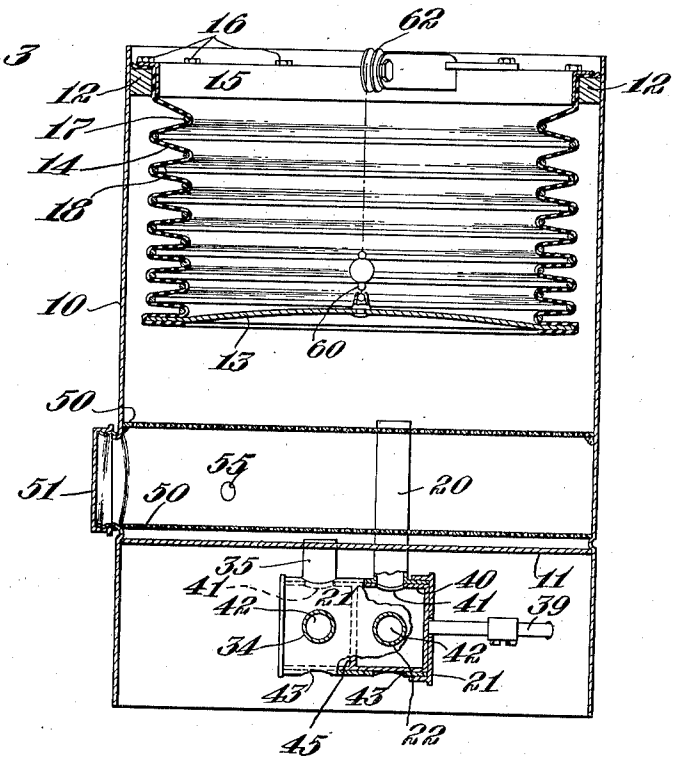
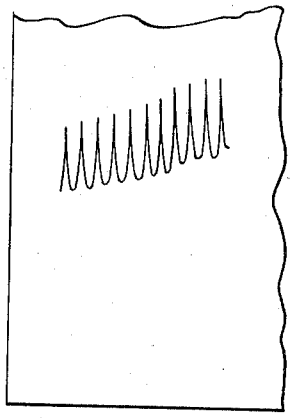


Fig. 5



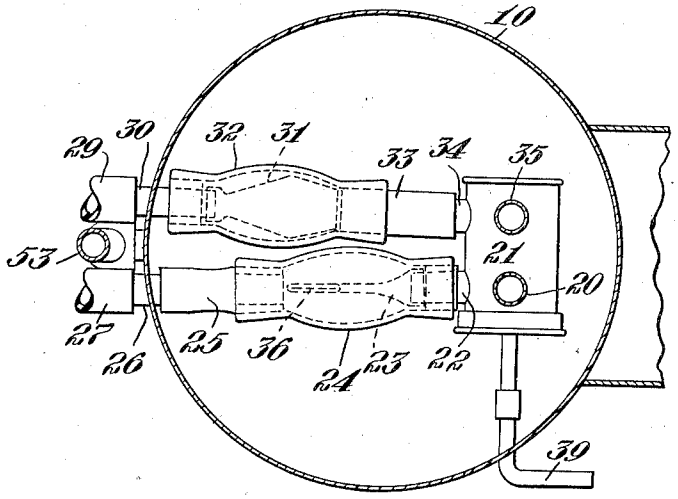


Fig. 4

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Patented Apr. 23, 1940 2,198,230

UNITED STATES PATENT OFFICE

2,198,230

SPIROMETER

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Application May 20, 1938, Serial No. 208,957

2 Claims. (Cl. 128—2.08)

This invention relates to spirometers, and more particularly to a spirometer which is adapted to be used for measuring metabolism although it may also be used for other purposes.

In measuring metabolism by what is commonly known as the "closed circuit" method, a system is employed in which the patient's lungs and breathing passages are connected by air-tight means to the interior of an air-tight chamber. This chamber ordinarily has a portion which moves in such a manner as to maintain a substantially constant pressure in the closed system as a whole. The movable portion of said chamber thus serves as a means of measuring changes in the volume of gases in said closed system, i. e., it moves in one direction when the patient inhales, and it moves in the opposite direction when the patient exhales. The exhaled gases during transit from the patient's breathing passages to the chamber are passed through a chemical which removes therefrom the carbon dioxide added to the gases through the lung walls, so that the volume of the average exhalation which reenters the chamber from the patient's lungs is less than the volume of the preceding average inhalation by an amount which directly represents the volume of oxygen removed by the patient's lungs during that average inhalation. By recording the movements of the movable portion of the chamber during an appropriate length of time, a record is made which indicates the amount of oxygen absorbed by the patient's lungs during that period, and from that record an accurate average oxygen consumption per unit of time may be obtained. It is in connection with such a "closed circuit" method that my improved spirometer is primarily intended for use.

The principal object of the present invention is to provide a spirometer in which a movable wall is suspended from the side walls or top of the spirometer chamber.

A further object is the provision of a suspended movable wall located within the chamber.

A further object is the provision of a novel and efficient spirometer which is economical to manufacture and is durable and accurate in use.

Other objects relate to the construction and mode of operation and will be apparent from a consideration of the following description and accompanying drawings, which exemplify one embodiment of my invention chosen for the purposes of illustration.

In the drawings:

Fig. 1 is a plan view of a spirometer embodying my invention;

Fig. 2 is a side elevation of the spirometer shown in Fig. 1 with parts broken away and shown in section;

Fig. 3 is a section on the lines 3—3 of Fig. 1;

Fig. 4 is a section on the line 4—4 of Fig. 2; and

Fig. 5 is a plan view of a kymograph record or spirogram made in use of the spirometer for measuring metabolism.

A cylindrical chamber is provided by the metallic side wall 10 and bottom wall 11, the latter being secured at its periphery to the former in any suitable manner. This chamber has an opening at its upper end.

An outstanding horizontal support 12 is secured to the inside of the side wall 10 adjacent its upper end. A circular metallic plate 13 (hereinafter called the "bellows bottom") is resiliently suspended from the support 12 (Figs. 1 and 3) by the relatively thin vulcanized rubber wall 14 (hereinafter called the "bellows side wall"). This bellows bottom wall 13 may be made flat but it is preferably made of dome or slightly conical shape so that its central portion is higher than its periphery to thereby provide a more rigid member with a minimum of mass, and thereby to permit the connection to the bellows bottom wall of means for indicating or recording its movements, said connection being located at a point above the center of gravity of the bottom wall. The lower end of the bellows side wall 14 is cemented or otherwise secured to the bellows bottom 13 adjacent the edge thereof. The upper end of the bellows side wall 14 is removably secured to the support 12 by means of the metallic ring 15 and bolts 16, the bolts passing transversely through holes in the ring 15 and bellows side wall 14, and then being screwed into the support 12, thus clamping the bellows side wall against the surface of the support 12. The bellows side wall 14 and bottom 13 thus form an air-tight closure for the opening in the upper end of said cylindrical metallic chamber, and they cooperate with the side wall 10 and bottom wall 11 of said chamber to provide a substantially air-tight spirometer chamber.

The bellows side wall is molded so that it normally has a cross section substantially as shown in Fig. 3, and the free suspension of the bellows bottom from the support 12 by means of the resilient bellows side wall insures movement of the bellows bottom in a substantially vertical

direction when the volume of gases within the spirometer chamber is increased or decreased. Metallic rings 17 and 18 (Fig. 3) may be mounted in the angles of the bellows side wall to minimize lateral displacement of this side wall during vertical movements of the bellows bottom wall, these rings however are not essential, since substantially the same effect may be obtained by making the bellows side wall of a rubber which has precisely the right amount of rigidity in various portions thereof, for example, by increasing the proportionate amount of rubber at the angles of the side wall. Obviously the bellows side wall may be made in other forms and of a material other than rubber. The function of the side wall is merely to hold the bellows bottom in a suspended position for free vertical movement and to form a flexible closure between the bellows bottom and the opening in the end of the spirometer chamber. Other means for accomplishing these functions will be apparent to persons skilled in the art.

One-way communication between the interior of the spirometer chamber and the patient's mouthpiece 19 (Fig. 2) for inhalation is provided as follows: The tube 20 (Figs. 3 and 4) provides communication between the spirometer chamber and the interior of the chamber 21; the tube 22 and the attached one-way rubber valve 23 provide one-way communication from the chamber 21 to the chamber 24; and the tubes 25, 26, 27 and the forked tube 28 provide communication between the chamber 21 and the mouthpiece 19 (Figs. 2 and 4), the one-way valve 23 prevents the passage of gases from the mouthpiece to the spirometer chamber, but permits the passage of gases from the spirometer chamber to the mouthpiece upon the extertion of a slight negative pressure at the mouthpiece.

One-way communication between the mouthpiece 19 and the interior of the spirometer chamber for exhalation is provided as follows: The other branch of the forked tube 28 (directly behind the branch shown in Fig. 2), the tubes 29 and 30 and the one-way rubber valve 31 provide one-way communication from the mouthpiece to the interior of the chamber 32; the tubes 33 and 34 provide communication between the chamber 32 and the chamber 21; and the tube 35 provides communication between the chamber 21 and the interior of the spirometer chamber,—the one-way valve 31 permits the passage of gases only in the direction from the mouthpiece towards the spirometer chamber upon exertion of a slight positive pressure at the mouthpiece.

The valves 31 and 23 are of well-known construction; the gases emerge from the transverse slit 36 (Fig. 4) which is normally closed by the resiliency of the rubber but which easily opens when the gases flow under the slightest pressure from the interior of the valve outwardly through the slit 36.

A metallic cylinder 40 is freely rotatable within the chamber 21 (Fig. 3) and has a handle 39 (Figs. 3 and 4) secured to one end thereof by means of which it may be rotated about its longitudinal axis within the chamber 21. A vertical partition 45 divides this cylinder vertically into two separate chambers. This cylinder 40 is provided with two pairs of ports. One pair of these cylinder ports, 41, 41 (Fig. 3) in the adjustment of the cylinder 40 shown in Fig. 3, register with two corresponding ports in the top of the chamber 21 and provide communication respectively between the two chambers of the cylinder 40 and the tubes 20 and 35. The other pair of ports in the cylinder 40, in the adjustment shown in Fig. 3, register with ports 42, 42 in the side of the chamber 21 and provide communication respectively between said two chambers of the cylinder 40 and the tubes 22 and 34. When the cylinder 40 is in the position shown in Fig. 3, the mouthpiece communicates with the interior of the spirometer chamber through two separate air-tight passages,—one for inhalation and the other for exhalation, since the partition 45 divides the cylinder 40 into two separate compartments. When the cylinder 40 is rotated 90° counterclockwise (looking at Fig. 4), the ports 41, 41 register with the ports 42, 42 in the side of the chamber 21 and the other pair of ports in the cylinder 40 register with the ports 43, 43 in the bottom of the chamber 21. Thus in this position of the cylinder 40 all communication between the mouthpiece and the spirometer chamber is closed and the mouthpiece communicates with the atmosphere by means of the registry between the latter pair of cylinder ports and the ports 43, 43 in the bottom of the chamber 21.

A pair of spaced perforated plates 50, 50 are located adjacent the bottom of the spirometer chamber and the space between these plates is utilized for the insertion of soda lime, a chemical adapted to remove carbon dioxide from gases exhaled from the patient's lungs; as explained above, these gases enter the spirometer chamber through the tube 35. A transverse opening in the spirometer chamber side wall 10 is provided for cleaning and refilling this soda lime compartment, and this opening is closed by the interiorly threaded cap 51.

A flexible metallic cable 53 (Figs. 1 and 2) has one end secured to the metallic member 54 through which the tubes 27 and 29 loosely pass, and the other end secured to the base of the wall 10. This cable supports the tubes 27, 29, and through them the mouthpiece.

A hand operable valve 55 (Figs. 1 and 3) provides communication between the interior of the spirometer chamber and the exterior thereof, and this valve is used to admit oxygen to the interior of the spirometer chamber. The oxygen is ordinarily supplied from a tank of compressed oxygen (not shown).

A flexible chain 60 has one end secured to the center of the bellows bottom 13 (Fig. 3) and the other end secured to the top of the counterweight 61 (Figs. 1 and 2). This chain passes over freely rotatable pulleys 62, 63. The counterweight 61 is mounted for free vertical movement within the cylinder 65 (Fig. 2). This counterweight is light enough so that it will not cause movement of the bellows bottom 13, but as soon as the bellows bottom is moved vertically, the counterweight attached thereto by the chain 60 moves a corresponding vertical distance, i. e., when the bellows bottom moves downwardly the counterweight moves upwardly, and when the bellows bottom moves upwardly the counterweight moves a corresponding distance downwardly.

A kymograph drum 67 is removably secured to a rotatable vertical shaft (not shown) which is mounted in suitable bearings and extends through a transverse hole provided in the plate 68. Any suitable mechanism, such as clock-works, is mounted beneath the plate 68 and is connected to said vertical shaft so that upon actuation of the clock-works, said vertical shaft and the kymograph drum 67 are continuously rotated at a constant speed in one direction. A handle 69 is con-

nected to the kymograph actuating mechanism to stop and start it.

A graphic record pen **70** is connected to the counterweight **61** and moves vertically therewith; said pen is secured to a horizontal member **73** which extends through a longitudinal slot (not shown) in the cylinder **65** and has its end secured to the counterweight **61**. A horizontal pin **71** (Figs. 1 and 2) is connected to the opposite side of the counterweight **61** and projects through a longitudinal slot **72** in the cylinder **65**. This pin **71**, longitudinal slot **72**, the longitudinal slot on the opposite side of the cylinder **65** and the horizontal pen support **73**, cooperate to prevent rotation of the counterweight in the cylinder **65**.

A thermometer **80** communicates with the interior of the spirometer chamber and records the temperature of the gases therein.

A removable cover **85** fits over the top of the spirometer chamber. This cover is provided with a notch (not shown) which registers with a notch **86** (Fig. 2) in the top of the wall **10** to permit the chain **60** to pass freely therethrough and the device may be operated with the cover in place if a large enough aperture in the cover is provided so that neither positive nor negative pressures are developed in the space below the cover during movement of the bellows bottom.

In use the patient grips the two spaced rubber tabs **90** of the mouthpiece **19** between his teeth and the rubber flange **91** is inserted between the patient's gums and lips. The cable **53** is adjusted so that the patient will not be required to support any of the weight of the mouthpiece or tubes **27, 28, 29**.

In use of the spirometer for measuring metabolism, oxygen is ordinarily placed in the spirometer chamber. To charge the spirometer chamber with oxygen the handle **39** of the cylinder **40** is turned to the proper position to close all communication between the mouthpiece and the spirometer chamber, oxygen is then admitted to the spirometer chamber through the valve **55**, and the valve **55** is then closed. Enough oxygen is ordinarily admitted to supply the patient for the duration of the test, and the admission of this oxygen elevates the bellows bottom to some extent. A blank of kymograph paper is mounted on the surface of the drum **67** and the pen **70** is adjusted to lightly contact the surface of the paper.

It is ordinarily essential that the patient recline and be fully relaxed during metabolism measurements. Thus the patient is made comfortable, his nose is obstructed by a suitable spring clip so that he must breathe through his mouth, and the mouthpiece is then inserted in his mouth and the metallic cable adjusted so that the patient bears none of the weight of the mouthpiece and attached tubes. He is usually permitted to breathe through the mouthpiece for a short period with the mouthpiece communicating with the atmosphere through the ports **43, 43** in the bottom of the chamber **21**.

When the patient has become accustomed to the mouthpiece and is breathing normally, the handles **39** and **69** are turned to respectively connect the mouthpiece with the interior of the spirometer chamber and to start the uniform rotation of the gymograph drum. As the patient inhales he draws gases from the interior of the spirometer chamber into his lungs and thus decreases the volume of gases within the spirometer chamber. In correspondence with this decrease in volume the bellows bottom moves downwardly, which downward movement causes the counterweight and pen to move upwardly, the pen making an upward stroke on the kymograph chart. When the patient exhales he expels the gases from his lungs into the spirometer chamber through the tube **35**. Since his lungs have removed some of the oxygen from the inhaled gases, and since the soda lime removes the carbon dioxide from the exhaled gases, the volume of exhaled gases which returns to the interior of the chamber is, on the average, less than the volume of inhaled gases which was removed, and consequently, on the average, the bellows bottom is not raised to its full previous level. Hence the downward stroke of the kymograph pen (corresponding to the upward movement of the bellows bottom) ordinarily terminates at a point slightly above the lower extremity of the next preceding pen stroke (see Fig. 5), and the difference in elevation between the lower extremities of these two pen strokes graphically represents the amount of oxygen removed by the patient's lungs during one inhalation. As the patient continues to inhale and exhale a definite record is made of each respiration and a definitely upwardly sloping spirogram (see Fig. 5) results. Ordinarily a straight line is later drawn to represent the average upward slope of the spirogram, and this so-called oxygen line provides a means of measuring the average oxygen consumption of the patient during a given period.

Ordinarily the respiration is recorded for a period of six or more minutes so as to provide a fair average record of oxygen consumption.

The same measurements may be made with a spirometer chamber containing only air, i. e., without initially supplying excess oxygen to the chamber. In using only air the same apparatus may be utilized, but a larger spirometer chamber should ordinarily be provided so that there will be an ample supply of air and thus an ample supply of oxygen. In such an apparatus, although the spirometer chamber is normally larger, the bellows side walls and bottom are not necessarily larger.

In use of the spirometer for measuring the vital capacity of the patient's lungs the patient merely takes a deep breath and exhales into the spirometer. The volume of his breath is recorded by the difference between the initial level of the bellows bottom and its level upon completion of exhalation.

It is obvious that the bellows may be made with a cross section other than circular; for example, it may be made of rectangular cross section and four bellows side walls connected together at their corners would then be used. In use of the term "bellows side wall" in the annexed claims, I include a single bellows side wall as shown in the drawings, as well as a plurality of side walls connected together at their corners, the latter arrangement being in effect the same as a single side wall.

I claim:

1. A spirometer comprising a substantially air-tight chamber having an opening in one end thereof, a horizontal plate of upwardly convex cross section suspended within said chamber for vertical movement therein, means forming a substantially air-tight seal between the edges of said plate and the sides of said chamber adjacent said opening, means connected with the interior of said chamber permitting passage of gases therefrom to the patient's lungs upon inhalation by the patient and permitting passage of gases

from the patient's lungs to the interior of said chamber upon exhalation by the patient and means connected to said plate above its center of gravity to measure vertical movements thereof.

2. A spirometer comprising a substantially air-tight chamber having an opening in the top thereof, an open ended bellows suspended from adjacent the top of said chamber, said bellows having a resilient side wall having its upper end secured to said chamber and a substantially horizontal bellows bottom secured to said bellows side wall adjacent the lower end thereof, said bellows side wall and bottom being free from engagement within said chamber below the connection between the upper end of the bellows side wall and the chamber and forming a suspended substantially air-tight vertically movable closure for said chamber opening, means connected with the interior of said chamber permitting passage of gases therefrom to the patient's lungs upon inhalation by the patient and permitting passage of gases from the patient's lungs to the interior of said chamber upon exhalation by the patient, and means connected with said bellows bottom to measure vertical movement thereof.

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