

June 26, 1962

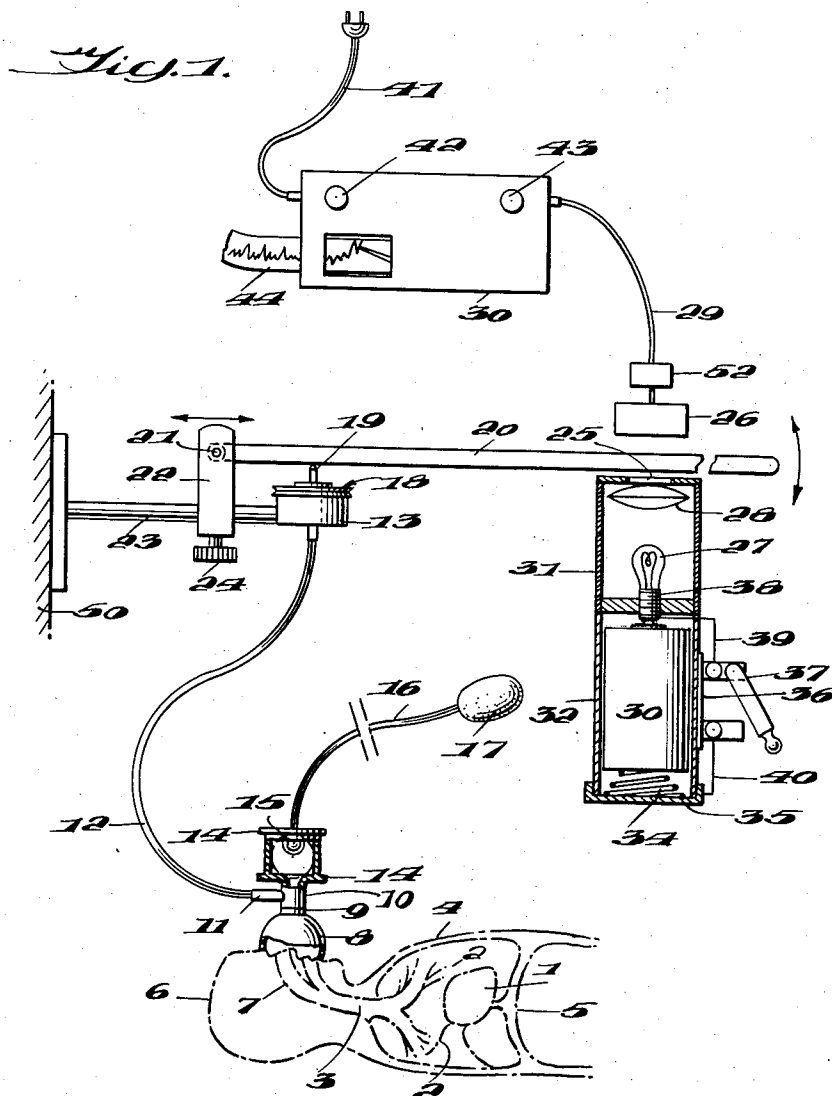
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3,040,736

METHOD FOR DETERMINING THE FORM OF WAVES PRODUCED IN
THE LUNGS AND RESPIRATORY PASSAGES BY THE BEATING
OF THE HEART AND MOVEMENTS OF BLOOD WITHIN
THE HEART, LUNGS AND CHEST CAVITY

Filed July 6, 1954

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

Fig. 3.

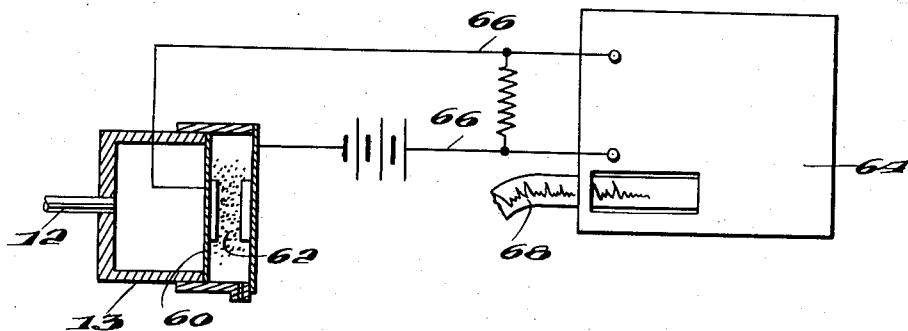


Fig. 4.

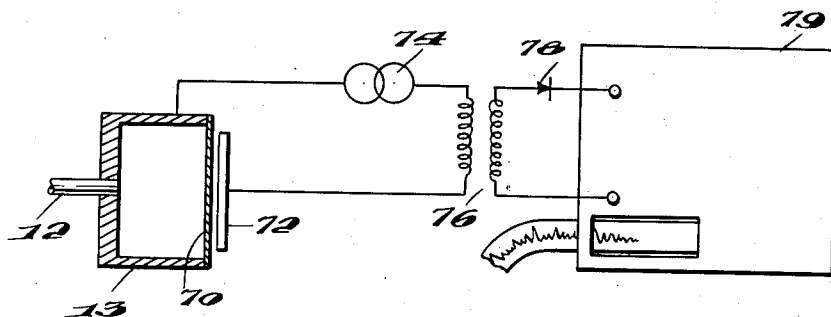
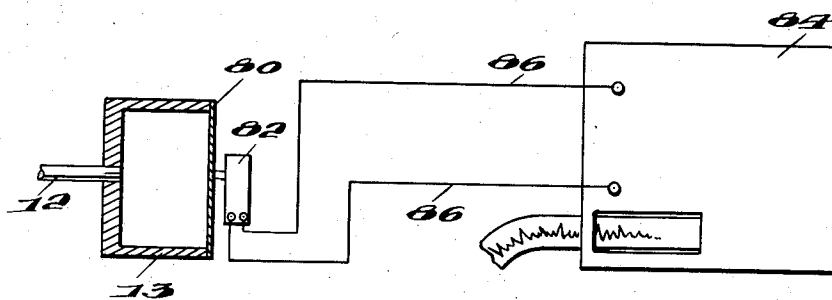


Fig. 5.



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3 Sheets-Sheet 3

Fig. 6.

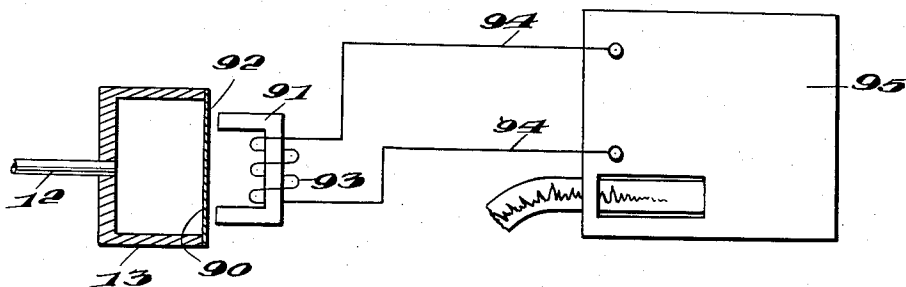


Fig. 7.

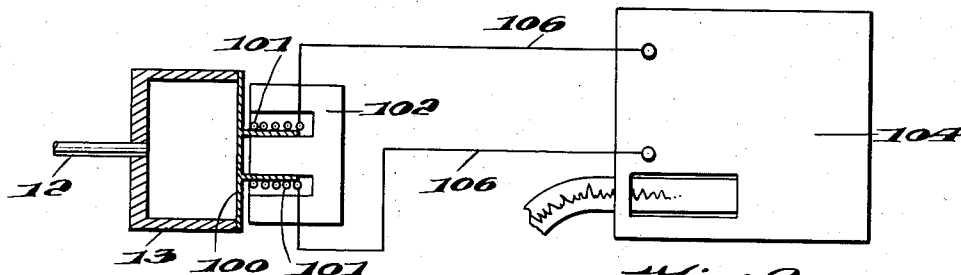
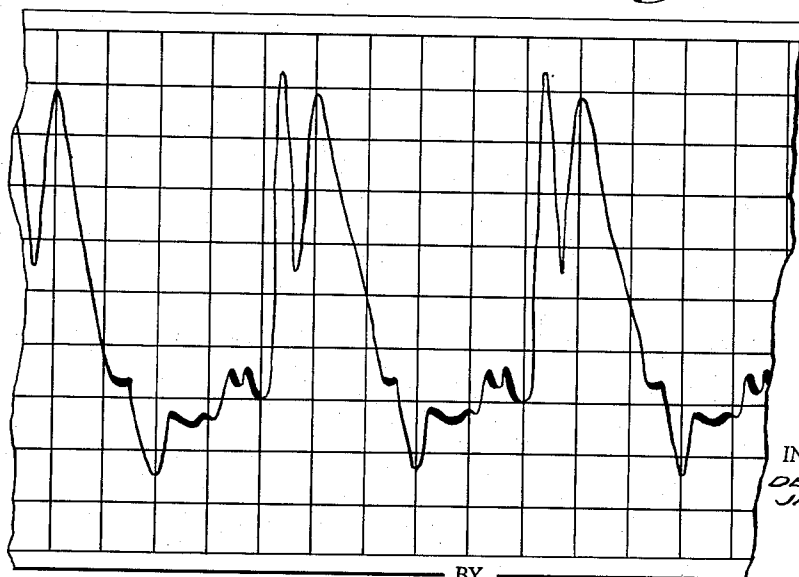


Fig. 2.



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METHOD FOR DETERMINING THE FORM OF WAVES PRODUCED IN THE LUNGS AND RESPIRATORY PASSAGES BY THE BEATING OF THE HEART AND MOVEMENTS OF BLOOD WITHIN THE HEART, LUNGS AND CHEST CAVITY

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12 Claims. (Cl. 128-2.05)

This invention pertains to a new method and improved apparatus for the diagnosis and progressive study of a large number of pathological conditions as these may exist in the heart or lungs, or in other structures of the body such as the blood vessels, the thyroid or adrenal glands, or the brain (e.g., tumors) as these other structures or organs may indirectly affect the heart or lungs.

Contemporary studies of heart or lung pathology are usually based upon results obtained by the use of such procedures or techniques as percussion, auscultation, blood pressure determinations, fluoroscopy or X-ray photography, ballistocardiography, electro-cardiography, cardiac catheterization, plethysmography, venous pressures or modification or combination of one or more of these procedures. Notwithstanding this formidable array of diagnostic aids it not infrequently happens that correct diagnoses are missed during the life of the patient and sometimes even at the autopsy. Since heart and general circulatory diseases constitute one of the main causes of death at the present time, it is desirable that all possible aids be recruited toward the solution of these problems, some of which, such as essential hypertension have defied all investigations. The novel method described below has been successfully utilized for diagnosing and for studying from day to day the therapeutic progress, or the lack thereof, of certain forms of heart and lung disease, and the improved equipment described herein has enabled me to secure permanent graphic records of the action of the heart and of the circulation of the blood in the lungs and chest.

My unique method is based upon the vibration phenomena of air, or other respiratory media, such as oxygen, war-gases, nitrous oxide, ether vapor, helium, etc., as these gases are caused to be vibrated by undulating waves resulting from the beating of the heart and the circulation of the blood within the chest. These undulatory vibrations, which are small and rapid, are normally superimposed upon the relatively large and slow waves of air which result from inspiration and expiration.

The small amplitude and relatively high frequency waves upon which the novel method of this invention is predicated are readily distinguished from the relatively large amplitude and low frequency waves created by inspiration and expiration. In the process of recording by electrical transducing means both groups of waves, i.e., the "heart beat" waves and the waves resulting directly from inspiration and expiration, these latter waves may be eliminated by filter means positioned in the electrical recording circuit. However, I have obtained satisfactory results by having the patient cease breathing and remain in a state of complete immobility for a period of five seconds just after the end of a normal expiration.

Preparatory to recording the aforesaid waves of small amplitude and relatively high frequency, the patient should lie down and remain at rest for a period of fifteen minutes in a quiet room. During this period he should sit on a nose and mouth enclosing mask and become accustomed to breathing through it in a normal fashion with is breathing or air valve open. The mask may be held in the face by the patient or an attendant nurse, but it has been found more satisfactory to use the rubber straps

conventionally supplied with nose and mouth enclosing masks to hold the mask in place with the patient lying supine and completely at rest on the table. The data for a visual display are taken through the nose—not through the mouth which must be kept closed, with the mask fitted down airtight over both the mouth and nose. The reason for this is that it is quite difficult for a patient to keep his mouth open without moving his tongue, cheeks, soft palate, pharynx, larynx, vocal cords or even his diaphragm or chest walls. But if the mouth is kept closed with the tip of the tongue resting gently just against the posterior surface of the lower incisor teeth it is quite easy for the patient—just after the end of a normal, quiet exhalation—to remain perfectly quiet for five seconds (and usually much longer). During this brief interval the attendant nurse, or preferably the patient, closes the breathing or air valve on the mask and the record is taken. The record is made just after the end of expiration because the patient's vocal cords are then relaxed, and the airway passage is then open from the nostrils into the lungs. That is, the patient is just ready to draw air into the lungs but he delays the actual inspiration for a brief interval while the record is taken. Many records may be taken in rather rapid sequence is desired. The operator of the recording device can watch the movements of the stylus or writing arm in order to make the records at the proper time as above discussed.

Chart records made by my novel method are different from those made by any other known process, and they may be used in diagnosis or in the therapeutic follow-up of such conditions as coronary thrombosis, cardiac arrhythmias, valvular lesions, coarctation of the aorta, hypertension, cor pulmonale, patent ductus arteriosus, aneurism, etc., and in a great variety of clinical conditions in which cardiac or pulmonary complications may be present or anticipated. In anesthesiology it not infrequently happens that a patient receives enough curara, or similarly acting drug, to produce complete immobility of all the striated muscles including those of respiration. On such occasions, this method can be used to advantage, in intervals between artificial inflations of the lungs, to record the actions of the heart, or its response to remedial or new drugs. In this latter field, especially in laboratory experiments, much valuable information regarding new or old drugs which act on the heart or bronchioles may be obtained in curarized animals. The records may be obtained directly from a tracheal cannula with the animal intact or with the chest open. This method may, to a large extent, replace older methods in which the chest is opened and a myocardiograph, a strain gauge, or other instrument is attached directly to the heart in order to study its action under varying circumstances. My technique is expected to be especially useful in the study and evaluation of new drugs.

A large number of different forms of equipment may be employed in a variety of ways to produce a visual display of the undulating wave forms above discussed. As a matter of clarity, I wish first to present a preferred form of apparatus as indicated in FIGURE 1 which I have successfully used in recording the undulatory waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs and chest cavity. In this figure which represents a general and schematic presentation of the equipment, reference numeral 1 represents the patient's heart, 2 the lungs, 3 the trachea near the level of the larynx, 4 the chest wall, 5 the diaphragm and 6 the patient's head rotated to the left as related to the anterior view of the chest. The naso-pharyngeal cavity is indicated at 7, which opens outwardly through the nostrils, while posteriorly and inferiorly the pharynx connects, through the larynx, with the trachea. The oral cavity connects with

the pharynx just above the epiglottis, but if the mouth is kept closed, the air in the oral cavity plays no part in production of the aforesaid record. But under some circumstances it is desirable to make records of the above-described undulating waves with the mouth open, using an ordinary commercial anesthesia mask into which the subject can breathe through both mouth and nose, or a special mouthpiece may be used with the nostrils closed. Special practice is necessary to obtain good records in this manner.

The face mask which is preferably used is shown at 8 with its tubulature 9 connected with the special fitting 10. From the special fitting 10 a small tubulature 11 connects with a relatively small diameter flexible rubber tube 12 which transmits the vibrations of the air column to the tambour enclosure 13. At 14 is shown a special framework which carries a small inflatable rubber bulb 15 which connects through tube 16 with the hand operated bulb 17. When bulb 15 is deflated, the subject can easily breathe back and forth through the special fitting 10 into the atmosphere. But when the subject suddenly squeezes bulb 17 air is forced through tube 16 into bulb 15 which expands and closes off the outer opening of special fitting 10. This prevents the vibrations within the face piece 8 from escaping out into the open air and forces them to be transmitted into the tambour enclosure at 13. The membrane 18, covering the tambour enclosure may be made of rubber or metal or other suitable material. This membrane carries on its upper surface a small circular metal plate from the center of which a small post 19 supports a movable arm or writing lever 20 on the transverse knife edge top of the post. The writing lever 20 is pivotally mounted by hinge pin 21 on the base post 22 which is longitudinally adjustable along supporting rod 23. The supporting rod 23 is fixedly supported at 50 by any suitable structure. The longitudinal adjustment controls the lever arm and consequently the extent of the magnification of movement which the writing lever 20 experiences in its travel between the light slit 25 positioned within housing 31 and the photoelectric cell 26 which is spaced from said slit. Base post 22 is held immovable in adjusted position by set screw 24. The photoelectric cell is preferably of the emissive type. A beam of light emerging from a light source in the form of lamp bulb 27, passes through condensing lens 28, light slit 25 and strikes upon the sensitive surface of photoelectric cell 26. Writing lever 20 which is formed with a small mass and hence a low degree of inertia adjustably intercepts this light beam, and with each beat of the heart the lever registers a series of small rapid vibrations, usually about fourteen in number but varying in character and number from patient to patient. These rapid interruptions of the light beam cause corresponding variations in the output of the photoelectric cell which is employed to energize through conductors 29 a recording device which may comprise an electrocardiograph as shown at 30. It is to be noted that the tambour is here represented for illustrative purposes as being in a perpendicular position while the lamp, lens and photoelectric cell are also shown in the vertical position. In actual practice the axis passing through the lamp, lens and photoelectric cell should be arranged at right angles to the direction of vibration of the tambour writing point. The aforesaid tambour, light controlling means and photosensitive device serves as a percussion transducer which is responsive to the waves existing in the gas column of which the patient's naso-pharyngeal cavity and trachea form a part.

Reference numeral 31 indicates the housing which carries the light source 27, the condensing lens 28 and the light slit 25 while at 32 is shown the casing holding the cell or battery 33 and the spring 34 which makes electrical contact between the cell or battery and the metal cap 35. The insulating plate 36 carries the switch 37 which is connected to the lamp base 38 by the insulated

conductor 39 and to the metal cap 35 by the insulated conductor 40. The power cable 41 connects the electrocardiograph mechanism to the source of electrical energy which may be 110 volts A.C. At 43 is shown the selector switch on the electrocardiograph which selects the input channel through which the electrical quantities representing the vibrations are recorded. A specially wired and electrically controlled device (R-wave injector) may be inserted between the plug of the connecting wires 29 and the electrocardiograph device 30, and this device may be used to show, by means of a very small superimposed V-wave, the exact instant when the ventricles contract. The use of the R-wave injector may be of considerable help in following through the various events of the cardiac cycle. At 44 is indicated the general appearance of the record as it emerges from the recorder. Further description of the electrocardiograph is believed unnecessary since I employ this device only as a means to provide a graphic record of the small and rapid undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs, and chest cavity. It is contemplated that other known types of sensitive recording devices may be used in lieu thereof in which a stylus traces the record on chart paper or the like, or in which the traces are formed by the impingement of a light beam on a light sensitive surface such as a photographic film.

FIG. 2 is exemplary of the record of vibrations obtained by the use of the above-described equipment and technique wherein are shown in graphic form the small amplitude and rapid rate undulations produced in the lungs and respiratory passages by the beating of the heart and movements of blood in the heart, lungs, and chest cavity. Inasmuch as the record of vibrations shown in the trace of FIG. 2 was made at the end of expiration as above described, the relatively large and slow undulations created by inspiration and expiration are not superposed upon the vibration curve. If other techniques are employed to obtain the record data while the patient is normally breathing, a low frequency, high pass filter 52 shown in FIG. 1 connected in the output of photoelectric tube 26 can be adjusted to eliminate, prior to recording the test data, the undesired undulations caused by the patient's breathing.

FIG. 1 is illustrative of the use of a displacement type of transducing device for converting the mechanical movements of the tambour membrane into electrical energy. It is contemplated that other transducing type mechanisms may be substituted for the device shown in FIG. 1 which may be responsive to the quantum or amplitude of change or the rate of change without departing from the scope of this invention. FIGS. 3, 4 and 5 are schematic representations of other types of transducing systems which may be employed to record the undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs, and chest cavity. FIG. 3 discloses a variable resistance transducing mechanism wherein the membrane or diaphragm 60 of the tambour 13 is vibrated in accordance with the pressure of the undulating waves in tube 12. Reference numeral 62 represents a carbon granule microphone which is associated with diaphragm 60 and is energized thereby. The output of the carbon granule microphone 62 is connected to the input terminals of recorder 64 by conductors 66 so that the record on chart sheet 68 will faithfully indicate the pressure variations within the tambour. In FIG. 4, a metallic diaphragm 70 cooperates with a spaced plate type electrode 72 connected in circuit with an oscillator 74, coupling transformer 76, rectifier 78 and recorder 79. Movement of the thin metallic diaphragm 70 in accordance with the pressure of the waves received in tambour 13 via tube 12 will cause the air gap between flexible diaphragm 70 and plate 72 to vary, thus changing the capacitance of the oscillator circuit and causing the stylus of the recorder to follow the pressure variations of the tambour. The movement of

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diaphragm 80 disclosed in FIG. 5 is translated into electrical energy by piezo-electric crystal 82, the output of which is connected to the input terminals of recorder 84 by leads 86. Pressure changes within tambour 13 result in the vibration of diaphragm 80 and the variation of pressure applied to piezo-electro crystal 82. As a result, the output response of the crystal varies in accordance with the pressure applied thereto and this electrical energy output is recorded on the chart of recorder 84.

I have found that in making certain diagnoses it is desirable to employ vibration information resulting from the employment of means for converting the motion of the tambour membrane into electrical energy which is proportional to the rate of pressure change as distinguished from the quantum of pressure. FIGS. 6 and 7 disclose recording systems wherein the transducing means are of the velocity type and respond to rate of pressure change. In FIG. 6, diaphragm 90 is formed of a thin flexible iron sheet, and a permanent magnet identified by reference numeral 91 is positioned adjacent to the diaphragm but spaced therefrom a distance equal to the width of air gap 92. Coil 93 is positioned about the magnet and is connected by leads 94 to the input terminals of recorder 95. When flexible diaphragm 90 is vibrated in accordance with the pressure waves conducted to tambour 13 through tube 12, air gap 92 varies in width to change the reluctance of the magnetic path, and hence a voltage is generated in coil 93 which is proportional to the rate of pressure change. FIG. 7 discloses a somewhat similar velocity type transducing means wherein diaphragm 100 which may be formed of flexible paper, rubber, metal, or clothlike material, has a coil 101 mounted thereon so that the coil vibrates in accordance with the pressure waves which are conducted to tambour 13 through tube 12. Coil 101 is positioned to cut the magnetic lines of flux created by permanent magnet 102 as coil 101 is moved in accordance with the vibrations of diaphragm 100. The output of coil 101 is a function of the rate of cutting of the lines of magnetic flux and hence serves to energize the recorder 104 through conductors 106 with a voltage which is proportional to pressure changes within tambour 13. It will be clear that suitable filters may be utilized with the circuitry shown in FIGS. 3 to 7 inclusive for the purpose of eliminating unwanted waves such as the waves resulting from inspiration and expiration.

From the above description it is clear that my invention contemplates the recording of the undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs, and chest cavity by the use of various types of transducing means. The transducing means serve to translate the wave pressures into electrical responses, which in turn energize a recording device to produce a graphic record on the chart thereof. The selection of the particular type of transducing device will be dependent upon the diagnoses and results to be achieved, and, accordingly, my invention contemplates the broad concept of determining the forms of the aforementioned waves irrespective of the particular types of mechanisms utilized in achieving the graphic records.

I claim:

1. A method of determining the forms of undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of positioning a percussion transducer responsive to said undulating waves in communication with a respiratory passage containing a gas column vibrated by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, and translating the response of said transducer into a permanent record of said undulating waves.

2. A method of determining the forms of undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood

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within the heart, lungs and chest cavity, comprising the steps of positioning a percussion transducer responsive to the pressure of said undulating waves in communication with a respiratory passage containing a gas column vibrated by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, and translating the response of said transducer into a graphic record of said undulating waves.

3. A method of determining the forms of undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of positioning a percussion transducer responsive to the rate of pressure change of said undulating waves in communication with a respiratory passage containing a gas column vibrated by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, and translating the response of said transducer into a graphic record of said undulating waves.

4. A method of determining the forms of undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of positioning a percussion transducer responsive to the pressure waves of inspiration and expiration and to said undulating waves in communication with a respiratory passage containing a gas column vibrated by the pressures of inspiration and expiration and by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, filtering from the transducer output the component resulting from the pressures of inspiration and expiration and translating the transducer output component resulting from said undulating waves into a graphic record.

5. A method of determining the forms of undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of positioning a transducing device for translating into electrical energy the said undulating waves in communication with a respiratory passage containing a gas column vibrated by the beating of the heart and movements of the blood within the heart, lungs and chest cavity and recording the electrical output energy of said transducing device to obtain a graphic record of said undulating waves.

6. A method of determining the forms of undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of positioning a transducing device for translating into electrical energy the pressure of said undulating waves in communication with a respiratory passage containing a gas column vibrated by the beating of the heart and movements of the blood within the heart, lungs and chest cavity and recording the electrical output energy of said transducing device to obtain a graphic record of the pressure of said undulating waves.

7. A method of determining the forms of undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of positioning a transducing device for translating into electrical energy the rate of pressure change of said undulating waves in communication with a respiratory passage containing a gas column vibrated by the beating of the heart and movements of the blood within the heart, lungs and chest cavity and recording the electrical output energy of said transducing device to obtain a graphic record of the rate of pressure change of said undulating waves.

8. A method of determining the forms of undulating waves produced in the lungs and respiratory passages of a person by beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of placing a mask over the face to enclose

the nose and mouth of said person, subjecting a percussion transducer responsive to said undulating waves to the pressure variations existing within the interior of said mask, and translating the response of said transducer into a permanent record of said undulating waves.

9. A method of determining the forms of undulating waves produced in the lungs and respiratory passages of a person by beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of placing a mask over the face to enclose the nose and mouth of said person, subjecting a percussion transducer responsive to the pressure waves of inspiration and expiration and responsive to said undulating waves to the pressure variations existing within the interior of said mask, filtering from the transducer output the component resulting from the pressures of inspiration and expiration, and translating the response of said transducer resulting from said undulating waves into a permanent record.

10. A method of determining the forms of undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of positioning a recorder input circuit including a variable resistance in communication with a respiratory passage containing a gas column vibrated by the beating of the heart and movements of the blood within the heart, lungs and chest cavity so that said resistance will be varied in accordance with the wave energy existing in said gas column, and recording in graphic form the variations in said resistance resulting from said undulating waves.

11. A method of determining the forms of undulating

waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of positioning a recorder input circuit including a variable capacitance in communication with a respiratory passage containing a gas column vibrated by the beating of the heart and movements of the blood within the heart, lungs and chest cavity so that said capacitance will be varied in accordance with the wave energy existing in said gas column, and recording in graphic form the variations in said capacitance resulting from said undulating waves.

12. A method of determining the forms of undulating waves produced in the lungs and respiratory passages by the beating of the heart and movements of the blood within the heart, lungs and chest cavity, comprising the steps of positioning a recorder input circuit including a variable reluctance in communication with a respiratory passage containing a gas column vibrated by the beating of the heart and movements of the blood within the heart, lungs and chest cavity so that said reluctance will be varied in accordance with the wave energy existing in said gas column, and recording in graphic form the variations in said reluctance resulting from said undulating waves.

References Cited in the file of this patent

UNITED STATES PATENTS

1,686,504	Dodge	Oct. 2, 1928
2,073,412	Cappelli	Mar. 9, 1937
2,099,938	Lockhart	Nov. 23, 1937
2,139,509	Marcellus	Dec. 6, 1938