Jan. 24, 1928.

1,657,078

H. A. FREDERICK ET AL

ACOUSTIC STETHOSCOPICS

Filed Dec. 3, 1925

Fig.2.

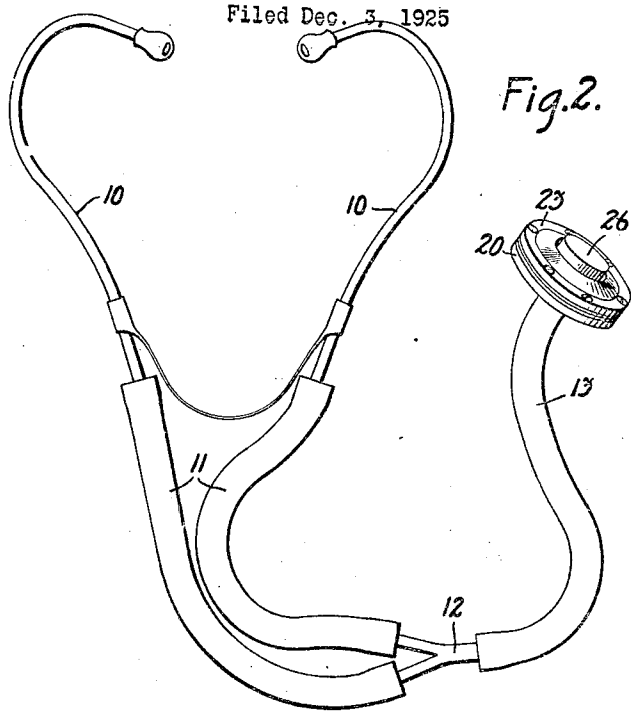


Fig.3.

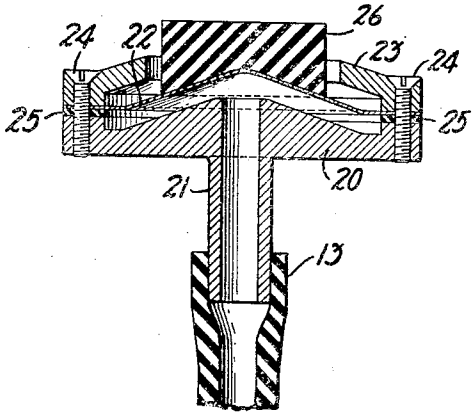
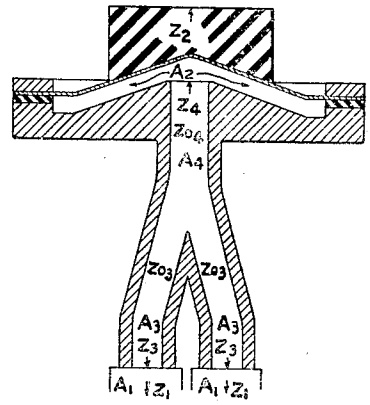


Fig.1.



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Patented Jan. 24, 1928. 1,657,078

UNITED STATES PATENT OFFICE.

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ACOUSTIC STETHOSCOPICS.

Application filed December 3, 1925. Serial No. 72,915.

This invention relates to acoustic devices and particularly to stethoscopes.

An object of the invention is to provide a simple, durable and inexpensive acoustic instrument which will faithfully and efficiently reproduce in the ear of an observer the internal body sounds such as those of the circulatory and the respiratory organs, or sounds from other subjects under study.

A feature of the invention is the acoustic matching of impedances from the body to the ear passage thereby providing a stethoscope with substantially no transition losses.

The mechanical impedance of a given area of the chest or other part of the human body, and that of the ear canal or a column of air of a definite area and termination being known, the invention provides means for transmission of sound energy therebetween at maximum efficiency.

The invention in its preferred form comprises in part a pick-up device consisting of a vibratory diaphragm carrying a contact member of soft elastic material. These elements are so proportioned that they comprise a coupling which substantially serves as a perfect transformer. From the space behind the diaphragm to the ear canals, the intervening air passages have been constructed in exact ratios from predetermined values of the relative impedances of these elements, completing an accurate acoustic line from body to ear as will be hereinafter described.

Referring to the drawings, Fig. 1 is a diagrammatic sketch in section of the instrument which will be referred to in the mathematical discussion.

Fig. 2 is a perspective view of the invention in its preferred form.

Fig. 3 is a cross sectional view of the pick-up device.

It is well-known from the theory of the transformation of mechanical impedances by means of diaphragms and fluids confined in chambers, that the ratio of the impedances (Z) is directly proportional to the squares of the effective areas (a), that is:

$$\frac{Z_1}{Z_2} = \frac{a_1^2}{a_2^2}. \quad (1)$$

It is also well known that the expression

$$Z_0 = \sqrt{\frac{\frac{a(r+jwm)}{\left(g+\frac{jw}{s}\right)}}{a}} \quad (2)$$

is the mechanical impedance of an air column of uniform area with distributed constants where r, g, m and s are the resistance, conductance, mass and stiffness per unit length and area, w is 2π times the frequency and a is the total area. In the case of a column of air, where r and g are negligible in comparison with the other factors, the expression reduces to the form

$$Z_0 = a\sqrt{ms}. \quad (3)$$

Since the values of m and s are known for air the above expression reduces to

$$Z_0 = 41 \cdot 5a \frac{\text{dyne seconds}}{\text{cm.}}. \quad (4)$$

Due to the unevenness of the chest wall, especially for emaciated patients, the maximum satisfactory area of contact is taken as 3.9 square cm. for which the impedance is approximately $15000 \frac{\text{dyne seconds}}{\text{cm.}}$. At the ear the area of the canal is approximately .5 sq. cm. with a termination such that the impedance is approximately $95 \frac{\text{dyne seconds}}{\text{cm.}}$.

Now in the system by which the motion of the chest wall of a patient produces the sensation of hearing on the part of an observer, the two elements, the impedances of which differ in magnitude, can be joined to transmit the vibrational energy of the patient efficiently by use of an acoustic transformer, just as in electric systems unequal impedances are often connected by an electric transformer to obtain maximum efficiency. In this connection and referring to Fig. 1 of the drawings, Z_1 is the impedance of the ear canal, A_1 the effective area at this point, Z_3 the impedance of one of the tube branches, and A_3 the area of this tube. We

find from equation (1) that the impedance of the ear measured from the tube is

$$Z_3 = Z_1 \frac{A_3^2}{A_1^2}. \quad (5)$$

At the chest wall Z_2 is the impedance looking into the body, A_2 is the effective area of the diaphragm, Z_4 is the impedance of the connected outgoing air passage and A_4 is the area of this passage. Substituting in equation (1) as before the following expression is obtained for the chest impedance measured through the tube A_4

$$Z_4 = Z_2 \frac{A_4^2}{A_2^2}. \quad (6)$$

The characteristic impedance of each ear tube of area A_3 by equation (4) is:

$$Z_{03} = 41.5 A_3. \quad (7)$$

For minimum transition loss at the Y junction in the branching air tubes, the sum of the characteristic impedances of the two branches must be the same as that of the main tube. Thus there results the following equation:

$$2Z_{03} = Z_{04} \quad (8)$$

from which

$$2A_3 = A_4. \quad (9)$$

Also for maximum efficiency $Z_3 = Z_{03}$ and $Z_4 = Z_{04}$ and by solving the various equations the areas at the various parts of the system for the terminal impedances specified above, are found to be as follows:

$$A_2 = A_1 \sqrt{\frac{2Z_2}{Z_1}} = 8.88 \text{ sq. cm.}$$

$$A_3 = 41.5 \frac{A_1^2}{Z_1} = .109 \text{ sq. cm.}$$

$$A_4 = 2A_3 = .218 \text{ sq. cm.}$$

It is therefore clear that for a given ear impedance Z_1 and chest impedance, Z_2 only one acoustic line can exist for which the transmission of sound from the chest wall to the ear drum will occur without loss due to improper impedance relations and that when this condition exists the distortion of sounds by the system will be a minimum.

In Fig. 2 the stethoscope is shown comprising ear tubes 10, connecting tubes 11, Y piece 12, main tube 13, and a pick-up device 14. The construction of the air passage elements from the pick-up device 14 to the ear may be of any well known type and of any suitable material so long as the cross-sectional area is the size specified in the conclusions of the mathematical analysis. The main tube 13 is made with a cross-sectional area twice as great as one of its branch tubes 11, as noted above if one person is to observe but may be made any multiple of 2 for larger numbers of observers.

Referring to Fig. 3 which shows the pick-up device in cross-section, a base 20 has a stem 21 forming a mounting for the main tube 13. A diaphragm 22 is held in position and protected by an annular ring 23 which is attached to the base 20 by means of screws 24 or threads. The ring 23 and base 20 constitute a casing for the diaphragm. The diaphragm 22 may be of any suitable metal and may be corrugated or ribbed to increase the stiffness of the material. To obtain the greatest effective area with a minimum diameter and to withstand excessive pressure, the diaphragm is preferably made conical although this is not necessary to the functioning of the instrument as a flat diaphragm with proper characteristics could be employed. The conical diaphragm further makes possible a more compact and rugged structure. A gasket 25 is used between the ring 23 and the base 20 to form an air tight connection.

Cemented to the center and covering approximately one-half the area of the diaphragm is a contact element 26 comprising a mass of elastic material, such as rubber. The preferred diameter of this contact element is determined by experiment while that of the diaphragm is determined by computation as in the above case.

A specific example with exact dimensions of the various chambers is given herewith for the purpose of more fully disclosing the invention. In one instrument constructed and successfully employed by applicants, the area of the contact element 26 is 3.9 sq. cm. with a diameter of approximately 2.2 cms. This element with a depth of approximately 1 cm. is cemented to the center portion of the conical diaphragm 22. The conical diaphragm has a free diameter of 3.8 cms. which provides an effective area of substantially 8.88 sq. cms. The diameter of the cone portion is 3.4 cms. The casing has a diameter of 4.7 cms. which is the over-all dimension of the pick-up device.

Leading from the diaphragm chamber is the main tube of 0.53 cm. diameter and branching at the Y into tubes 11, having diameters of .37 cms. for the case of one observer. These dimensions make the area of the main tube passage .218 sq. cms. and that of the branch passages .109 cms. maintaining the total area constant from the diaphragm chamber to the ear channels including ear pieces.

The above described instrument has been constructed from the standpoint of matched impedances and the instrument has greatly increased and improved the transmission of internal body sounds. For the purpose of completely disclosing the invention it has been described in connection with a specific instrument, but the invention is to be limited only by the scope of the attached claims.

What is claimed is:

1. A stethoscope having a diaphragm and sound passages for transmitting sounds from said diaphragm to a point of reception, said diaphragm and sound passages being proportioned to transmit said sound with substantially zero transition losses.

2. The method of increasing the efficiency of the transmission of sound in acoustic stethoscopes and like instruments comprising matching the acoustic and the mechanical impedances of the instrument throughout, from the ear canal to the vibrating surface under study.

3. In a stethoscopic device, a casing, a diaphragm, therein, a contact element secured to said diaphragm, and a series of sound passages proportioned to correctly couple the impedances at the ends of said series of sound passages.

4. In an acoustic stethoscopic device having a vibratory member proportioned to match the impedance at the source of sound, sound passages leading from said vibratory member to the point of reception, said sound passages being proportioned to match the impedance at the point of reception.

5. In a stethoscopic device, a diaphragm, a chamber adjacent said diaphragm, and an outgoing passage leading from said chamber, said outgoing passage dividing into two or more branch passages, the ratio between the areas of said chamber, outgoing passage and branch passages being such as to correctly couple the mechanical impedances therebetween for audible frequencies.

6. In a stethoscopic device, a diaphragm, a contact element secured thereto, a chamber adjacent said diaphragm, an outgoing passage leading from said chamber, and branch passages leading from said outgoing passage, the constants of said diaphragm and contact element and the areas of said chamber and passages being proportioned to transmit sound at the greatest efficiency between said contact element and the end of said branch passages.

7. In a stethoscopic device having a detector end and a receiving end, an acoustic line coupling said ends, comprising a plurality of sections of different cross sectional areas in series the ratio of the square of the areas of adjacent sections varying directly as the impedances.

8. In a stethoscopic device having a detector end with an impedance equal to that of a given area of chest wall and a receiving end with an impedance equal to the ear canal impedance, and an acoustic line correctly coupling said ends and said impedance so that transmission loss and distortion will be a minimum.

9. A sound receiving instrument comprising a pick-up element matched in impedance to the medium from which the sounds are to be received, an ear piece element matched in impedance to the ear canal, and an acoustic transmission path interconnecting said pick-up element and ear piece element and having an impedance, looking into each of substantially the same magnitude as that of the respective elements throughout the frequency range of the sounds to be transmitted.

In witness whereof, we hereunto subscribe our names this 1st day of December A. D., 1925.

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