Nov. 24, 1931. F. A. MITCHELL 1,833,055

DIAPHRAGM FOR SOUND REPRODUCING APPARATUS

Filed Oct. 21, 1926

Fig. 2

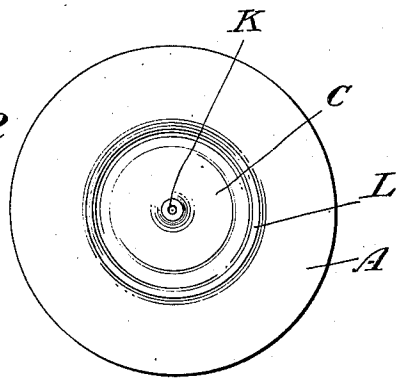


Fig. 1

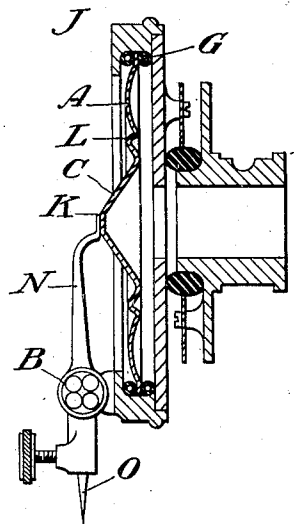


Fig. 3

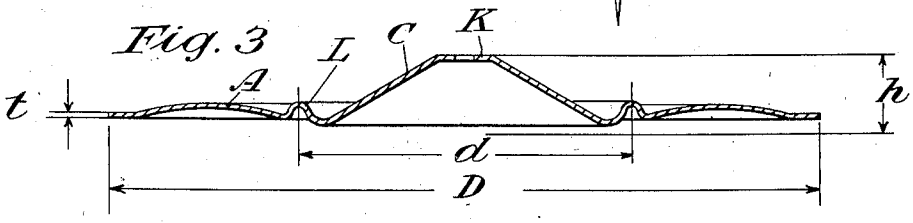


Fig. 4

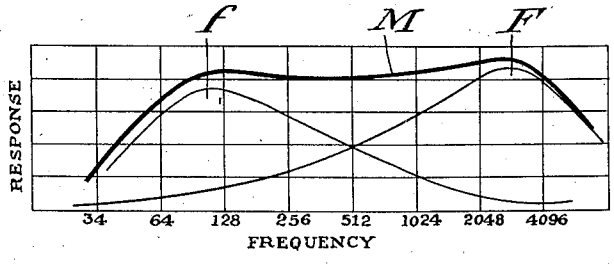


Fig. 5

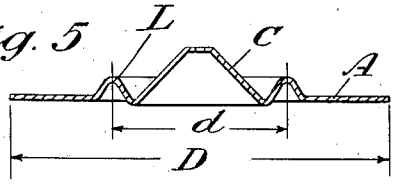


Fig. 7

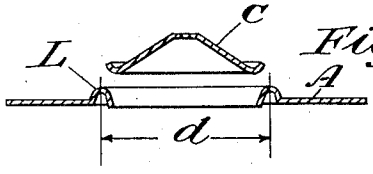


Fig. 6

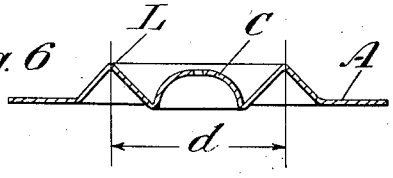
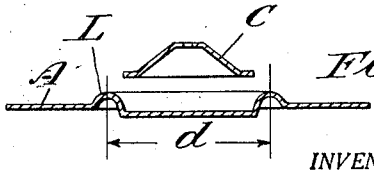


Fig. 8



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UNITED STATES PATENT OFFICE

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DIAPHRAGM FOR SOUND REPRODUCING APPARATUS

Application filed October 21, 1926, Serial No. 143,135, and in Great Britain October 27, 1925.

This invention relates to diaphragms for use in the reproducers of talking machines, radio and telephonic apparatus, and the like, and has special reference to that class of metal diaphragm having conical or other shapes formed therein.

As hitherto constructed such diaphragms are more sensitive to a certain note or notes than to others, thus rendering a distorted reproduction of the original sound waves, and moreover, they tend to give unequal volumes of sound relative to the sound wave pressure.

The object of the present invention is to provide an improved construction of diaphragm for use in apparatus of the above character which will be sensitive to extreme frequencies of the musical scale and will give substantially equal volume of sound throughout the middle and upper frequencies for an equal sound wave pressure.

The invention consists in a diaphragm for use in apparatus responsive to or adapted to reproduce sound vibrations, comprising two zones separated by a flexing ring, the inner zone being relatively rigid in itself and able to vibrate as a whole relative to the outer zone, said inner zone not exceeding in diameter one half the total diameter of the diaphragm.

The invention also consists in a diaphragm for use in apparatus of the kind referred to comprising two zones separated by a flexing ring, the inner zone having a mass so proportioned that its natural frequency is at least an octave and preferably about three octaves above the natural frequency of the outer zone.

This invention also consists in a diaphragm of the above character formed of aluminium or alloy and having a protective coating or covering of an elastic material.

Other novel features will be disclosed with reference to the accompanying drawings, in which:—

Fig. 1 shows a complete sound-box fitted with one of the improved diaphragms.

Fig. 2 is a plan view of a diaphragm.

Fig. 3 is an enlarged section of the diaphragm shown in Fig. 2.

Fig. 4 is a graph showing the acoustic result obtained by the improved diaphragm.

Figs. 5 and 6 are examples of alternate constructions for diaphragms according to this invention.

Fig. 7 shows a diaphragm having two independently formed zones ready for assembly.

Fig. 8 is a modified form of Fig. 7.

In carrying my invention into effect, I prefer to employ aluminium or aluminium alloy for the construction of my improved diaphragm for the reason that such material while having a low specific gravity is sufficiently ductile to permit of its being formed into a suitable shape to produce the effects which the invention aims at attaining, although any suitable material, such as celluloid or other mouldable substance, may be used.

I have found that the thickness of the material of the diaphragm should be between .0015 and .0035 of its overall diameter and for the purpose of illustration the thickness of .005″ has been chosen, this being .0025 of the diameter of the diaphragm which in the following example is 2″.

Fig. 3 shows the sectional contour of a diaphragm, the constructional details of which are (by way of example) fully explained in the following description:—

The diaphragm is formed with two relatively rigid zones A and C (see Fig. 2) separated from one another by means of a flexing flute or ring L.

The diaphragm is normally mounted in a sound-box as shown in Fig. 1, the edge of the diaphragm being held but not clamped between the rubber gasket rings G in the sound-box rim J. The centre K of the dia-

phragm is attached to the stylus bar N or to its equivalent vibrating member in the usual way, and the sound wave impulses are to be applied to the center of the inner zone of the diaphragm.

The stylus bar is mounted on frictionless ball bearings B in such a manner that the stylus bar has no elastic frequency of its own but merely transmits all audio-frequency vibrations from the needle point O to the diaphragm centre K without noticeable distortion.

The sound-box case is mounted on a connector, as described in Patent No. 1,546,924, of July 21, 1925, to prevent any excessive vibrations causing distortion.

In order to obtain a semi-rigid central zone C in the diaphragm, I form an obtuse cone, the base diameter d of which should not exceed one half of the overall diameter D of the diaphragm.

The outer zone A is also preferably semi-rigid and is shaped as shown in Fig. 3 of the drawings.

The inner zone C and the outer zone A are flexibly connected together by means of the ring L which is preferably U-shaped in section and is adapted to bend or flex at its maximum at approximately the diameter d.

The diaphragm is so proportioned that the two zones are naturally responsive to different frequencies which are preferably over two octaves apart.

The relative values of these resonant peaks are so proportioned that they combine to give the diaphragm an almost equal response efficiency value over a range of three or more octaves.

The following is the method by which I obtain the correct proportions to suit my purpose:—

The area a of the central zone is preferably determined by the equation

$$a = \pi r \sqrt{r^2 + h^2}$$

Where $r = .25\sqrt{3\sqrt{9h^4 + 4h^2R^2 + 4R^4} - 9h^2 - 2R^2}$

h = the height of the cone $\left(\text{usually } \frac{R}{5}\right)$

R = the radius of the complete diaphragm

$\pi = 3.1416$

For example:

Where $h = .508$ c. m. (allowance being made for the turn at L.)

R = 2.54 c. m. for a 5.08 c. m. (2 inch) diaphragm.

I obtain from the above equation:—

$r = .25\sqrt{3\sqrt{173.762} - 15.266}$

$= 1.232$ c. m. = the radius of the base d of the central cone-shaped zone.

Therefore the area a is as follows:—

$a = 3.87\sqrt{1.518 + .258}$

$= 5.16$ square c. m. = area of central zone.

The area of the outer zone A is determined by the equation

$$A = \pi R^2 - \pi r^2.$$

From the above equation I obtain

A = (20.270 − 4.769) square c. m.

= 15.50 square c. m. = area of outer zone.

From the above figures I will now proceed to determine the relative frequencies of the two zones.

In the example I suggested an aluminium diaphragm 2″ diameter by .005″ thick (when flat) which in centimeters is 5.08 c. m. diameter by .0127 c. m. thick.

The specific gravity of pressed aluminium is about 3.1 which determines the total weight of the above diaphragm to be .8 gramme. This can also be determined by actual weighing.

As the total diaphragm weighs .8 gramme, the relative weight of the two zones A and C can be arrived at as follows:

The area $A + C$ (πR^2) : .8 gramme : : the area C (πr^2) ; w, where w is the weight in grammes of the inner zone C.

Calculation shows $w = .19$ grammes, which when subtracted from the total weight:—

.8 − .19 = .61 gramme = the weight W of the outer zone A.

The natural frequency f of a zone is determined from the following equation:—

$$f = \frac{\pi d^3 \sqrt{2\pi r t E}}{D\, a x w^2}$$

Where $d = 2r$

D = 2R

t = thickness of the diaphragm

E = modulus of elasticity for aluminium = 773,400.000 other symbols being as before.

For example, a cone C having dimensions as set forth above has a natural frequency f as follows:—

$$f = \frac{643.966}{.18627} = 3457 \text{ vibrations per second,}$$

and the outer zone A having dimensions as above has a frequency F as follows:—

$$F = \frac{643.966}{5.7714} = 111.5 \text{ vibrations per second.}$$

From the above, it will be seen that the natural frequency can be reduced by increasing the area and weight of a zone or the frequency can be increased by reducing the area and weight, there being a certain relation of sizes and weights which will give the desired result which is an equal response for an equal

sound wave impulse over a range of musical frequencies.

Therefore, I have so proportioned the dimensions to suit the material used to give two extreme musical frequencies f and F which when blended as shown in the graph (Fig. 4) will give an almost equal response (denoted by the line M) for all frequencies between about 100 per second up to about 4000 per second, and which will effectively reproduce musical notes having frequencies between about 60 per second to about 6000 per second. It will be seen that this almost embraces the common musical scale.

If the two natural frequencies f and F are spaced further apart there is a falling off in response to the middle frequencies (at about 512, see Fig. 4) and if the frequencies f and F are brought nearer together there is a loss in response to the extreme frequencies.

It will be seen from the above that I have chosen what I consider to be approximately the best dimensions for a diaphragm constructed according to my invention, but it must be understood that a slight deviation one way or the other will not appreciably depart from the scope of the invention.

This latitude is specially applicable to the determination of the relative areas of the zones A and C which can be compensated for by altering other factors. Broadly, I proportion the diameter d (see Fig. 3) so that it is between $\frac{1}{3}$ and $\frac{1}{2}$ the total diameter D and when using aluminum I limit the thickness t to between .0015 and .0035 the diameter D.

The actual shape of the area C may be varied as shown in Figs. 5 or 6, the flexing annulus or ring being suitably shaped to allow the centre zone C, denoted by the diameter d, to vibrate without undue restraint from the outer zone A.

To insure a more rigid central zone and to facilitate flexing on the diameter d, the inner cone or shaped piece C may be formed separately and may be inserted within the outer zone A as shown in Figs. 7 and 8, the centre portion C being cemented or otherwise fastened into position when assembled.

The cone and annulus C and A may be formed in the diaphragm by spinning, pressing or otherwise.

The outer zone of the diaphragm may be of a different thickness, hardness or material from the inner zone, and in order that the diaphragm may not be deleteriously affected by exposure to atmosphere, I have found it desirable to coat or cover one or both sides of the diaphragm (by spraying or otherwise) with a thin film of elastic material, such as rubber or one of the cellulose derivatives or the diaphragm may be electro-plated with any suitable metal or otherwise treated for the purpose set forth.

While I have shown and described preferred and satisfactory embodiments of the invention, it is to be understood that the drawing and description is by way of illustration only, and that changes as desired may be made within the scope of the appended claims, to which reference must be had for a definition of the limitations of the invention.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is to be performed, I declare that what I claim is:—

1. A diaphragm, comprising two zones separated by a flexing ring, the inner zone being relatively rigid in itself and able to vibrate as a whole relative to the outer zone, said inner zone not exceeding in diameter one half the total diameter of the diaphragm, and said zones being so proportioned that the natural frequency of the inner zone is at least an octave above the natural frequency of the outer zone.

2. A diaphragm comprising two zones separated by a flexing ring, the inner zone being so proportioned that its natural frequency is from one to three octaves above the natural frequency of the outer zone.

3. A diaphragm comprising two zones separated by a flexing ring, the inner zone being relatively rigid in itself and able to vibrate as a whole relative to the outer zone, the inner zone not exceeding in diameter one half the total diameter of the diaphragm and the natural frequency of each zone being determined by the equation

$$f=\frac{\frac{\pi d}{D}\sqrt[3]{2\pi r t E}}{axw^2}$$

4. A diaphragm comprising two zones separated by a flexing ring, the inner zone being so proportioned that its natural frequency is at least an octave and preferably about three octaves above the natural frequency of the outer zone, and the natural frequency of each zone being determined by the equation

$$f=\frac{\frac{\pi d}{D}\sqrt[3]{2\pi r t E}}{axw^2}$$

5. A diaphragm comprising two zones separated by a flexing ring, said zones being so proportioned as to be responsive to two spaced frequencies which combine to give approximately equal response to equal sound wave impulses between the two said frequencies and throughout a range of at least two musical octaves.

6. A diaphragm comprising two zones separated by a flexing ring, the inner zone being relatively rigid in itself and able to vibrate as a whole relative to the outer zone, the diameter of the inner zone not exceeding one half the total diameter of the dia-

phragm and the area of said inner zone being approximately one third the area of the outer zone.

7. A diaphragm comprising two zones separated by a flexing ring, the inner zone being so proportioned that its natural frequency is at least an octave above the natural frequency of the outer zone, and the area of said inner zone being approximately one third the area of the outer zone.

8. A diaphragm comprising two zones separated by a flexing ring, said zones being so proportioned as to be responsive to two spaced frequencies which combine to give approximately equal response to equal sound wave impulses between the two said frequencies and throughout a range of at least two musical octaves, and the area of the inner zone being approximately one third the area of the outer zone.

9. A diaphragm comprising two zones separated by a flexing ring, the inner zone being so proportioned that its natural frequency is at least an octave and preferably about three octaves above the natural frequency of the outer zone, and the area of said inner zone being within 10% of that determined by the equation

$$a-\pi r\sqrt{r^2+h^2}$$

10. A diaphragm comprising two zones separated by a flexing ring, said zones being so proportioned as to be responsive to two spaced frequencies which combine to give approximately equal response to equal sound wave impulses between the two said frequencies and throughout a range of at least two musical octaves, and the area of said inner zone being within 10% of that determined by the equation

$$a-\pi r\sqrt{r^2+h^2}.$$

11. A diaphragm comprising an inner zone, an outer zone, a flexing ring comprising a single corrugation connecting said zones, and said inner zone comprising a hollow portion having inclined walls connected to the flexing ring in a plane to one side of the plane occupied by the outer zone.

12. A diaphragm comprising a body including inner and outer zones, said outer zone being slightly bowed, and said body having a flat edge portion.

13. A diaphragm comprising inner and outer zones connected by a flexing portion, said outer zone being slightly bowed, and said diaphragm including a flat edge portion surrounding said body portion.

14. A diaphragm comprising inner and outer zones of which one is more rigid than the other, a corrugation connecting said zones, said outer zone being slightly bowed, and the outer edge of said outer zone being flat.

15. A diaphragm comprising inner and outer zones, the outer of said zones being slightly bowed, and the inner of said zones being substantially in the form of a frustum.

16. A diaphragm comprising inner and outer zones, a flexing ring connecting said zones, the outer of said zones being slightly bowed, and the inner of said zones being substantially in the form of a frustum.

Signed at London, England, this 4th day of October, 1926.

FRANK ALLEN MITCHELL.