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P. B. FLANDERS

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SOUND RECORDING AND REPRODUCING INSTRUMENT

Filed April 28 1928

FIG. 1.

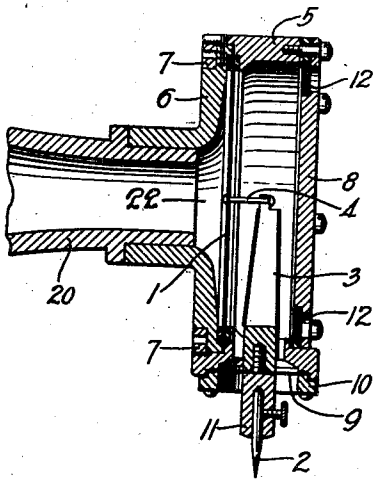


FIG. 2.

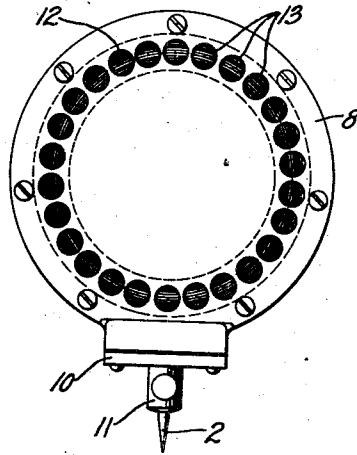


FIG. 3.

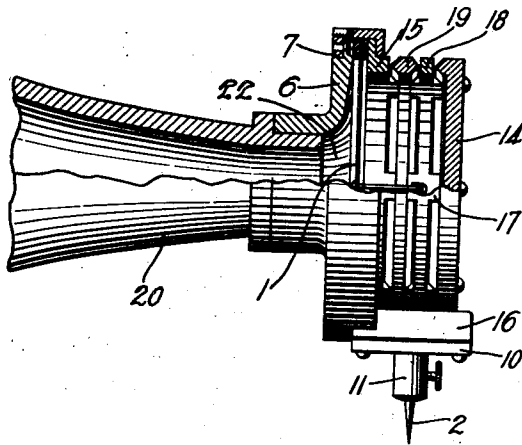
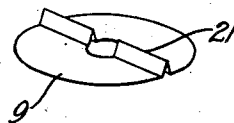


FIG. 4.



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## SOUND RECORDING AND REPRODUCING INSTRUMENT

Application filed April 28, 1928. Serial No. 273,525.

This invention relates to sound recording and reproducing instruments, and more particularly to sound boxes for phonographs, loud speakers, and the like.

5 An object of the invention is to improve the quality of phonograph sound reproduction by eliminating the high pitched radiation that takes place from the back of the diaphragm in the usual open type of sound box. It is well known that, for this purpose, 10 it is not sufficient merely to enclose the back of the diaphragm by an air-tight cover, for the reason that the elasticity of the enclosed air chamber so formed interferes with the 15 normal mode of motion of the diaphragm, and causes a deterioration in the quality of the reproduced sounds. I have found also that partial enclosures ordinarily produce 20 similar effects, since they tend to act like Helmholtz resonators, and to produce abnormal reactions on the diaphragm at their resonance frequencies.

In accordance with this invention distortion of the reproduced sounds due to enclosing the back of the diaphragm is prevented 25 by so arranging the enclosure that it adds to the diaphragm a damping load of impedance similar in character to that due to the horn, while at the same time it strongly attenuates any sound waves that may tend to 30 be radiated from the back of the diaphragm. In order that the efficiency of reproduction may not be impaired the load on the back of the diaphragm is preferably made small in 35 comparison with that due to the horn.

The damping effect on the back of the diaphragm is produced by providing the enclosure with an air leakage path which acts 40 as a pure acoustic resistance. This resistance dissipates the energy of the radiated sound waves and prevents their being radiated to the surrounding air. The similarity of the impedance characteristics of the horn load 45 and that due to the enclosure is achieved by properly proportioning the volume of the enclosing air chamber and the resistance of the leakage path therefrom, with respect to the volume of the horn coupling air chamber, and to the acoustic resistance of the horn. 50 Acoustic resistance devices suitable for use

as resistive leakage paths are disclosed in my copending application Serial No. 273,523, filed April 28, 1928.

Other objects of the invention thus include the improvement of the damping characteristics of sound box enclosures, and the improvement of the tone quality of sound reproducers having enclosed sound boxes. 55

A feature of the invention, by which the design of sound box enclosures for stylus operated phonographs is greatly simplified, is an air-tight pivot support for a stylus arm. By this means irregular openings around the stylus arm pivot are eliminated and the air leakage from the enclosed chamber is confined entirely to the resistive path. 60 65

In the detailed description which follows a limited number of embodiments of the invention in phonograph sound boxes will be described. It will be understood, however, 70 that the invention is not restricted to the particular devices shown, but may be applied to other types of sound reproducers without departing from the spirit of the appended claims. 75

Referring to the drawings, Figs. 1 and 2 show, respectively, a cross section and an elevation of an improved sound box embodying the invention; Fig. 3 shows in part section an alternative construction embodying 80 the invention; and Fig. 4 illustrates a detail of the air-tight stylus support.

The sound box shown in Figs. 1 and 2 comprises a diaphragm 1 arranged to be driven 85 in the usual manner by a stylus 2 through a pivoted needle arm 3 to which the diaphragm is coupled by a driving link 4. The diaphragm is mounted in a recessed supporting ring 5, and is enclosed in front by a face plate 6 which is secured to the member 5 by 90 a screwed clamping ring 7. The face plate 6 and the ring 7 also serve to clamp the diaphragm in position. The face plate 6 is provided with a flanged central opening for coupling to a sound conduit or horn 20, which is 95 preferably of the exponential type, that is, one having a cross-sectional area which increases in equal ratios for equal distances along the axis. The space between the face plate 6 and diaphragm 1 constitutes an air 100

chamber 22 which, in accordance with well known principles, acts as a coupling member between the diaphragm and horn.

The back of the diaphragm is enclosed by a cover plate 8, and, in order that the enclosure may be complete a special air-tight support is provided for the stylus arm. Instead of using a pivot support of the conventional type the stylus arm is mounted through the center of a small circular diaphragm 9 which is clamped by a clamping ring 10 in a recessed opening in the side of the ring member 5. The stylus arm is made in two parts, the lower part 11, which serves as the stylus holder, having a projecting screw which passes through a hole in the center of the diaphragm 9 and is screwed into the base of the upper portion of the arm. The diaphragm 9 may be made of very thin aluminum sheet or of other flexible material, in which case very little elastic restraint will be placed upon the angular vibration of the stylus arm in the direction perpendicular to the diaphragm 1. To restrain the motion in other directions the diaphragm 9 is provided with a stiffening rib along its diameter parallel to the plane of diaphragm 1. This is shown in detail in Fig. 4, the rib 21, in this case, being formed by folding or embossing the diaphragm along a diameter. To insure the proper assembly of the stiffened diaphragm in the sound box, fine diametral slots parallel to the plane of diaphragm 1 are cut in the rim of the recess in plate 5, in which the pivot diaphragm is mounted, and in the base of the upper part of the stylus arm. The ends of the rib fit closely into these slots, thus ensuring that the stiffening effect is in the proper direction, and does not interfere with the normal vibration of the stylus arm.

An air leakage path from the air chamber back of the diaphragm, is provided by an acoustic resistance device 12, which preferably consists of a flat annulus formed by winding a fine metallic ribbon into a closely spaced flat spiral, whereby a uniform finely slotted structure is obtained. If the slots are very narrow, .005 inch or less, the impedance to the flow of air is controlled almost entirely by viscosity and is substantially of a purely resistive character. If the slots are all uniform the resistance value is readily calculable from the dimensions. The principles involved in the design of resistance structures of this type, and methods suitable for their manufacture are described in my co-pending application Serial No. 273,523, filed April 28, 1928. The resistance device is mounted in an annular recess in the back plate 8, a series of holes 13 in the back of the recessed portion being provided to complete the air leakage path.

The manner in which the back enclosure should be proportioned will be understood from the following considerations of the

principles involved and from the computation of an illustrative example.

The acoustic load on the front of the diaphragm consists of the horn impedance modified by the velocity absorbing or shunting effect of the elasticity of the air in the chamber formed by the face plate 6. For high quality reproduction it is desirable that the horn impedance should be a constant pure acoustic resistance at all frequencies, which condition may be met in practice by the use of a slowly divergent logarithmic horn. The load on the front of the diaphragm may thus be considered as composed of a constant acoustic resistance shunted by an elasticity. In order that the enclosing of the back of the diaphragm may not produce any distorting effect, it is necessary that the additional acoustic load due to the enclosure should at all frequencies bear a constant numerical ratio to load on the front of the diaphragm. The impedances introduced by the enclosing arrangement are of the same type as those that make up the horn load, the acoustic resistance device 12 corresponding to the horn, and the enclosed air chamber providing the shunting elasticity. The constant numerical ratio of the two loads may be secured by proportioning the two air chambers so that their elasticities are in the desired ratio, and proportioning the horn and the resistive device to have resistances in the same ratio. The elasticity of an air chamber in which the air is compressed by a diaphragm has the value, as measured at the diaphragm.

$$S = \frac{\rho c^2 A_d^2}{V} \text{ c. g. s. units} \quad (1)$$

where

$S$  denotes the elasticity,  
 $\rho$  the density of air,  
 $c$  the velocity of sound in air,  
 $A_d$  the area of the diaphragm, and  
 $V$  the volume of the air chamber.

The elasticities of the two chambers enclosing the diaphragm may therefore be given any desired ratio by simply proportioning their volumes in the inverse ratio.

The resistive load placed on the diaphragm by the horn has the value  $Z_h$  given by the equation.

$$Z_h = \frac{41.3}{A_h} \cdot A_d^2 \text{ c. g. s. units}, \quad (2)$$

where  $A_h$  is the diameter of the horn throat opening. The resistive load added by the finely slotted leakage path from the rear chamber is the impedance due to the viscous resistance to air flow in the slots and has the value

$$Z = \frac{12\mu l}{d^3} \cdot A_d^2 \quad (3)$$

where

$\mu$  is the viscosity coefficient of air,  
 $d$  the separation between the walls of the slots,

$l$  the length of the slots in the direction of flow, and

$A_s$  the total cross sectional area of the slots composing the leakage path.

If the width of the slots is less than about .005 inch the reactance of the path is negligibly small, and the impedance comprises only the resistance given by Equation 3.

Equations 2 and 3 enable the principal dimensions of the resistance device to be designed for any preassigned ratio of the load impedances. For example, let it be assumed that the load impedance added by the enclosure should be one tenth of that due to the horn. This fraction is not large enough to have any noticeable effect upon the loudness of the reproduced tones. From Equations 2 and 3 it follows that

$$\frac{l}{d^2} = \frac{1}{10} \cdot \frac{41.3}{12\mu} \cdot \frac{A_s}{A_h} \quad (4)$$

The slot area  $A_s$  is the area of slot exposed by the holes 13 in the back plate, and is equal to the total area of the holes multiplied by a space factor dependent upon the construction of the resistance device. A value of .005 cm (.002 inch) may be assumed for the slot width  $d$ , and an equal value for the thickness of the ribbon by which the slots are formed, in which case the space factor is 0.5. There is then left to be determined the length  $l$  of the slots, and the total area of the holes 13, these values being capable of some mutual adjustment to secure the best practical construction. If it be assumed, for example, that the outlet area of the holes is twice the area of the horn throat the value of  $l$  works out to be .05 cm. This is also the width of the ribbon that must be used to wind the resistance unit. If it is desired to use a wider ribbon either the separation  $d$  may be increased, or the total exposed area of the resistance unit may be increased, for example by adding another unit of smaller diameter and providing additional holes in the back plate. Resistance devices of the type described are completely effective for preventing the escape of any sound wave energy from the back of the diaphragm, practically all of the energy being dissipated in overcoming the viscosity of the air.

For the ratio of 10 to 1 in the impedances assumed in the foregoing computation the air chamber volumes should be in the inverse ratio, or 1 to 10. This corresponds roughly to a back air chamber ten times as deep as the front air chamber.

Resistance devices other than the slotted type described above may be used for the enclosure damping resistance. The device 12 may for example be replaced by a flat annulus of porous material such as celotex. In

that case, however, the resistance cannot be calculated, and the proper dimensions of the celotex ring must be determined experimentally. The irregularity of the cellular structure in porous materials; moreover, results in an irregularity in their impedance characteristics, and in consequence the damping action is not uniform at all frequencies.

In Fig. 3 the damping resistance for the back enclosure is obtained by a slotted structure of a somewhat different type. The diaphragm 1 and the face plate 6 are mounted on a supporting ring 15 having a projecting part 16 in which the needle arm is supported in the same manner as in Fig. 1. The back of the diaphragm is enclosed by a back plate 14 and by rings 18 and 19 which form the side walls of the enclosure. These rings are partially cut away to accommodate the needle arm where they join the projecting part 16. In addition they are separated from each other and from the elements 14 and 15 by a number of small projecting bosses, such as 17, to provide a plurality of peripheral slots of width about .008 cm. The sides of the rings are tapered down almost to knife edges to reduce the length of the slots to a minimum, the reason for this being that a very short length is necessary for a low resistance value with the rather limited slot area available in this structure.

What is claimed is:

1. An acoustic system comprising in combination a diaphragm, a sound conduit, an air chamber between said diaphragm and said conduit, and a casing enclosing the other side of said diaphragm, said casing having a plurality of apertures adapted to provide an acoustic path of substantially pure resistive impedance at all important speech frequencies, and the cross sectional area of said apertures and the volume of the air chamber enclosed by said casing being proportioned to provide an acoustic load on said diaphragm which is a constant fraction of the acoustic load due to said horn and said first mentioned air chamber.

2. An acoustic system comprising in combination a diaphragm, a sound conduit coupled to one side of said diaphragm, a casing enclosing the other side of said diaphragm, said casing having a plurality of apertures forming parallel walled slots of width between the walls less than .005 inch, and the cross sectional area and length of said apertures being proportioned with respect to the area of said conduit whereby the apertures present a load impedance to said diaphragm which is constant and less than 20 per cent of the load due to said conduit at all important speech frequencies.

3. A sound reproducing instrument comprising a diaphragm, a horn, an air chamber between said diaphragm and said horn, and a casing enclosing the other side of said dia-

phragm, said casing having a plurality of apertures forming parallel walled slots of width less than .005 inch between walls, the acoustic impedance of said apertures and the volume of the air chamber enclosed by said casing being proportioned respectively with respect to the acoustic impedance of said horn and the volume of the air chamber between the horn and the diaphragm to provide an acoustic load which is a substantially constant fraction at all important speech frequencies of the load due to the horn and its associated air chamber.

4. A phonograph sound box comprising a diaphragm, a casing enclosing one face of said diaphragm, a stylus arm adapted to drive said diaphragm and means for pivotally supporting said stylus arm on said casing, said means comprising a flexible diaphragm mounted in an aperture in said casing, said flexible diaphragm providing an acoustic seal between said stylus arm and said casing.

5. A phonograph sound box comprising a diaphragm, a casing enclosing one face of said diaphragm, a stylus arm adapted to drive said diaphragm, and means for pivotally supporting said stylus arm on said casing, said means comprising a flexible circular diaphragm attached to said needle arm with its plane perpendicular to the axis thereof and mounted in an aperture in said casing, said flexible diaphragm providing an acoustic seal between said stylus arm and said casing.

In witness whereof, I hereunto subscribe my name this 27th day of April, 1928.

PAUL B. FLANDERS.

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