July 1, 1930. C. R. HANNA 1,768,903

SOUND PRODUCING DEVICE

Filed March 25, 1927

Fig. 1.

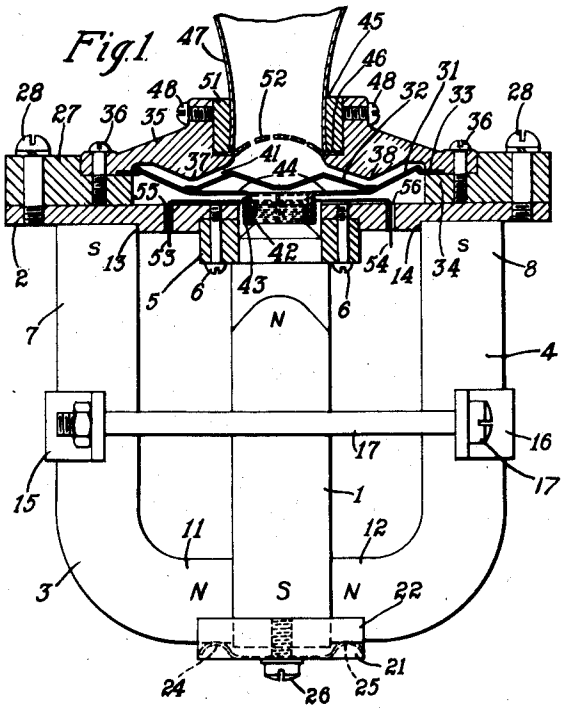


Fig. 2.

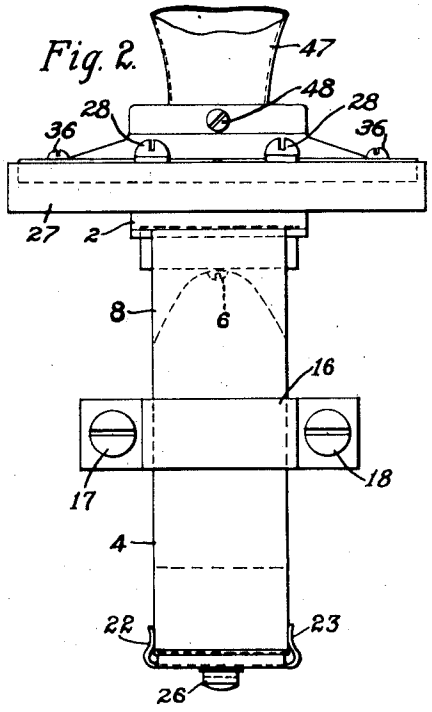


Fig. 3.

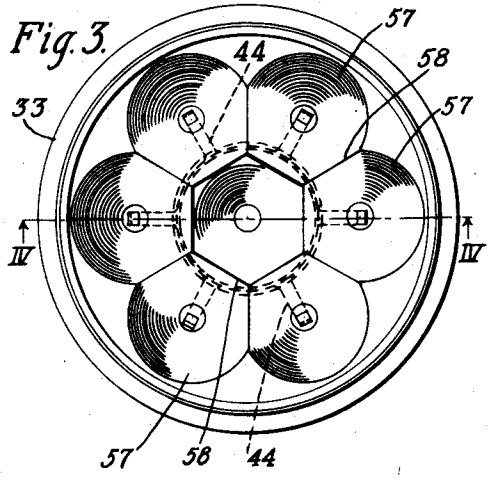
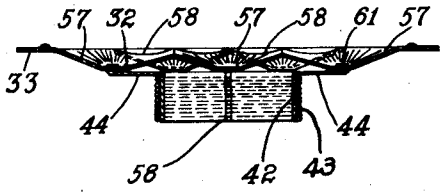


Fig. 4.



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UNITED STATES PATENT OFFICE

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SOUND-PRODUCING DEVICE

Application filed March 25, 1927. Serial No. 178,164.

My invention relates to sound-producing devices and more particularly to devices of the type known as loud speakers.

One object of my invention is to provide an electro-dynamically operated sound-producing device in which the sound-output pressure is at all times proportional to the energizing current, for large values of current.

Another object of my invention is to so design a loud speaker that the diaphragm thereof shall produce uniform air velocity in the throat of the horn over a wide range of sound frequencies, provided the effective current in the actuating means therefor remains constant.

Another object of my invention is to provide an electro-dynamic sound-producing device particularly adaptable for use with a horn having an exponential curvature.

A still further object of my invention is to provide an improved magnetic circuit for a sound-producing device of the type described.

In a copending application filed by Joseph Slepian and Clinton R. Hanna, Serial No. 690,405, on February 4, 1924, and assigned to the Westinghouse Electric and Manufacturing Company which has matured into Patent No. 1,623,561, there is disclosed an exponently curved horn particularly adaptable for use in connection with loud-speakers, such as are employed in radio reception and in public-address systems. In the Hanna and Slepian application, it is pointed out that, by utilizing a horn of the shape disclosed, it is possible to maintain a constant ratio between the sound pressure radiated from the horn and the average air velocity at the throat of horn, over a wide range of frequencies.

By the present invention, which is in the nature of an improvement over the invention disclosed in my former application, I have provided a diaphragm-actuating mechanism that is peculiarly adaptable for use in connection with an exponentially curved horn. By properly proportioning the relative mass and stiffness of the various component parts of my actuating mechanism, I have produced a device that gives a uniform air velocity, in the throat of an exponential horn, resulting in a sound output that is substantially free from distortion over a wide range of frequencies.

Among the novel features that are considered characteristic of my invention are those set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with further objects and advantages thereof, will best be understood by reference to the following description taken in connection with the accompanying drawings, in which

Figure 1 is a side elevational view, partly in section, of a preferred embodiment of my invention,

Fig. 2 is an end elevational view,

Fig. 3 is a top plan view of a preferred type of diaphragm, and

Fig. 4 is a sectional view of the diaphragm, taken along a line corresponding to the line IV—IV of Fig. 3.

Referring specifically to Figs. 1 and 2, the magnetic portion of my improved loud speaker preferably comprises a central pole piece 1, a bridging member 2, and two L-shaped magnets 3 and 4. The bridging member 2, which is made of a magnetic material having a high permeability, is provided with a central opening into which projects a reduced, cylindrical portion of the central pole piece 1. The pole piece 1 is maintained in position centrally of the opening in order to define an air-gap, the holding means therefor comprising a non-magnetic collar 5 frictionally mounted thereon and fastened to the under side of the bridging member 2 by a plurality of screws 6.

The L-shaped permanent magnets 3 and 4 which, together with the central pole piece 1, are preferably made of cobalt-steel, are so arranged that the ends of the longer portions 7 and 8 thereof abut the under side of the bridging member 2, while the ends of the shorter portions 11 and 12 are held in firm contact with the lower portion of the central pole piece. The L-shaped magnets are clamped firmly against the central pole piece 1, and against shoulders 13 and 14 provided

on the bridging member, by means of a plurality of U-shaped members 15 and 16, tension being exerted thereon through a plurality of tie-rods 17 and 18.

A guard element 21, provided with upturned edges 22 and 23, and with spring portions 24 and 25, is mounted on the lower end of the central pole piece 1 by means of a screw 26 and serves to prevent movement of the lower ends of the L-shaped magnets with respect to the said pole-piece. The spring portions 24 and 25 of the guard element exert an upward pressure on the L-shaped magnets, thus tending to maintain the upper ends thereof in firm contact with the bridging member 2.

A mounting element 27 of non-magnetic material such as brass or the like, and which may or may not be circular in shape, is mounted on the bridging member 2, and is held firmly in position by a plurality of screws 28. The mounting element is provided with a centrally located circular opening 31, slightly larger in diameter than a diaphragm 32 which is suspended therein from a flexible annulus 33 that, in turn, is tightly clamped between a shoulder 34 surrounding the opening 31 and a non-magnetic horn-supporting element 35. A plurality of screws 36 maintain the horn-supporting element 35 in position on the mounting element 27, and provide the necessary pressure to hold the annulus 33 tightly clamped.

The under surface of the horn-supporting element 35 is provided with a plurality of conical protuberances 37 and 38 which cooperate with depressions in the diaphragm 32 to define an air chamber 41, the dimensions of which are very accurately pre-determined.

A coil supporting form 42, on which is wound a coil 43 adapted to carry currents representing the sounds to be reproduced, is suspended from the under surface of the diaphragm by a plurality of arms 44. These arms, which will later be referred to collectively as the "spider", have a definite amount of stiffness, the value of which is definitely predetermined, and which is hereinafter designated as S_1.

In the drawing, the circular air-gap between the central pole piece 1 and the bridging member 2 is greatly exaggerated, in order that the coil supporting form 42 and the winding 43 may be more clearly visible. In an actual embodiment of my invention this air gap is about 1.5 millimeters wide.

The horn-supporting element 35 is provided with a central opening 45 having a surrounding raised portion or collar. Interiorly of the opening is a circular shoulder 46 on which is supported the throat 47 of an exponential horn, a plurality of set screws 48 passing through the collar and contacting a ferrule 51 carried by the horn, serving to hold the same in fixed position relative to the opening.

A dome-like guard element 52, provided with perforations, also rests upon the shoulder 46, and is held in position by the lower end of the horn. This element prevents foreign objects from being so inserted into the horn as to cause injury to the diaphragm.

The manner in which the leads are brought out from the coil forms no part of the present invention. In the drawing, Fig. 1, leads 53 and 54 are shown as passing down through openings 55 and 56 drilled in the bridging member. This arrangement, however, is merely illustrative, it being perfectly feasible to pass the leads up and over the bridging member 2, bringing them out through the space between the sides thereof and the lower edge of the central opening 31 in the mounting member 27.

The spaces between the sides of the bridging member 2 and the lower edges of the central opening in the mounting member 27 also have the additional function of preventing the building up of any back-pressure on the diaphragm when it is in motion. This is an important feature, inasmuch as it is desirable that the diaphragm shall be impeded as little as possible, on the side opposite the horn.

Referring to Figs. 3 and 4, the diaphragm 32 is preferably made of an extremely light material, such as aluminum, and is extremely thin in order that it may have a very low mass. The necessary internal stiffness is secured by embossing the diaphragm with a plurality of cone-shape depressions 57, which mutually intersect on hyperbolic lines.

By embossing the diaphragm with a plurality of conical depressions, all of which have curved surfaces, all tendency for the diaphragm to vibrate nodally is obviated. True piston, or plunger action can, therefore, be obtained by applying the driving force to the apices of certain of the cones, with the assurance that the diaphragm will neither buckle nor vibrate in any manner except as a whole.

The mounting annulus 33, preferably of high-grade rubber, or the like, is firmly affixed to the periphery of the diagram by a suitable cement.

The coil mounting form 42 is preferably made of aluminum, of a thickness of not more than .003 of an inch, and may be provided with a slot 58 to prevent the circulation of eddy currents under potentials induced therein when the form is moving in the air gap.

The spider arms 44 may be made integral with the form 42, and they may be provided with terminating portions 61 adapted to be inserted through small openings in the diaphragm 32 and riveted or soldered in place.

Oxidized or enameled aluminum wire has been found to be the best material for the coil

43, the wire being cemented to the form by cellulose nitrate, or other material.

A sound-producing system, such as has been described, is essentially a low-pass mechanical filter, adapted to effectively pass a definite band of sound frequencies. The rate of flare of the horn, and the area of the mouth opening thereof determine the lower cut-off frequency, while the upper cut-off frequency is largely determined by the characteristics of the mechanical vibratory system.

By properly choosing the various proportions of the mechanical vibrating system, the upper cut-off frequency may be made as high as desired.

The following relations, if adhered to, will give rise to a system which produces a constant air velocity in the throat of the horn over a wide range of frequencies:

1. The mass M of the coil 43 and form 42 in grams should together be equal to the mass M_1 of the diaphragm, for the greatest efficiency.

2. The acoustic damping, or mechanical resistance, R, of the horn upon the diaphragm, must equal

$$\pi f_c M \frac{\text{dynes sec.}}{\text{cm.}}$$

where f_c equals the upper cut-off frequency.

3. The stiffness, S_1, of the spider, and S_2, of the air chamber, should equal

$$\pi^2 f_c{}^2 M \text{ and } 2\pi f_c{}^2 M \frac{\text{dynes}}{\text{sec.}}$$

respectively.

The term "stiffness", as applied to the air-chamber, refers to the reaction force on the diaphragm, per unit deflection thereof, when the opening to the horn is closed, and is preferably expressed in dynes per centimeter of deflection.

Considering the diaphragm to act as a piston, the acoustic damping, R, is $41.2 \frac{A_d^2}{A_0}$ in which A_d equals the effective area of the diaphragm, and A_0 is the area of the horn orifice, or throat, at the point where it merges with the air chamber. The correct value of R may be obtained by proper choice of A_0 in relation to A_d.

The stiffness of the spider S_1, in mechanical units, may be determined by an application of well-known physical and mechanical theories and formulæ. The stiffness, S_2, of the air chamber, is the total reaction force on the diaphragm per unit deflection of the diaphragm when the orifice of the horn is closed. The value of the stiffness S_2 may be calculated by the employment of ordinary and well-known laws relating to the pressure and volume of gases.

The overall efficiency of a number of loud speakers constructed according to my invention has been calculated, and verified experimentally. In careful designs it has been found that, in the range of frequencies where the response is uniform, the motion of the diaphragm is so large as to generate a back-voltage substantially one half as great as the voltage required to overcome the clamped impedance of the coil, i. e., the impedance of the coil when motion is not permitted. Under such conditions, the efficiency of the device is approximately 33⅓ per cent, considerably greater than the efficiency of any other high-quality loud speaker with which I am familiar.

Although I have illustrated and described a specific embodiment of my invention, many modifications thereof are possible. My invention, therefore, is not to be limited except in so far as is necessitated by the prior art, and by the spirit of the appended claims.

I claim as my invention:

1. In combination, a diaphragm, an actuating coil carried by a form, and a plurality of resilient arms integral with said form for attaching it to said diaphragm.

2. In combination, a diaphragm, an actuating coil carried by a form, and a plurality of resilient means integral with said form for connecting said form and said diaphragm, the mass of said coil and form being equal to the mass of said diaphragm.

3. In combination, a diaphragm, an actuating coil therefor carried by a non-magnetic form, and a plurality of resilient arms integral with said form for attaching it to said diaphragm.

4. In combination, a diaphragm, an actuating coil therefor carried by a non-magnetic form, and a plurality of resilient arms integral with said form for attaching it to said diaphragm, the mass of coil and form being equal to the mass of said diaphragm.

5. In combination, a non-magnetic diaphragm, an actuating coil therefor carried by an aluminum form, and a plurality of resilient means integral with said form for attaching it to said diaphragm, the mass of said form and coil being equal to the mass of said diaphragm.

6. In a sound-reproducing device, a diaphragm having a plurality of conical depressions therein, and an air chamber having a wall provided with conical raised portions adapted to co-operate with said depressions.

7. In a sound-reproducing device, a diaphragm having a plurality of conical depressions eccentric with respect to one another, and an air chamber having a wall provided with conical raised portions adapted to co-operate with said depressions.

8. In a sound-reproducing device, a diaphragm having a plurality of conical depressions therein, the bases of said depressions intersecting along hyperbolæ.

9. In a sound-reproducing device, a diaphragm having a plurality of conical, mu-

tually intersecting depressions therein, and an air chamber having a wall provided with conical protuberances adapted to co-operate with said depressions.

10. In a sound-reproducing device, a magnetic circuit comprising a central pole piece having a reduced end portion, a plurality of L-shaped permanent magnets, a bridging member provided with an opening to accommodate said reduced portion and means for maintaining said pole piece in fixed relation to said bridging member.

11. In a sound-reproducing device, a magnetic circuit comprising a central pole piece having a reduced end portion, a plurality of L-shaped permanent magnets, a bridging member provided with an opening, means for maintaining said reduced end portion substantially concentric with said opening and means for maintaining said L-shaped magnets in contact with said pole piece and said bridging member.

12. In a sound-reproducing device, a pole piece, a magnetic circuit comprising a bridging member of magnetizable material provided with an opening in which is positioned a reduced end portion of said pole piece, a plurality of L-shaped permanent magnets, means including a plurality of collar-members and a plurality of tie-rods for so removably positioning said permanent magnets in contact with said pole piece and said bridging member that the reduced end of said pole piece and bridging member assume opposite polarities.

13. In a sound-reproducing device, a diaphragm having a plurality of conical depressions therein, a coil supporting form, and resilient means connected between said form and the apices of certain of said conical depressions.

14. In a sound-reproducing device, a diaphragm having a plurality of conical depressions therein, a coil-supporting form, and resilient means connected between said form and the apices of certain of said conical depressions, said resilient means being integral with said coil-supporting form.

15. In an acoustic device, a diaphragm actuating means therefor connected thereto through resilient means, an air chamber, the stiffness of said resilient means being substantially one half that of said air chamber.

In testimony whereof, I have hereunto subscribed my name this 21st day of March, 1927.

CLINTON R. HANNA.