July 4, 1933. D. G. BLATTNER 1,917,012

SOUND TRANSLATING DEVICE

Filed Feb. 5, 1931 2 Sheets-Sheet 1

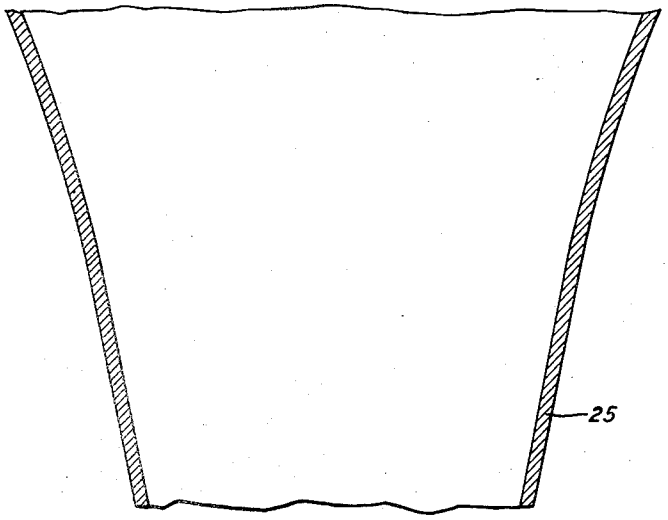
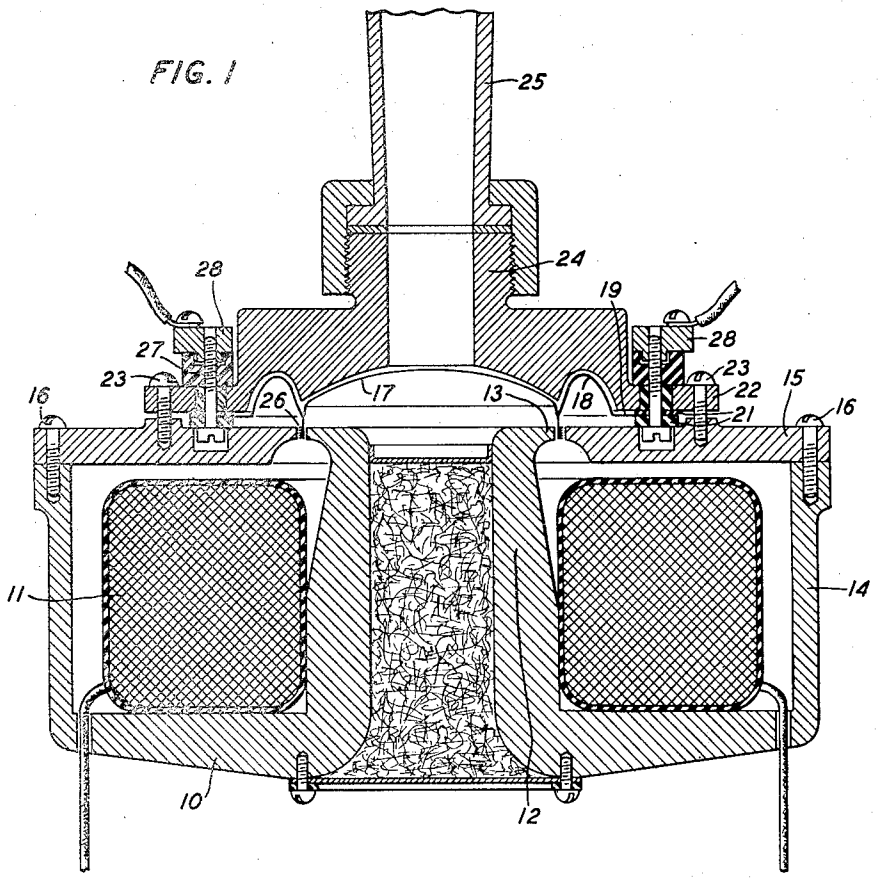


FIG. 1



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FIG. 2

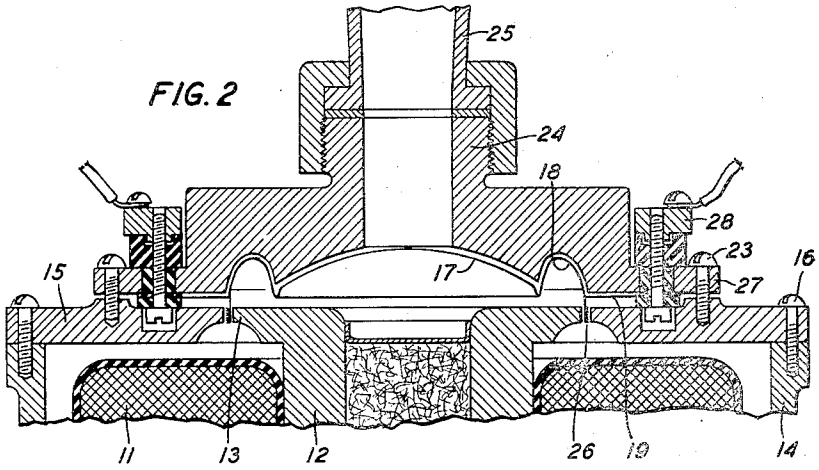


FIG. 3

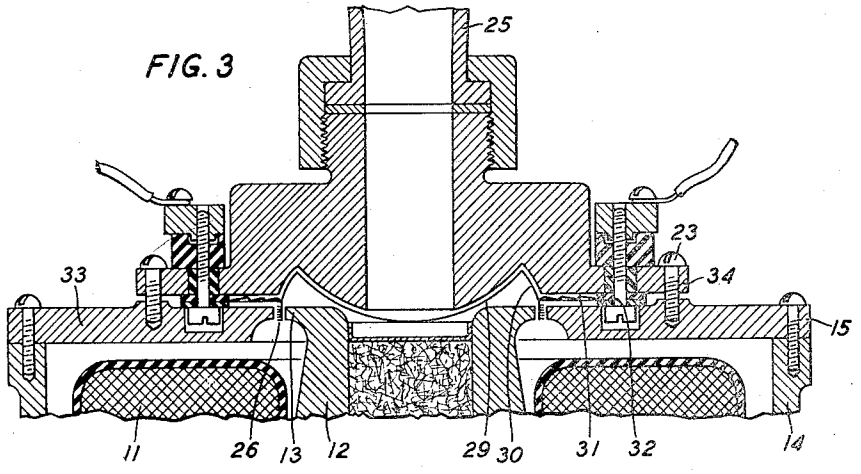
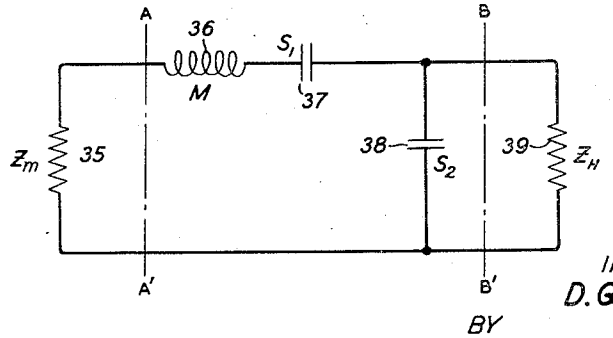


FIG. 4



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UNITED STATES PATENT OFFICE

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SOUND TRANSLATING DEVICE

Application filed February 5, 1931. Serial No. 513,466.

This invention relates to sound translating devices and more particularly to moving coil actuated receivers for use with a horn.

An object of this invention is to translate speech and music uniformly and with high efficiency over a wide frequency range.

In a specific embodiment a loud speaker in accordance with this invention comprises an electromagnet having concentric pole pieces, a diaphragm carrying an annular coil disposed in the narrow annular air gap formed by said pole pieces, a throat member mounted on one of said pole pieces, and a horn associated with said diaphragm through said throat member. The diaphragm comprises a rigid central portion consisting of a dished portion including a trough or flute portion, a flexible portion, and a portion adapted to be clamped. The driving coil may be affixed to the diaphragm at either the inner or outer edge of the trough or flute portion.

In accordance with one feature of this invention the inner surface of the throat member conforms to the dished and trough portions of the diaphragm and the clearance between the diaphragm and the inner surface of the throat member is made such that a maximum air chamber stiffness is obtained while allowing sufficient amplitude of vibration of the diaphragm to produce sound waves of a desired intensity.

In accordance with another feature of this invention, the horn load impedance effective at the diaphragm, the mechanical motional resistance at the driving coil, and the characteristic impedance of the band-pass filter defined by the effective diaphragm mass, the diaphragm edge stiffness, and the stiffness of the air chamber immediately adjacent the diaphragm, are made substantially equal throughout a wide frequency range.

In accordance with still another feature of this invention the upper cut-off frequency of the acoustic system is so chosen that a substantially constant sound pressure is obtained at any point in the sound field over a wide portion of the audio frequency spectrum and the undesirable effect of the contraction of the sound field with increasing frequency is compensated for.

These and other features of this invention will be understood more fully from the following detailed description with reference to the accompanying drawings in which:

Fig. 1 is an elevational view in cross-section of a moving coil loud speaker showing one embodiment of this invention;

Figs. 2 and 3 are fragmentary cross-sectional views of alternative embodiments of this invention;

Fig. 4 is a schematic diagram of an electrical circuit corresponding to the acousto-mechanical system of a loud speaker of the type comprehended in this invention.

In one embodiment shown in Fig. 1, a loud speaker in accordance with this invention comprises an annular troughed magnetic frame 10 enclosing an energizing winding 11. The frame 10 includes a hollow central portion 12 having an accurately machined flange forming an annular pole piece 13, and an outer pole 14. An annular pole piece 15 having a central aperture conforming closely in contour to the pole piece 13 is detachably mounted on the pole 14 by bolts 16. A diaphragm having a dished central portion 17, a flute or trough portion 18 and a flexible portion 19 is secured, together with interposed washers 21, between the outer pole piece 15 and throat member 24 by means of screws, such as 23.

The throat member comprises a flanged portion 22 suitably drilled for allowing passage of bolts 23 for affixing the throat member to the pole piece 15 and a threaded cylindrical portion 24 adapted to cooperate with the throat of a horn 25, which is preferably of the so-called exponential type. The inner surface of the throat member conforms to the shape of the surface of the diaphragm adjacent thereto. The clearance between the inner surface of the throat and the diaphragm is made as small as is feasible to make the stiffness of the diaphragm chamber formed by the diaphragm and the throat a maximum while allowing sufficient clearance to enable the diaphragm to oscillate with sufficient amplitude to propagate sound waves of a desired intensity. The diaphragm is actuated by a coil 26, which may consist of a flat conducting ribbon wound edgewise to form a rigid unit, attached to the ridge defined by the junction of the dished portion 17 and the trough portion 18 of the diaphragm, and disposed in an annular gap formed by concentric pole pieces 13 and 15 of the electromagnet. Leading in wires (not shown) for the coil 26 are brought out to terminal bolts 27 insulated from the flange

portion 22 and threaded to terminal blocks 28.

In another embodiment of this invention shown in Fig. 2, the driving coil 26 is attached to the outer edge of the trough portion 18 of the diaphragm.

In still another embodiment of this invention illustrated in Fig. 3, the diaphragm comprises stiff dished portions 29 and 30, a flexible corrugated portion 31 and a flat portion 32 which is clamped between the pole piece 33 of an electromagnet and the flanged portion 34 of the throat member by screws such as 23.

Several relationships that should be observed in the design of a loud speaker of the type comprehended by this invention will be apparent from the following. The acousto-mechanical circuit of a moving coil loud speaker of the horn type may be represented by an analogous electrical circuit as shown in Fig. 4. In the figure, 35 designates an impedance equivalent to the mechanical motional resistance Z_m of the actuating mechanism resulting from the associated input electrical system; 36 is an inductance representative of the effective mass M of the diaphragm; 37 is a capacity equivalent to the diaphragm edge stiffness S_1; 38 is a capacity equivalent to the stiffness S_2 of the throat chamber effective at the diaphragm; and 39 is an impedance representitive of the impedance Z_H of the horn load effective at the diaphragm. It will be evident from Fig. 4 that that portion of the circuit between the lines A—A′ and B—B′, that is the portion comprising the elements corresponding to the effective diaphragm mass M and stiffness S_1 and S_2 constitutes a selective network of the band-pass filter type with terminating impedances Z_m and Z_H.

The horn load impedance Z_H is determined by the effective area of the diaphragm and by the area of the throat opening. The mechanical motional resistance Z_m of the actuating element, that is the annular coil 26, may be determined algebraically by

$$Z_m = \frac{B^2 \pi a d n}{2\rho} \qquad (1)$$

where B = the flux density in the air gap;
a = the area of the conductor;
d = the diameter of the coil;
n = the number of turns in the coil; and
ρ = resistivity of the conductor.

It has been found that for uniform transmission throughout the pass band of the acousto-mechanical system represented by Fig. 4, the terminating impedances Z_H and Z_m should be equal throughout this band to the characteristic impedance Z_o of the filter, which is dependent upon the effective diaphragm mass M and stiffnesses S_1 and S_2.

In a loud speaker of the type disclosed in Fig. 1, the horn load impedance Z_H, which may be determined from known empirical relations, the mechanical motional resistance Z_m, which may be determined by Equation (1), and the characteristic filter impedance Z_o, which likewise may be determined from known empirical relations, should be substantially equal throughout the pass band. It is desirable to make both terminating impedances Z_m and Z_H equal to the characteristic filter impedance Z_o; if this is impossible, satisfactory performance at a slight sacrifice in efficiency can be obtained by making only one of the terminating impedances correct. The discrimination of such a single section filter terminated in this way is not sharp and, therefore, the rate of decrease in transmission above and below the cut-off frequencies is not excessively rapid.

In loud speakers of the horn type, as the frequency increases the dispersion of the sound field diminishes so that the sound pressure will increase toward the axis of the horn if the acoustic power is constant and will be a maximum on the horn axis. It has been found that by proper selection of the high frequency cut-off of the system the transmission loss for frequencies between, say 3000 and 4000 cycles, may be made to compensate for the contraction of the sound field so that a substantially uniform pressure may be obtained at any point in the sound field. The extent to which this constant response level is maintained above, say 4000 cycles, is dependent mainly upon the rigidity of the central portion of the diaphragm, that is in the embodiment shown in Fig. 1, for example, the portion consisting of the dished portion 17 and trough portion 18, and of the moving coil and its support.

In a specific example, a loud speaker, such as is shown in Fig. 1, may have a horn load impedance Z_H of 13,000 ohms. The mechanical motional resistance Z_m at the driving coil may be made equal to Z_H, that is 13,000 ohms, in accordance with Equation (1). The characteristic filter impedance Z_o may be made equal to Z_H and Z_m by properly proportioning the effective diaphragm mass M and the stiffnesses S_1 and S_2. Thus, assuming a lower cut-off frequency (F_1) of 100 cycles and an upper cut-off frequency (F_2) of 3000 cycles the values of M, S_1 and S_2 may be determined as follows:

$$M = \frac{Z_o}{\pi(F_2 - F_1)} = 1.4 \text{ grams} \qquad (2)$$

$$S_1 = \frac{4\pi F_1^2 Z_o}{F_2 - F_1} = .563 \times 10^6 \text{ dynes/cm.} \qquad (3)$$

$$S_2 = \pi(F_1 + F_2) Z_o = 12.7 \times 10^7 \text{ dynes/cm.} \qquad (4)$$

In a specific loud speaker proportioned in accordance with Equations (2), (3) and (4)

it is definitely possible to obtain a substantially constant sound pressure on the axis of an exponentially tapered horn at least up to 7000 cycles. While the high frequency cut-off of the filter is set at 3000 cycles the attenuation for higher frequencies is not infinite and is counteracted by the sound field concentration to obtain fairly uniform results up to say 7000 cycles.

Although specific embodiments have been disclosed and described herein, it is to be understood that the figures and the impedance and other values given are merely illustrative of this invention and that modifications may be made therein without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. A sound translating device comprising a diaphragm including a rigid central portion having an annular ridge thereon, and a throat member a portion of the inner surface of which is spaced from and corresponds to the rigid central portion of said diaphragm.

2. A sound translating device comprising a diaphragm having a dished central portion, an annular trough portion, means for driving said diaphragm attached to the diaphragm at points removed from the center thereof, and a throat member the inner surface of which corresponds to the dished central and trough portions of said diaphragm.

3. A sound translating device comprising a diaphragm having a dished central portion, an annular trough portion joining with said dished central portion, a flexible portion, and a clamped portion, means including an annular coil attached to the junction of said dished central and trough portions for actuating said diaphragm, and a throat member the inner surface of which adjacent said diaphragm corresponds to said central and trough portions of said diaphragms.

4. A sound translating device comprising a diaphragm having a dished central portion and a flexible peripheral portion, means connected to said diaphragm at points removed from the center of said dished portion for driving said diaphragm, and a throat member a portion of the inner surface of which corresponds to the dished central portion of said diaphragm.

5. A sound translating device comprising a magnet having concentric pole pieces forming a narrow, annular air gap, a diaphragm consisting of a rigid portion having an annular ridge thereon, a flexible portion, and a peripheral portion clamped to the outer of said concentric pole pieces, an annular coil affixed to said annular ridge and disposed in said air gap, and a throat member the inner surface of which conforms to the rigid portion of said diaphragm.

6. A moving coil actuated loud speaker comprising a diaphragm, an air chamber adjacent said diaphragm, a horn acoustically connected to said air chamber, and means including a coil for actuating said diaphragm, the horn load impedance effective at the diaphragm, the mechanical motional resistance at said driving coil, and the characteristic impedance of the filter defined by the effective mass and edge stiffness of the diaphragm and the stiffness of said air chamber, being substantially equal throughout the pass band of said filter.

7. A sound translating device comprising a diaphragm, an air chamber adjacent said diaphragm, a horn acoustically coupled to said air chamber, and means including a coil for actuating said diaphragm, the mass and edge stiffness of said diaphragm and the stiffness of said air chamber being so proportioned that a uniform sound pressure is obtained at some specified point in the sound field of the horn throughout a band of frequencies within the audible frequency range.

8. A sound translating device comprising a diaphragm, an air chamber adjacent said diaphragm, a horn acoustically coupled to said air chamber, and means including a coil for actuating said diaphragm, the mass and edge stiffness of said diaphragm and the stiffness of said air chamber being so proportioned that a uniform sound pressure is obtained at some specified point in the sound field of the horn between at least 100 and 7000 cycles.

9. A moving coil actuated loud speaker comprising a diaphragm having a dished central portion, a flexible portion, and a clamped portion, a throat member forming an air chamber with said diaphragm, the inner surface of said throat member conforming to said dished central portion, means including a coil affixed to said diaphragm for actuating it, and a horn acoustically coupled with said air chamber, the mechanical motional resistance at said coil and the characteristic impedance of the filter defined by the effective mass and edge stiffness of said diaphragm and the stiffness of said air chamber being substantially equal between the upper and lower cut-off frequencies of said filter.

10. A moving coil actuated loud speaker comprising a diaphragm having a dished central portion and a flexible portion, a throat member forming an air chamber with said diaphragm, the inner surface of said throat member conforming to the face of the diaphragm adjacent thereto, means including a coil for actuating said diaphragm, a horn acoustically coupled with said air chamber, the horn load impedance effective at the diaphragm and the characteristic impedance of the filter defined by the effective mass and edge stiffness of said diaphragm and the stiffness of said air chamber being substantially equal throughout a band of frequencies of importance in speech and music.

11. A moving coil actuated loud speaker comprising a diaphragm having a dished central portion, a trough portion, a flexible portion, and a clamped portion, a throat member forming an air chamber with said diaphragm, the inner surface of said throat member conforming to said dished central and trough portions, means including an annular coil affixed to said diaphragm for actuating it, and a horn acoustically coupled with said air chamber, the horn load impedance effective at the diaphragm, the mechanical motional resistance at said coil, and the characteristic impedance of the filter defined by the effective mass and edge stiffness of said diaphragm and the stiffness of said air chamber, being substantially equal throughout a band of at least several thousand cycles within the audio frequency spectrum.

12. A sound translating device comprising a diaphragm, an air chamber adjacent said diaphragm, a horn acoustically coupled to said air chamber, and means including a coil for actuating said diaphragm, the mass and edge stiffness of said diaphragm and the stiffness of said air chamber being so proportioned that a uniform sound pressure is obtained on the axis of said horn throughout a wide band of frequencies within the audio frequency spectrum.

13. A sound translating device comprising a diaphragm, an air chamber adjacent said diaphragm, a horn acoustically coupled to said air chamber, and means including a coil for actuating said diaphragm, the mass and edge stiffness of said diaphragm and the stiffness of said air chamber being so proportioned that a uniform sound pressure is obtained on the axis of said horn between at least 100 and 7000 cycles.

14. A sound translating device comprising a magnet having concentric pole pieces forming an annular air gap, a diaphragm having a dished central portion, a trough portion intersecting with said dished central portion, a flexible portion, and a peripheral portion clamped to the outer of said concentric pole pieces, an annular coil attached to the diaphragm at the intersection of said central dished and trough portions, a throat member forming an air chamber with said diaphragm, the inner surface of said throat member conforming to the dished central and trough portions of said diaphragm, and an exponentially tapered horn acoustically coupled with said air chamber, the effective mass and edge stiffness of said diaphragm and the stiffness of said air chamber being so proportioned that a uniform sound pressure is obtained on the axis of said horn throughout a band of frequencies of at least 5000 cycles within the audio frequency spectrum.

15. An acoustic device comprising a diaphragm having a dish-shaped portion and a flexible portion, and a member adjacent one surface of said diaphragm forming an air chamber of high impedance therewith, the inner face of said member conforming to substantially the entire face of the diaphragm adjacent thereto but spaced therefrom a distance sufficient to clear the diaphragm when vibrated at its maximum amplitude, said member having an aperture in communication with said air chamber to permit passage of sound waves to the atmosphere.

16. An acoustic device comprising a diaphragm having a dished central portion surrounded by a flexible portion, a coil connected to the dished portion at points removed from the center thereof for driving it, and a sound box of high impedance on one side of said diaphragm having an opening at its center for the passage of sound waves, the surface of said sound box juxtaposed to said one side of said diaphragm conforming to the shape of substantially the entire diaphragm surface adjacent thereto and spaced from the diaphragm a distance only slightly greater than the maximum amplitude of the diaphragm displacement.

In witness whereof, I hereunto subscribe my name this 2nd day of February, 1931.

DAVID G. BLATTNER.