

July 24, 1934.

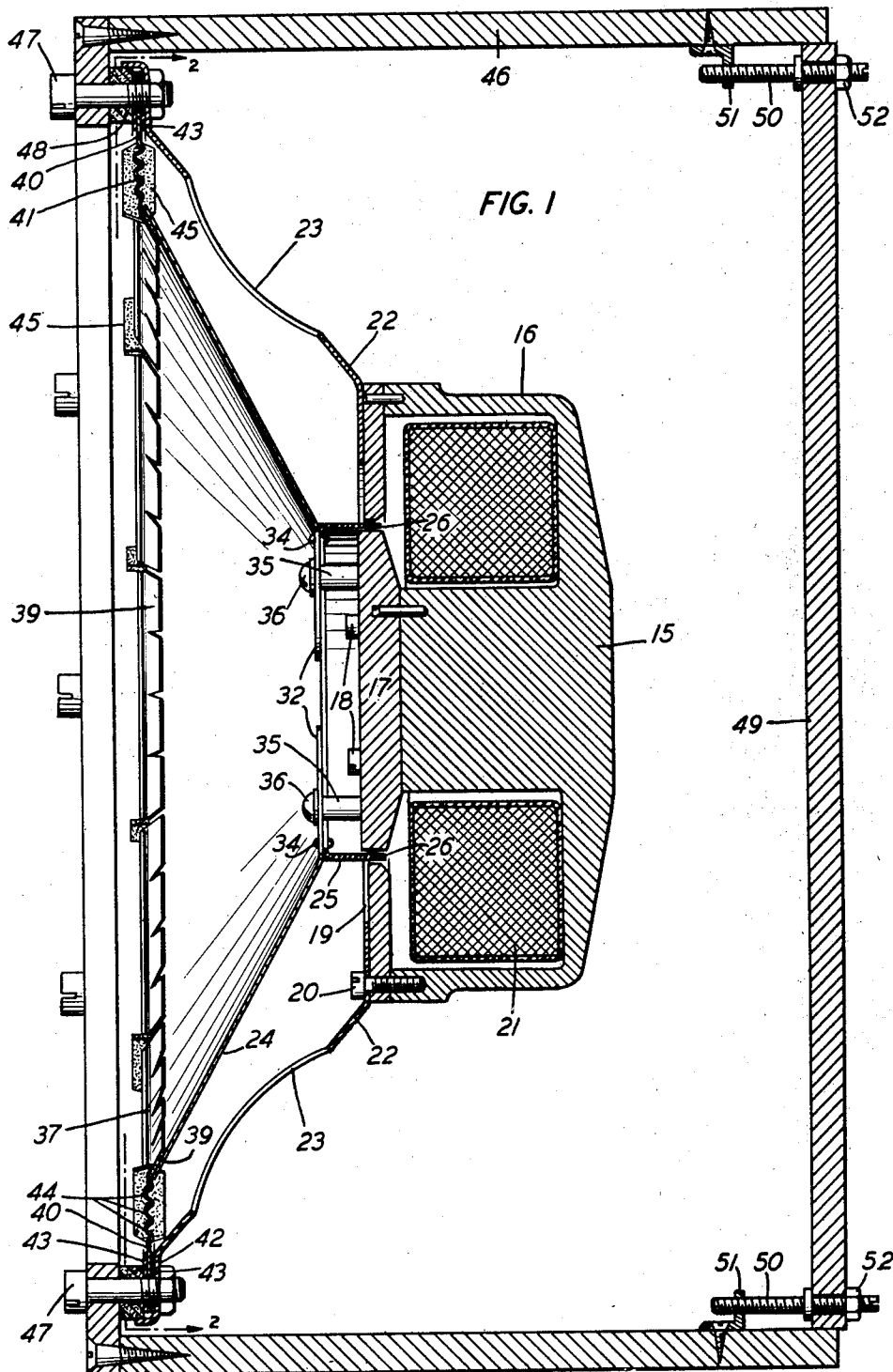
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1,967,223

VIBRATION TRANSMITTING DEVICE

Filed Jan. 6, 1933

4 Sheets-Sheet 1



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FIG. 2

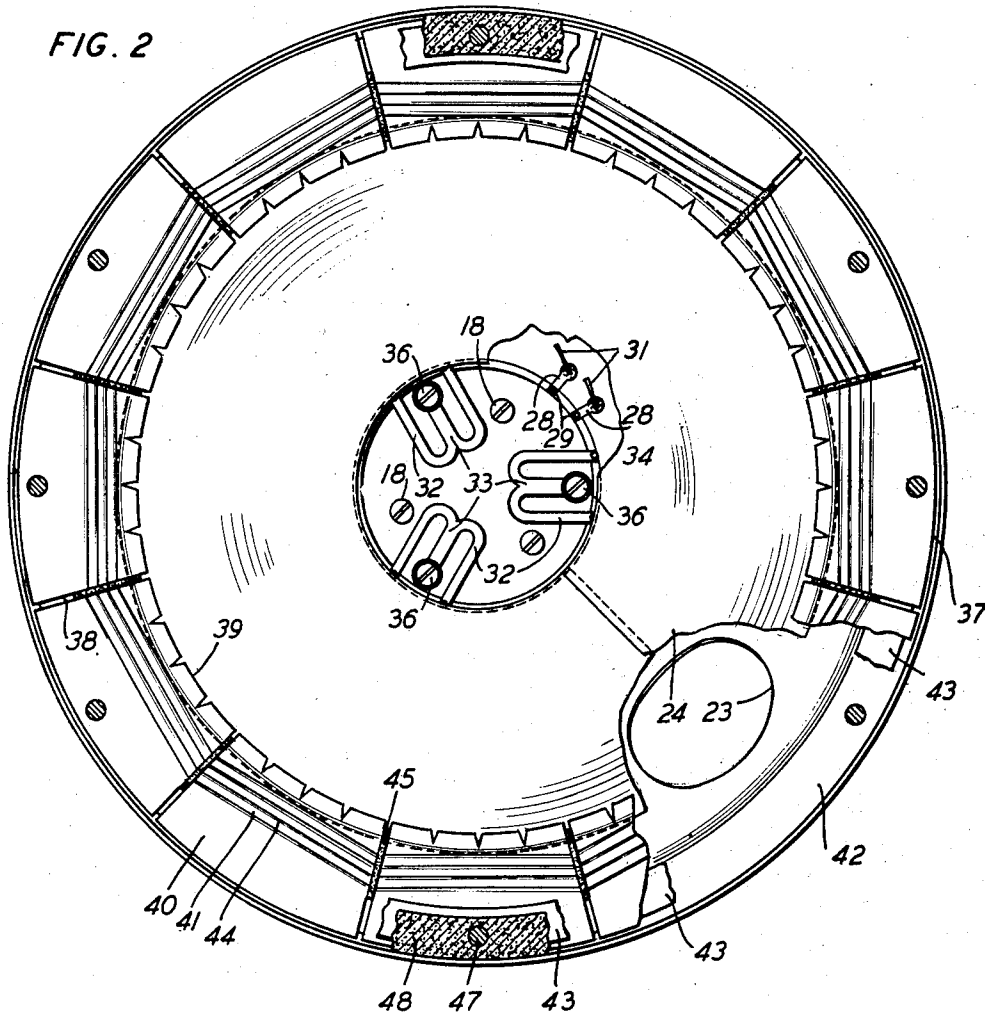
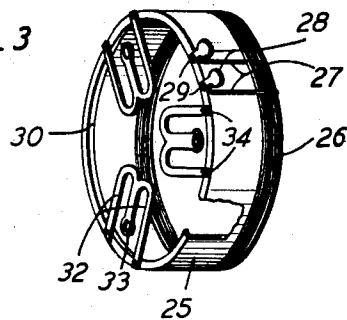


FIG. 3



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FIG. 4

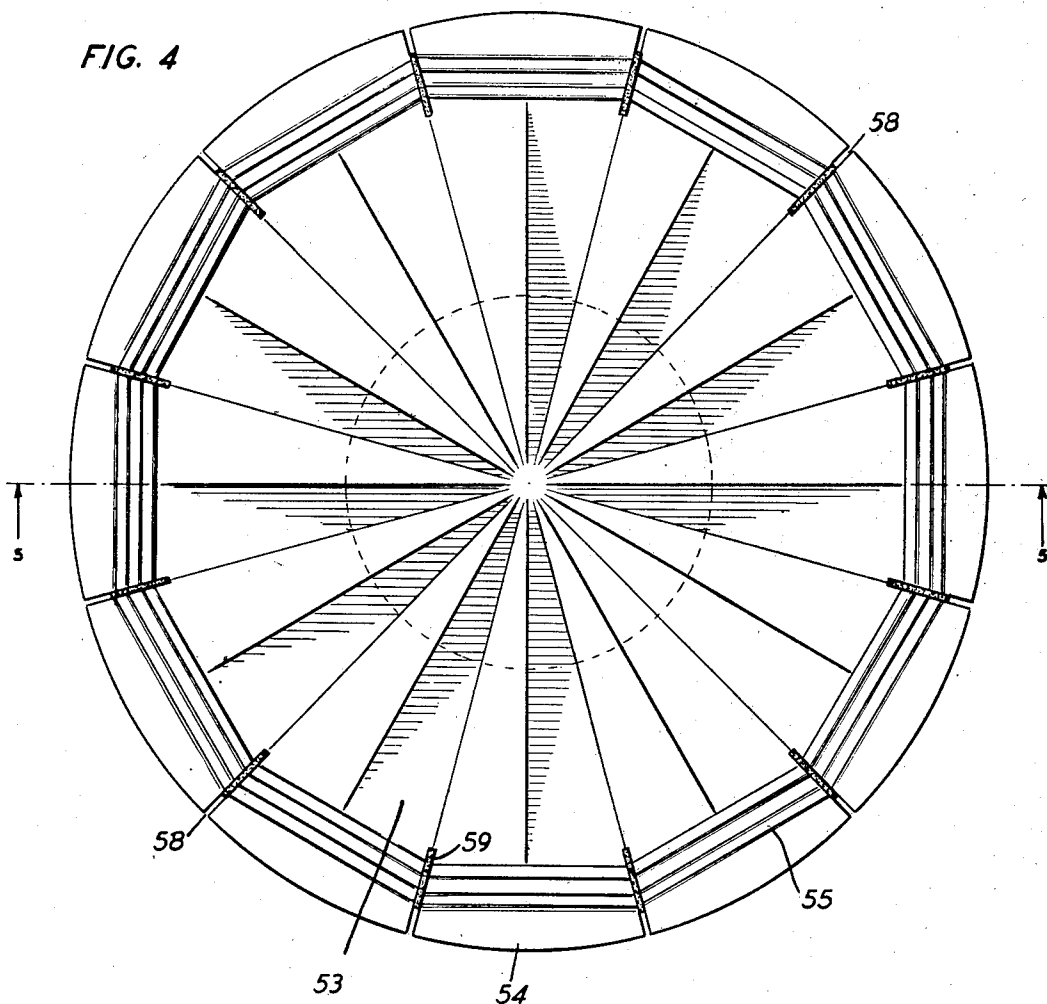
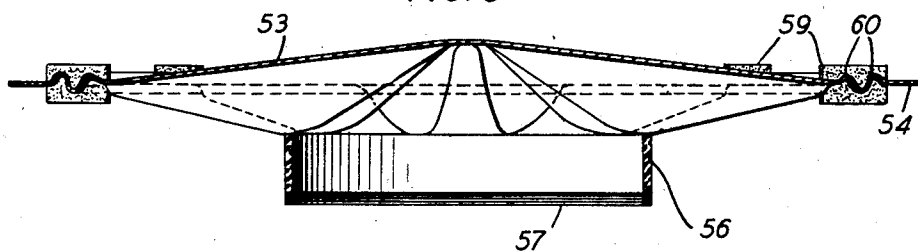


FIG. 5



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FIG. 6

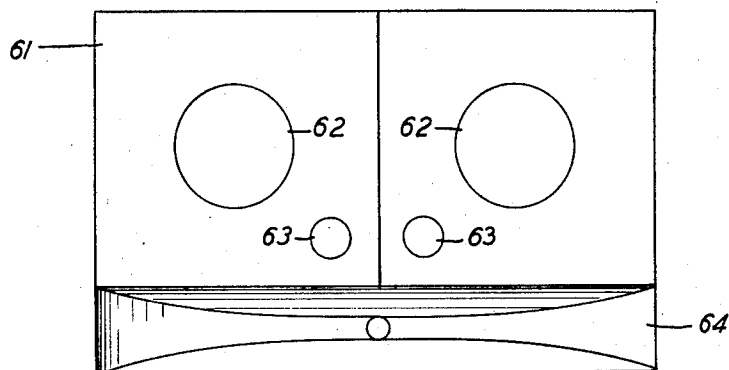
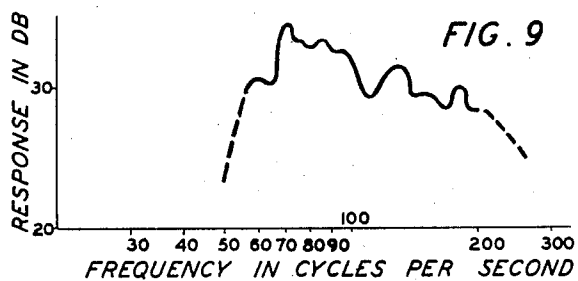
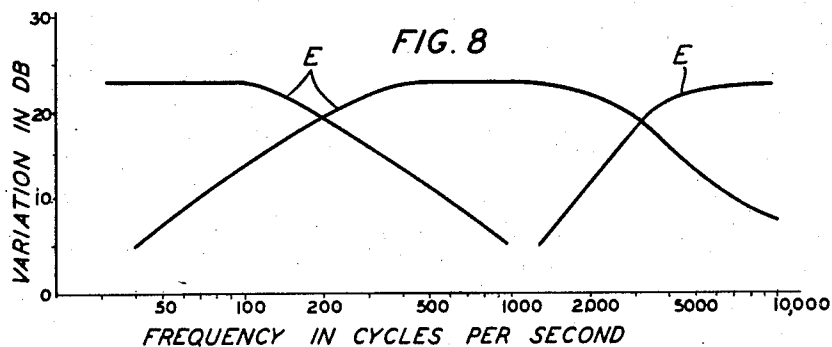
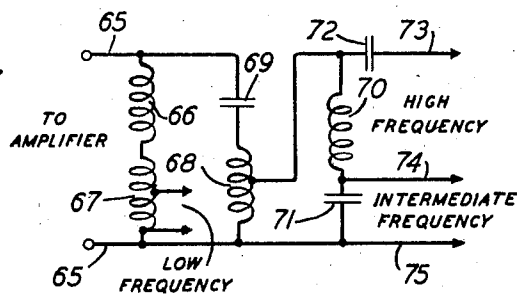


FIG. 7



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VIBRATION TRANSMITTING DEVICE

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Application January 6, 1933, Serial No. 650,391

17 Claims. (Cl. 181—31)

This invention relates to vibration transmitting devices and more particularly to a mounting for large direct acting diaphragms in sound translating devices.

One object of this invention is to flexibly support a diaphragm in sound translating devices so that the diaphragm may vibrate as a whole, analogous to a piston, with large amplitude and with low energy loss in the supporting means.

Another object of this invention is to render a sound translating device particularly efficient throughout a limited range of frequencies in the audio spectrum.

In one embodiment illustrative of this invention, a loudspeaker comprises a dished diaphragm sufficiently large to reproduce speech and music without the aid of a horn, an actuating device therefor, a support adjacent the periphery of the diaphragm, and a flexible annular mounting connecting the periphery of the diaphragm to the support. The mounting is preferably of light weight sheet material, such as duralumin, and may be divided into a plurality of sections by uniformly spaced slots. The slots are preferably sealed, for example, by strips of felt, to prevent the leakage of sound waves therethrough.

In accordance with one feature of this invention, the annular mounting is provided with a plurality of linear corrugations arranged in polygonal formation about the periphery of the diaphragm, certain of the corrugations being approximately tangent intermediate the ends thereof to the periphery of the diaphragm.

In accordance with another feature of this invention, the mechanical motional resistance at the actuating device and the impedance of the vibratory system, that is, the diaphragm and associated parts such as the actuating device and the supports therefor, are made substantially equal in magnitude at or near the natural or resonance frequency of the vibratory system so that a maximum vibrational velocity and maximum sound radiation throughout a limited range of frequencies is obtained.

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

Fig. 1 is a side elevational view in cross-section of a moving coil actuated loudspeaker illustrative of one embodiment of this invention;

Fig. 2 is a front view of the diaphragm and support assembly of the loudspeaker shown in Fig. 1, with portions broken away to show details of structure more clearly;

Fig. 3 is a perspective view of the driving coil and the support therefor of the loudspeaker shown in Fig. 1;

Fig. 4 is a plan view of a diaphragm illustrative of another embodiment of this invention;

Fig. 5 is a cross-sectional view along line 5—5 of Fig. 4;

Fig. 6 is a diagrammatic front view of a multi-unit loudspeaking apparatus embodying loudspeakers of the type shown in Fig. 1;

Fig. 7 is a schematic view of a filter network to be used in conjunction with the apparatus illustrated in Fig. 6;

Fig. 8 illustrates a transmission characteristic of a filter network of the type shown in Fig. 7; and

Fig. 9 illustrates a portion of the response characteristic of a loudspeaker constructed in accordance with this invention.

Referring now to the drawings, a loudspeaker as shown in Fig. 1, comprises a pot-type magnet having an inner or central pole 15 and an outer pole 16. A circular pole piece 17 is mounted on the pole 15 by screws 18 and an annular pole piece 19 is mounted on the pole 16 by screws 20, (only one of which is shown) and is concentrically disposed above the pole piece 17 to form a narrow annular air-gap. A coil 21 is disposed about the pole 15 and may be energized by either direct or alternating current. A dished metallic frame 22 is secured to the magnet structure by the screws 20 and is provided with a plurality of apertures 23 which are of sufficient area to prevent any appreciable confinement of air within the dished frame.

A direct acting frusto-conical diaphragm 24, which may be of paper, or other suitable material, is positioned within the frame 22 and carries a cylindrical sleeve 25, preferably of insulating material such as a phenolic condensation product, which is secured, as by cementing, to the smaller end of the diaphragm. The sleeve 25 extends into the air-gap between the pole pieces 17 and 19 and has mounted thereon an annular driving coil 26 for vibrating the diaphragm in accordance with energizing audio frequency currents. The end portions 27 of the driving coil 26, as shown more clearly in Fig. 3, are secured, as by cementing, to the sleeve 25, and extend along the outer surface of the sleeve to soldering terminals or lugs 28 which are secured, as by eyelets 29, to an inwardly directed flange 30 on the sleeve. Connection may be made to the coil 26 by conductors 31 which may be soldered to the terminals 28.

The smaller end of the diaphragm 24 is flexibly supported from the pole piece 17 by a plurality of resilient members, which may be of phosphor bronze, each having outer parallel fingers 32 and an intermediate finger 33. The outer fingers 32 are secured to the flange 30 as by eyelets 34; the intermediate fingers 33 are secured to studs 35 by screws 36 which extend through the studs and are threaded into the pole piece 17. The resilient members provide a

double cantilever action so that the driving coil 26 may vibrate in the air-gap, substantially parallel to the opposed faces of the pole pieces 17 and 19, and with but small restraint.

- 5 The diaphragm 24 is supported at its larger end by an annulus 37 of a light weight sheet material, such as duralumin. The annulus comprises a plurality of sections separated by narrow radially extending slots 38, each of the sections including a serrated flanged portion 39 suitably secured, as by cementing, to the larger end of the diaphragm 24, a flat peripheral portion 40, and an intermediate flexible portion 41. The peripheral portion 40 is seated upon a peripheral flange 42 on the frame 22, together with annular washers 43, which may be of paper.

- 10 In accordance with a feature of this invention, the intermediate portion 41 of each of the sections of the annulus 37 is formed with a plurality of parallel linear corrugations 44 which are arranged in polygonal formation about the periphery of the diaphragm 24, the innermost of the corrugations being substantially tangent at their midpoints to the periphery of the diaphragm. This construction permits large vibration amplitudes with a linear force-displacement relationship and without large energy losses due to internal mechanical dissipation in the deformed material. The slots 38 serve to increase the flexibility of the annulus 37 by allowing circumferential expansion of the diaphragm periphery. In order to prevent leakage of air between the opposite surfaces of the diaphragm, the slots 38 may be sealed, as for example by strips 45 of an expansible material, such as felt.

- 15 The loudspeaker assembly may be mounted within a closed casing 46, as shown in Fig. 1, by a plurality of bolts 47, which extend through the flange 42 and the front wall of the casing, a buffer and sealing ring 48, as of felt, being provided between the outer of the washers 43 and the adjacent wall of the casing 46. The rear wall 49 of the casing 46 may be slidably mounted with respect to the side, top and bottom walls, by spindles 50 which are threaded into brackets 51 and carry lock nuts 52. By movement of the rear wall 49, the volume and stiffness of the enclosed air chamber to the rear of the diaphragm may be adjusted to approximately the optimum values as described in greater detail hereinafter.

- 20 In another embodiment of this invention, shown in Figs. 4 and 5, a diaphragm of light weight material, such as duralumin, comprises a relatively rigid central radially fluted portion 53, a peripheral portion 54, and an intermediate flexible portion 55. The radial flutes may be in the form of triangular pyramids, to the apices of which a cylindrical sleeve 56 carrying a driving coil 57 may be affixed. The diaphragm is provided with radially extending slots 58, which may be sealed by strips 59 of a flexible material, such as felt. The flexible intermediate portion 55 of the diaphragm is formed with a plurality of parallel linear corrugations 60 arranged in polygonal formation about the central portion 53 and disposed perpendicular to radial planes passing through the apices of the radial flutes of the central portion. The innermost of the corrugations 60 are preferably tangent at their midpoints to the edges of the central portion of the diaphragm. The radial flutes and slots allow circumferential expansion of the periphery of the central portion of the diaphragm. Although, as shown in Figs. 4 and 5, the diaphragm consists of a single sheet of material it may, of course, be made in two

parts; that is, the radially fluted central portion 53 may be made in one piece and the peripheral and intermediate portions 54 and 55, respectively, may be made as a separate piece of the same or different material as the central portion 53.

Although a loudspeaker, such as shown in and described with reference to Fig. 1 may be used alone to translate speech and music, it may be used to particular advantage in a multi-unit loudspeaking apparatus to translate but a limited range of frequencies in the lower portion of the audio frequency spectrum. In one form shown diagrammatically in Fig. 6, a multi-unit loudspeaking device may comprise a pair of casings 61 each having a low frequency loudspeaker 62 and a high frequency loudspeaker 63 mounted therein. The low frequency loudspeakers may be of the general construction in Fig. 1, and the high frequency loudspeakers may be of the general construction shown and described in my Patent 1,907,723, granted May 9, 1933. A horn type loudspeaker 64 for reproducing intermediate frequencies may be disposed adjacent the baffle board 61 as shown.

In this arrangement, the several loudspeakers are connected to an amplifier or the like through a multi-channel filter network such as shown in Fig. 7. As shown in this figure, the filter network comprises line conductors 65 to be connected to the output of an amplifier or the like. An inductance 66 and an auto-transformer 67 are connected across the conductors 65 the transformer being provided with a pair of taps for connection to the low frequency loudspeakers 62. An auto-transformer 68 and a condenser 69 are also connected across the line conductors 65 and in series with each other. Another inductance 70 and condenser 71 are connected in series with each other and are shunted across a portion of the transformer 68, a series condenser 72 being connected to one terminal of the inductance 70. The terminal conductors 73, 74 and 75 are connected as shown, the conductor 74 forming a common lead to one terminal of each of the high and intermediate loudspeakers 63 and 74, respectively, and the conductors 73 and 75 forming respectively, the leads to the other terminals of the high and intermediate frequency loudspeakers. The various inductances and condensers are so proportioned, of course, that an optimum impedance relation exists between the filter network and the several loudspeakers.

A typical transmission characteristic for a filter network such as shown in Fig. 7 is illustrated in Fig. 8. The several loudspeakers should be so constructed that each will be particularly efficient throughout the range of frequencies passed most efficiently by the corresponding channel of the filter network. For example, in one arrangement, used in conjunction with a filter network having the transmission characteristic shown in Fig. 8, the low frequency loudspeakers 62 should be particularly efficient from the lowest audible frequency up to 200 cycles, the intermediate frequency loudspeakers 64 should be particularly efficient between say 200 and 3000 cycles, and the high frequency loudspeakers 63 should be particularly efficient between say 3000 and 10000 cycles or higher.

In a loudspeaker of the general construction shown in Fig. 1, high efficiency and uniform response over a limited range of frequencies in the lower portion of the audio-frequency spectrum may be attained by observing the following factors;

1. The cross-sectional area of the driving coil and the length of the coil conductor should be made as large and the resistivity of the conductor material as small as possible, the limit being determined by the maximum permissible mass and economical flux gap dimensions.

2. The magnetic flux density should be as high as economy of field magnet design will permit.

3. The resonance frequency of the vibrating system should be located at some frequency near the lower limit of the frequency range that it is desired to reproduce.

4. The electrical source impedance should be adjusted to give a mechanical motional impedance at the driving coil equal to the mechanical impedance of the vibrating system at some frequency within a fraction of an octave of the resonance frequency. Equality of these impedances at the resonance frequency gives the maximum attainable efficiency but a narrow range of uniform performance, while equality at a frequency removed from resonance gives a wider useful range. The relation between the electrical source impedance and the mechanical motional impedance may be expressed as follows:

$$R_m = \frac{(Bl)^2}{R_s + R_c} \quad (1)$$

where

R_m = mechanical motional impedance

B = flux of density in the air gap in which the driving coil vibrates

l = length of conductor in driving coil

R_c = blocked resistance of the driving coil

R_s = the electrical source impedance.

B and l should be made as large and R_c as small as economy of design and physical limitations will permit. R_s is then made of such a value as will make R_m equal to the mechanical impedance of the vibrating system at a frequency near resonance.

The mechanical impedance of the vibrating system throughout that portion of the audio frequency range in which the diaphragm vibrates as a whole, analogous to a piston, may be expressed as follows:

$$Z_a = R_R + j\left(\omega M - \frac{S}{\omega}\right) \quad (2)$$

where

R_R = the radiation resistance of the diaphragm
 M = the mass of the vibrating system, including air mass

S = the stiffness of the supports for the diaphragm and the driving coil plus the stiffness of the chamber to the rear of the diaphragm.

In a loud speaker of the construction in Fig. 1, the stiffness of the annulus 37 and of the flexible members 32 and 33, is small in comparison with the stiffness of the air chamber formed by the casing 46 to the rear of the diaphragm. The dimensions of the air chamber to give the proper stiffness is determined by the following relation:

$$V = \frac{1.4 \times 10^6 \times A_d^2}{(2\pi f_0)^2 M} \quad (3)$$

where

A_d = area of the diaphragm

f_0 = the desired resonance frequency

V = volume of the inclosed air chamber.

In a specific embodiment illustrative of this invention, a loudspeaker of the general construction shown in Fig. 1 may have a 12" diaphragm 24 actuated by a driving coil 26 having a diameter of approximately 4". The effective mass of the diaphragm 24 and driving coil support 25

may be about 36 grams. The casing 46 may be so proportioned in accordance with Equation (3) that the resonance frequency of the vibratory element is about 75 cycles. For a diaphragm of the dimensions given, a casing 2 feet square and 1 foot in depth has been found satisfactory. The mechanical motional resistance and the driving coil may be made substantially equal to the mechanical impedance of the vibratory element at about 90 cycles in accordance with Equation (1) using the following values:

$B = 7000$ gaussess

$l = 1600$ centimeters

$R_c = 5$ ohms.

A response curve for a loud speaker constructed as above set forth is shown in Fig. 9 from which it will be seen that a uniform response is obtained between say 60 and 200 cycles, the maximum difference being approximately 6 decibels. A decibel is a unit for expressing telephone transmission efficiency and levels and is discussed and defined in an article entitled "Decibels—Name for the Transmission Unit" by W. H. Martin, Bell System Technical Journal for January 1929, page 1.

Although specific embodiments of this invention have been shown and described, it is, to be understood, of course, that these embodiments are merely illustrative of this invention and that modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A vibrational element comprising a stiffened bodily vibratile central portion and a flexible supporting portion including a plurality of substantially linear corrugations arranged in polygonal formation about the periphery of said central portion.

2. A vibrational element comprising a central portion, a peripheral portion, and an intermediate portion more flexible than said central or peripheral portions, and including a plurality of substantially linear corrugations disposed in polygonal formation about said central portion.

3. A vibrational element comprising a relatively large central portion adapted to move bodily and a relatively narrow outer supporting portion including a plurality of linear corrugations substantially tangent intermediate the ends thereof to the periphery of said central portion.

4. A sound translating device comprising a dished diaphragm, a support adjacent the periphery of said diaphragm, and a flexible member connecting said diaphragm to said support and including a plurality of substantially linear corrugations arranged in polygonal formation about the periphery of said diaphragm.

5. A sound translating device comprising a diaphragm, a support adjacent the periphery of said diaphragm, and a flexible member connecting said diaphragm to said support, said member having a plurality of corrugations substantially tangent intermediate the ends thereof to the periphery of said diaphragm.

6. A sound translating device comprising a dished diaphragm, a support adjacent the periphery of said diaphragm, and an annular flexible member connecting said diaphragm to said support, and having a plurality of substantially linear corrugations arranged in polygonal formation about the periphery of said diaphragm, certain of said corrugations being substantially tangent at the midpoint thereof to the periphery of said diaphragm.

7. A sound translating device comprising a diaphragm, a support adjacent said diaphragm, and an annular member connecting said diaphragm to said support and having a plurality of parallel substantially equally flexible linear corrugations arranged perpendicular to a radius of said diaphragm. 80
8. A sound translating device comprising a diaphragm, a support adjacent the periphery of said diaphragm, and a flexible annular member connecting said periphery to said support, and having a plurality of parallel linear corrugations perpendicular to a radius of said diaphragm, the innermost of said corrugations being substantially tangent to the periphery of said diaphragm. 85
9. A sound translating device comprising a diaphragm, a support adjacent said diaphragm, and a flexible annulus connecting said diaphragm to said support and having a plurality of groups of consecutively adjacent parallel linear corrugations arranged in polygonal formation about said diaphragm. 90
10. A sound translating device comprising a dish-shaped diaphragm, a support adjacent the periphery of said diaphragm, and an annular member of greater flexibility than said diaphragm connecting the periphery of said diaphragm to said support and having a plurality of closely spaced concentric polygonal corrugations, the inner of said corrugations being substantially tangent to the periphery of said diaphragm. 95
11. A sound translating device comprising a relatively rigid diaphragm, a support adjacent said diaphragm, and a flexible annulus including a plurality of sections connecting said diaphragm to said support, certain of said sections having a plurality of parallel linear corrugations disposed at an angle to a radius of said diaphragm. 100
12. A loudspeaker comprising a large direct acting frusto-conical diaphragm, means connected to one end of said diaphragm for actuating it, a stationary support adjacent the smaller end of said diaphragm, flexible means connecting the smaller end of said diaphragm to said support, an annular supporting member adjacent the larger end of said diaphragm, and a flexible annulus connecting said larger end to said supporting member, said annulus having a plurality of linear corrugations disposed in polygonal formation around said larger end. 105
13. A loudspeaker comprising a large direct acting frusto-conical diaphragm adapted to vibrate as a whole, means for actuating said diaphragm, a support adjacent the smaller end of said diaphragm, a plurality of flexible members connecting the smaller end of said diaphragm to said support, an annular frame adjacent the larger end of said diaphragm, and a thin metallic annulus having an outer portion secured to said support, an inner portion secured to the larger end of said diaphragm, and an intermediate flexible portion including a plurality of substantially linear corrugations approximately tangent intermediate the ends thereof to the larger end of said diaphragm. 110
14. A sound translating device comprising a vibratory system including a diaphragm, and an actuating device connected to said diaphragm, the mechanical motional resistance at said actuating device being substantially equal to the mechanical impedance of the vibratory system at the resonance frequency of said vibratory system. 115
15. A sound translating device comprising a vibratory system including a diaphragm, means for actuating said diaphragm, and means forming an air chamber adjacent one surface of said diaphragm, the stiffness of said air chamber and the mass of said vibratory system being proportioned so that the resonance frequency of said vibratory system is below 100 cycles, the mechanical impedance of said vibratory system and the mechanical motional resistance at said actuating means being substantially equal at the resonance frequency of said vibratory system. 120
16. A loudspeaker comprising a vibratory system including a large direct acting diaphragm and means connected to said diaphragm for actuating it, said vibratory system having a resonance frequency below 100 cycles, and the mechanical impedance of said vibratory system and the mechanical motional resistance at said means being substantially equal at a frequency below 100 cycles. 125
17. A loudspeaker comprising a vibratory system including a large direct acting diaphragm and an actuating member connected to said diaphragm, a casing forming an air chamber adjacent one surface of said diaphragm, the stiffness of said chamber and the mass of said vibratory system being proportioned so that the resonance frequency of said system is below 100 cycles, and the mechanical impedance of said vibratory system and the mechanical motional resistance at said actuating member being substantially equal at the resonance frequency of said system. 130

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