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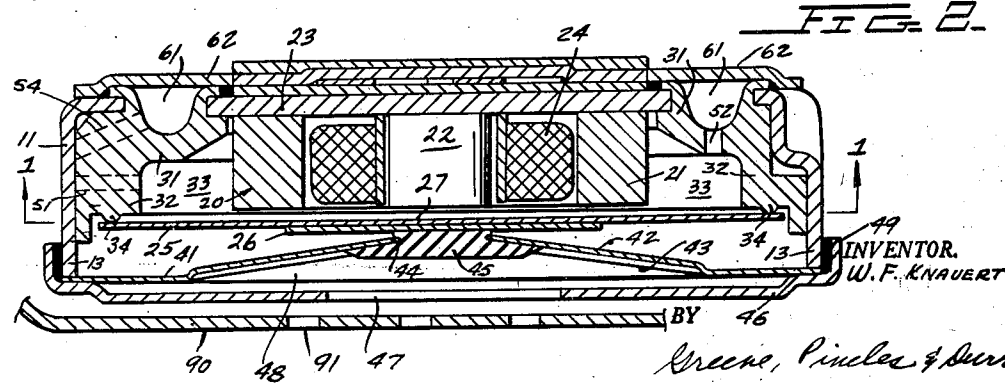
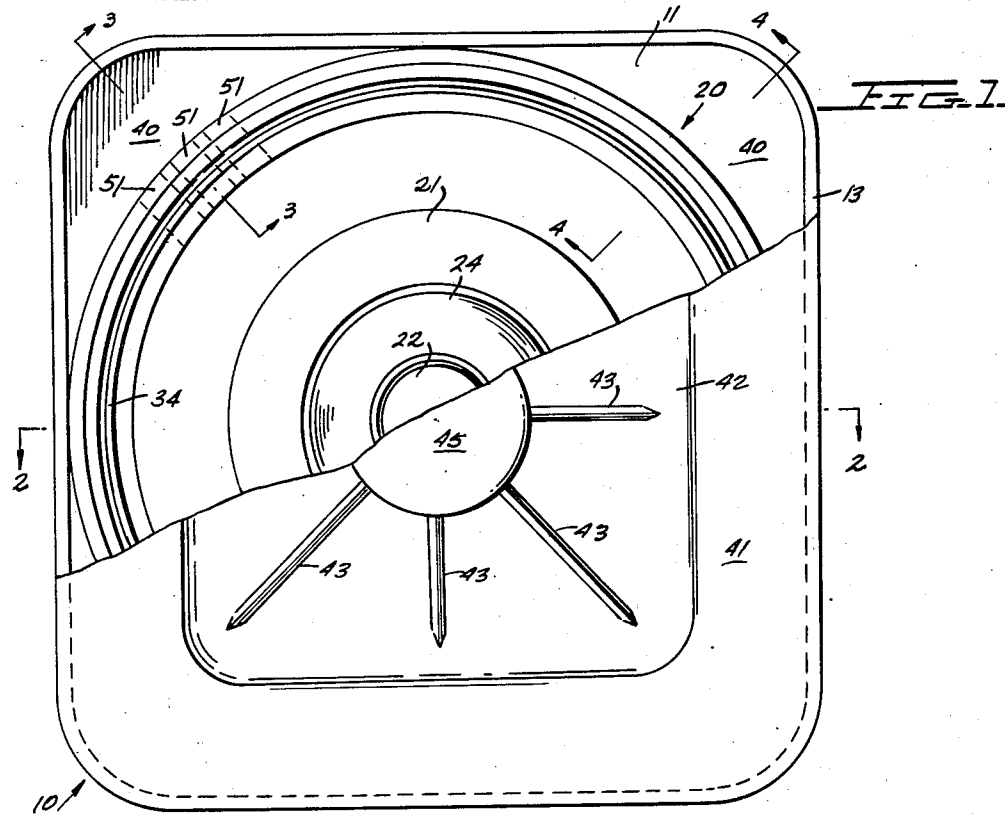
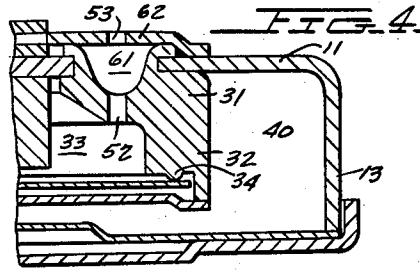
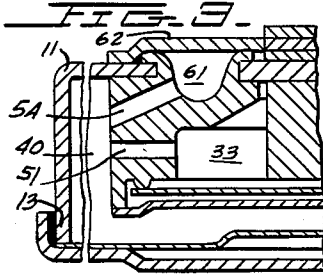
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ELECTRO-MECHANICAL SIGNAL TRANSDUCERS

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3 Sheets-Sheet 1



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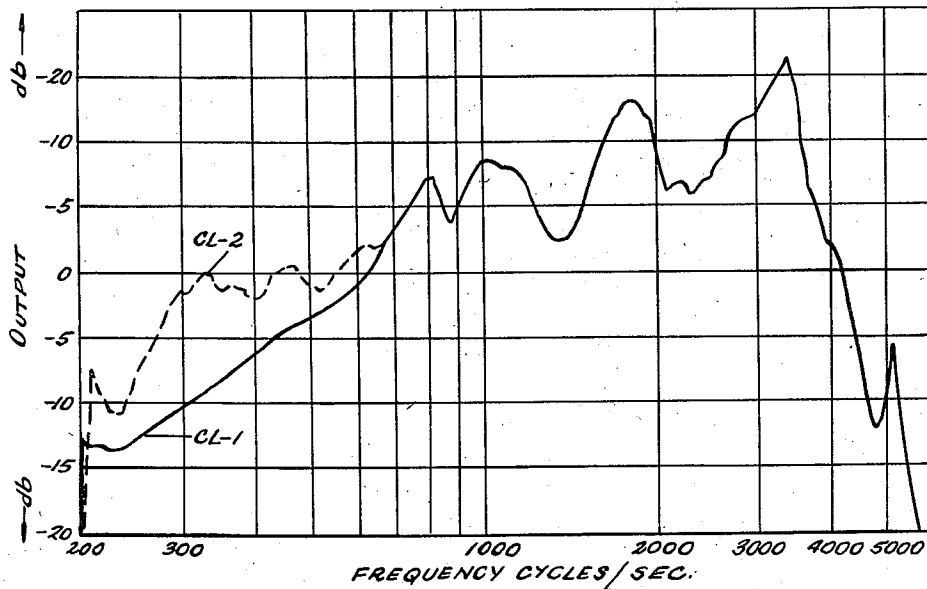
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ELECTRO-MECHANICAL SIGNAL TRANSDUCERS

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FIG. 5.



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FIG. 7

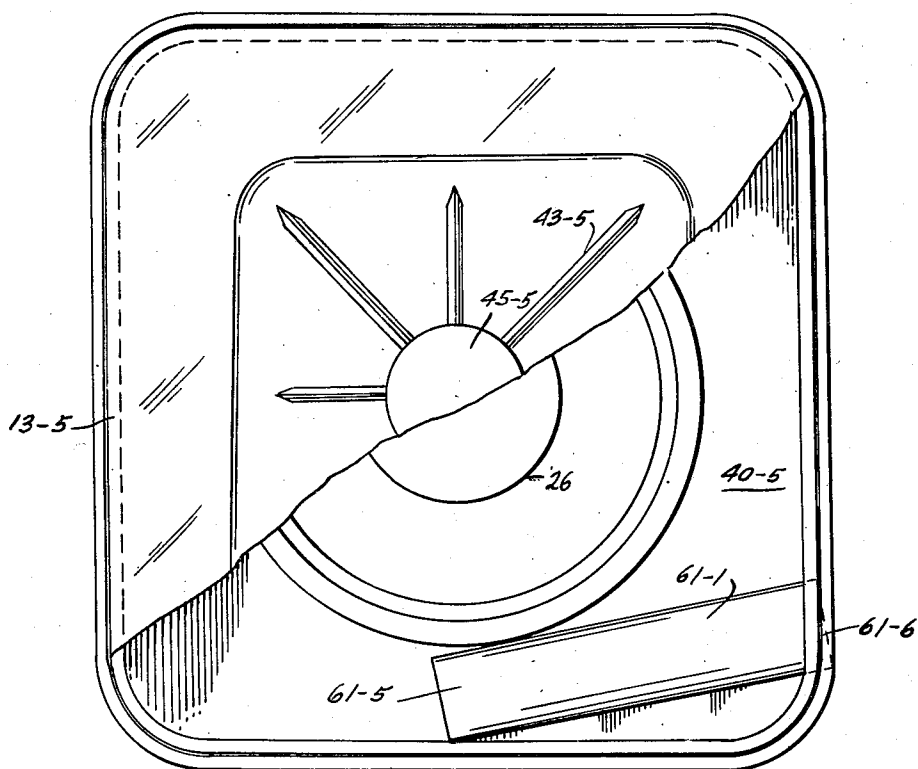
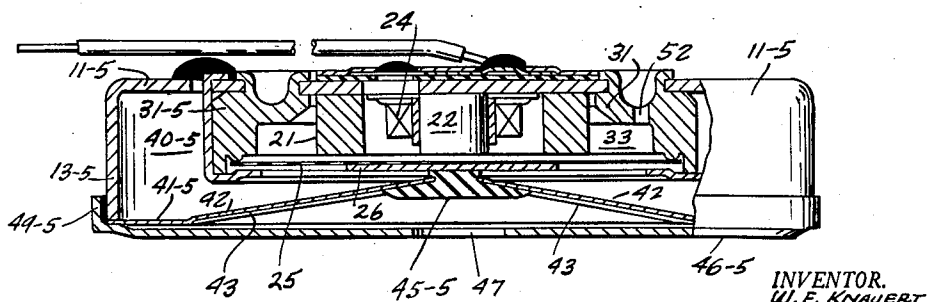


FIG. 8



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ELECTRO-MECHANICAL SIGNAL TRANSDUCERS

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2 Claims. (Cl. 179—115)

This invention relates to electromagnetic sound transducers, such as microphones used as a part of a compact small hearing amplifier worn on the body of the user, although the features of the invention are also applicable to other electromagnetic sound transducing devices, such as other types of microphones and receivers.

Among the objects of the invention are electromagnetic sound transducers combining within an extremely compact structure an array of acoustic elements which make it possible to operate such transducers as a microphone supplying a desired high output both in the low frequency part as well as in the intermediate and in the high frequency part of the principal speech frequency range.

The foregoing and other objects of the invention will be best understood from the following description of exemplifications thereof, reference being had to the accompanying drawings wherein;

Fig. 1 is a front view of one form of a flat hearing aid microphone exemplifying the invention;

Fig. 2 is a vertical cross-sectional view of the same microphone along lines 2—2 of Fig. 1;

Figs. 3 and 4 are cross-sectional views similar to Fig. 1 of portions along lines 3—3 and 4—4 of Fig. 1;

Fig. 5 is a curve diagram of frequency response characteristics of a microphone exemplifying the invention; and

Figs. 6 and 7 are views similar to Figs. 1 and 2 of another microphone exemplifying the invention.

Although sound transducing devices of the invention are also highly effective as receivers for reproducing sound, the practical form shown in Figs. 1 through 4 was evolved for supplying the electrical output to a transistor type hearing aid amplifier all elements of which including the microphone and the electric energy supply battery are mounted in a tiny flat casing small and compact enough for inconspicuous wear on the body of the user.

In the form shown in Figs. 1 through 4, a hearing aid microphone of the invention, generally designated 10 has all its elements combined within a small rectangular housing 11 having a depth of only about $\frac{3}{16}$ " and sides each of a width of only about $1\frac{3}{16}$ ". Because of its small size it may be mounted in the tiny amplifier casing directly behind the amplifier casing front wall 90 having openings 91 through which sound is propagated to the microphone 10.

Within the housing space of the housing 11 is mounted an electromagnetic transducer assembly. The transducer assembly comprises an electromagnetic core structure generally designated 20 comprising an outer magnetic core 21 and a central inner pole piece 22 the rear sides of which are magnetically joined by a yoke plate 23. In the form shown the outer magnetic core 21 and the pole piece 22 are all of circular or cylindrical shape and they are concentrically arranged so as to provide between them a circular space in which are mounted coil windings 24 the ends of which are suitably connected to terminal portions insulatingly mounted on an exterior surface portion of the microphone 10. The magnetic core

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structure 20 is arranged to cooperate with a circular vibratory armature diaphragm 25 of suitable spring metal having a central magnetic armature portion 26 separated from the end face of the central core pole 22 by a small air gap 27. The magnetic core 20 includes means for producing a permanent unidirectional flux passing axially from the yoke 23 through the pole piece 22 across the air gap 27 to the armature 26 and after passing generally radially therethrough, returning by way of the air gap separating it from the facing surfaces of the outer circular core 21 and therethrough to the yoke plate 23. In the form shown the outer circular core 21 is made of permanently magnetizable material, such as Alnico, which is permanently magnetized to produce the desired unidirectional flux interlinking the core 20, and the armature 26 and the windings 24 so that vibratory movement of the armature 26 induces a corresponding electric signal output in the windings 24.

In the form shown all elements of the magnetic core 20 are held in their proper position by an aligning mounting structure 31 to which they are suitably secured. The mounting structure 31 is formed of any non-magnetic solid material, brass for instance, and has a rim 32 enclosing an inner compartment space 33 the acoustic stiffness of which affects the operation of the microphone. The rim 32 has a seating surface with a curved seating ridge 34 on which the periphery of the vibratory armature 25 is held seated by the unidirectional magnetic flux forces exerted on the armature 26. Wall portions of the armature mounting structure 31 are shown combined with the surrounding housing 11 into a compartment enclosure as by affixing rear border portions of the housing 11 to wall portions of the mounting structure 31.

The acoustic vibrations of the surrounding air are transmitted to the vibratory armature 26 by an extremely light extended vibratory diaphragm 41 having a large area exposed to propagated sound. In the form shown the vibratory diaphragm 41 is of rectangular shape and its periphery is seated on and joined to the exposed edge of the rectangular rim 13 of the microphone housing 11. Good results are obtained by overlapping the periphery of the thin diaphragm 41 over the rim 13 of the microphone housing 11 and securing it thereto by a layer of interposed cementitious material. Any light material may be used for forming the vibratory diaphragm 41. Good results are obtained with diaphragms 41 made of a thin aluminum foil. Depending on the size of the microphone diaphragm the thickness of the aluminum foil may vary from 0.001 to 0.0015 inch or be slightly more. Thus in the case of a square diaphragm $\frac{3}{16}$ x $\frac{3}{16}$ inch in area good results are obtained with aluminum foil 0.001 inch thick and in case of a similar diaphragm $1\frac{1}{4}$ x $1\frac{1}{4}$ inch in area, with aluminum foil 0.0015 inch thick.

The extended diaphragm 41, although extremely thin and light, is given sufficient stiffness so that it operates in a manner analogous to a piston for transmitting acoustic vibrations of the air to the magnetic diaphragm armature 26, and generate thereby corresponding electric signals in the microphone windings 24. In order to provide the diaphragm 41 with the required stiffness the major region thereof is formed into a cone 42 which is given additional stiffness by forming it with a plurality of radial ridges 43.

The conical portion 42 of the diaphragm is provided at its center facing the armature 26 with a small opening 44 which is secured to the armature 26 by a small body portion of cementitious material 45 which is united to the adjacent portions of the armature 26 and of the central opening portion 44 of the diaphragm 41. Good results are obtained by first applying to the surface of the metallic armature 26 a thin coating of a resinous cement where-

upon a cementitious wax body portion 45 is united thereto and to the adjoining region 44 of the aluminum foil diaphragm 41. With the arrangement shown the extended vibratory diaphragm 41 confines in combination with the walls of the microphone housing 11 a rear compartment space 40 (Figs. 1, 3, 4) the acoustic stiffness of which affects the operation of the microphone.

To protect the thin foil diaphragm 41 against external forces its outwardly facing side is enclosed by a casing cover 46 having an opening 47 through which sound is propagated into the front compartment space 48 facing the diaphragm. The casing wall 46 may be of the same metal as the housing wall 11 such as brass, and it has a rim 49 which overlaps and is secured to the rim portion 13 of the housing 11 to which the periphery of the diaphragm is secured. Good results are obtained by applying a layer of cementitious material to the overlapping surfaces of the outer casing wall rim 49 and the housing rim 13. The armature diaphragm 25 is designed with sufficient stiffness so as to slightly overbalance the magnetic stiffness which tends to freeze the armature 26 in contact with the pole surfaces of the magnetic core 20 and to maintain the armature at a pole gap spacing at which it will operate in its most efficient vibrating condition for securing a maximum output when it is actuated by the main vibratory diaphragm 41.

The operating characteristics of the microphone shown are determined not only by the mechanical and magnetic characteristics of the core structure 20 with vibratory diaphragm 41, but also by the acoustic characteristics of the diaphragm rear compartment space 40, the inner compartment space 33 and the diaphragm outer compartment space 48. The opening 47 of the outer diaphragm compartment 48 is made large enough to secure maximum microphone output. The wall enclosures of the rear diaphragm compartment spaces 40 and 33 of the microphone are provided with the acoustic vents or openings for reducing their stiffness as follows: The stiffness of the inner mounting structure compartment 33 is reduced to a minimum by providing it with one or more acoustic passage connections 51 to the rear compartment space 40 extending within the housing 11. The inner compartment space 33 is also provided with further acoustic passage connections 52, 53 to the space on the exterior of the microphone housing to further reduce its stiffness. To reduce the stiffness of the rear compartment space 40 there is provided an acoustic passage 54 which together with the acoustic passage 53 connects it to the exterior space. The just described acoustic connections of the inner mounting structure compartment 33 and the rear diaphragm compartment 40 to the exterior space are designed to secure a maximum reduction of the stiffness of these compartment spaces and to obtain acoustic resonating systems which provide maximum response over the principal part of the speech frequency range. Because of the above described acoustic connections, the inner compartment space 33 may be considered as being part of the rear compartment space 40 of the microphone.

With the microphone of the type described above, in which the various acoustic compartments have been provided with the acoustic passage connections to the exterior space for securing a minimum of stiffness and obtaining the most effective resonating acoustic systems, it was found possible to obtain a satisfactory output over the principal part of the frequency range from about 500 to 3000 C. P. S. (cycles per second). However, the output of the microphone proved deficient in the lower frequency range between 200 and 500 C. P. S. This is illustrated by the low frequency portion CL-1 of the full-line response curve of Fig. 5 which is typical for a microphone described above in connection with Figs. 1-4. However, in practical amplifier hearing aids it is of great practical importance to provide the hearing aid microphone with the highest possible output level in the lower part of the frequency range between 200 and 500 C. P. S.

because the amplifier is as a rule similarly deficient in amplifying signals over this low frequency range.

According to the invention, a microphone of the type described above has its rear compartment space 40 and/or its inner compartment space 33 combined with a relatively long acoustic channel space having such length that its vibrating mass of air shall form in combination with the acoustic stiffness of the air in the rear compartment space 40 a Helmholtz resonator system which resonates or has a resonance frequency in the low frequency range between 200 and 500 C. P. S. and thereby materially raise the output level of the microphone over a substantial part of such low frequency range.

In the tiny flat microphone shown in Figs. 1 through 4 the body of the core mounting structure 31 is utilized for providing the long acoustic resonating channel which resonates with the rear compartment space 40 in the low frequency range between 200 and 500 C. P. S. To this end the circular mounting structure 31 is formed on the outer side thereof with a channel shaped depression 61 the walls of which form with an overlying wall member 62 the resonating channel 61 of the required length. The overlying wall member 62 of the resonating channel 61 may be formed by a thin sheet of metal, such as aluminum foil which is suitably secured to the underlying surfaces of the mounting structure 31, as by cement. The elongated channel space 61 is acoustically connected to the rear diaphragm compartment space 40 by one or more acoustic passages 54. The effective length of the elongated resonating channel space 61 is determined by opening 53 through which it opens into the surrounding exterior space. By changing the position of the acoustic opening connection 53 from longitudinal resonating channel 61 to the exterior microphone space, the length of the resonating channel 61 may be so chosen that the air mass thereof shall form with the acoustic stiffness of the air in the rear diaphragm compartment 40 an acoustic resonator which is resonant in the low frequency range between 200 and 500 cycles.

In the curve diagram of Fig. 1, curve portion CL-1 shows the frequency response of the microphone output over the low frequency range up to 600 C. P. S. when the microphone shown is formed without the additional elongated resonating channel 61. The dash line curve CL-2 shows the raised output level over the same low part of the frequency range obtained with a microphone having the resonating channel 61 of the invention just described.

Figs. 6 and 7 show another form of a microphone exemplifying the invention. It has a magnetic core structure 20 and armature diaphragm 25 identical with that of the microphone of Figs. 1 through 4 which are combined in a similar manner with a housing 11-5 and a main vibratory diaphragm 41-5 which are however of considerably greater width. The microphone housing of Figs. 6 and 7 is of sufficient width as to hold in vibrating position on its housing rim 13-5 the periphery of the extended vibratory diaphragm 41-5 having a square area of about $1\frac{1}{8} \times 1\frac{1}{8}$ inches. The rear diaphragm compartment 40-5 of the microphone of Figs. 6, 7 is combined with a longitudinal resonating channel 61-5 formed of a piece of metal tubing, of brass for instance. The resonating channel 61-1 is located within the housing 11-5 with one end 61-5 of the tubing 61-1 opening into this rear diaphragm compartment space 40-5 and the opposite tubing end 61-6 opening to the space on the exterior of the microphone. The length of the longitudinal channel space 61-1 is so proportioned that the mass of the air moving therein forms with the acoustic stiffness of the air in the rear diaphragm compartment 40-5 into which the channel 61-5 opens, a Helmholtz resonator which is resonant at a frequency in the low frequency range between 200 and 500 cycles for raising the response of the microphone in this low frequency range in

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a manner analogous to that described in connection with the corresponding elements of the microphone of Figs. 1 to 5.

The present invention makes it possible to provide electromagnetic microphone sound transducers of extremely compact and thin size suitable for mounting together with the other components of the hearing aid amplifier within a tiny miniature hearing aid amplifier casing about the same size as a cigarette lighter. Notwithstanding its minute size and thinness, the microphone of the invention is able to deliver a relatively high output not only in the speech frequency range above about 700 C. P. S. and higher but also in the low frequency range down to about 200 to 300 C. P. S. This is made possible by combining within the tiny microphone structure a channel shaped acoustic space which is combined with the wider compartment space underlying its vibratory diaphragm, a Helmholtz resonator which resonates in the frequency range between 200 and 500 C. P. S. and thereby achieving the desired raised output level over such low frequency range.

It will be apparent to those skilled in the art that the novel principles of the invention disclosed herein in connection with specific exemplifications thereof will suggest various other modifications and applications of the same. It is accordingly desired that in construing the breadth of the appended claims they shall not be limited to the specific exemplifications of the invention described above.

I claim:

1. In an electromagnetic sound transducing device, a magnetic core structure including at least one pole piece and windings interlinked with the magnetic path defined by said core structure, a magnetic armature arranged for vibration at a gap spacing from said pole piece and generating in said windings a corresponding output over a substantial part of the audio frequency range, an extended vibratory diaphragm having an intermediate portion connected to said armature for transmitting vibrations therebetween, a casing enclosing at least portions of said device and including a wall section overlying the outer side of said vibratory diaphragm and confining with it a front compartment having opening portions for propagating sound from exterior space to said front compartment and exciting vibrations of said vibratory diaphragm and vice versa, said casing including additional wall portions forming a rear compartment extending on the rear side of said vibratory diaphragm, a mounting structure within said rear compartment peripherially surrounding and carrying said magnetic core structure, an armature diaphragm extending over said mounting structure, said mounting structure including wall portions forming an acoustic channel of small cross sectional size compared to that of the rear compartment, said acoustic

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channel being connected with said rear compartment and forming therewith an acoustic system which resonates within a low frequency range between 200 and 500 cycles per second for raising the output generated in said windings over said low frequency range.

2. In an electromagnetic sound transducing device, a magnetic core structure including at least one pole piece and windings interlinked with the magnetic path defined by said core structure, a magnetic armature arranged for vibration at a gap spacing from said pole piece and generating in said windings a corresponding output over a substantial part of the audio frequency range, an extended vibratory diaphragm having an intermediate portion connected to said armature for transmitting vibrations therebetween, a casing enclosing at least portions of said device and including a wall section overlying the outer side of said vibratory diaphragm and confining with it a front compartment having opening portions for propagating sound from exterior space to said front compartment and exciting vibrations of said vibratory diaphragm and vice versa, said casing including additional wall portions forming a rear compartment extending on the rear side of said vibratory diaphragm, a mounting structure within said rear compartment peripherially surrounding and carrying said magnetic core structure, an armature diaphragm extending over said mounting structure, said mounting including inner wall portions associated with said core structure to confine with the latter and with said armature diaphragm an inner diaphragm compartment within the rear compartment, said inner compartment being acoustically coupled to outside portions of said rear compartment and constituting therewith and with said front compartment and with the other acoustic spaces and the other vibratory elements of said device a vibratory system which causes said windings to generate a desired high output level over the principal speech frequency range between about 500 and at least about 2000 cycles per second when said extended vibratory diaphragm is excited by corresponding acoustic vibrations, said mounting structure including additional wall portions forming an acoustic channel of small cross-sectional size compared to said rear compartment said acoustic channel being acoustically connected to said rear compartment and forming therewith an acoustic system which resonates within a low frequency range between 200 and 500 cycles per second for raising the output generated in said windings over said low frequency range.

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