June 4, 1946. R. BLACK, JR 2,401,328

SOUND TRANSLATING DEVICE

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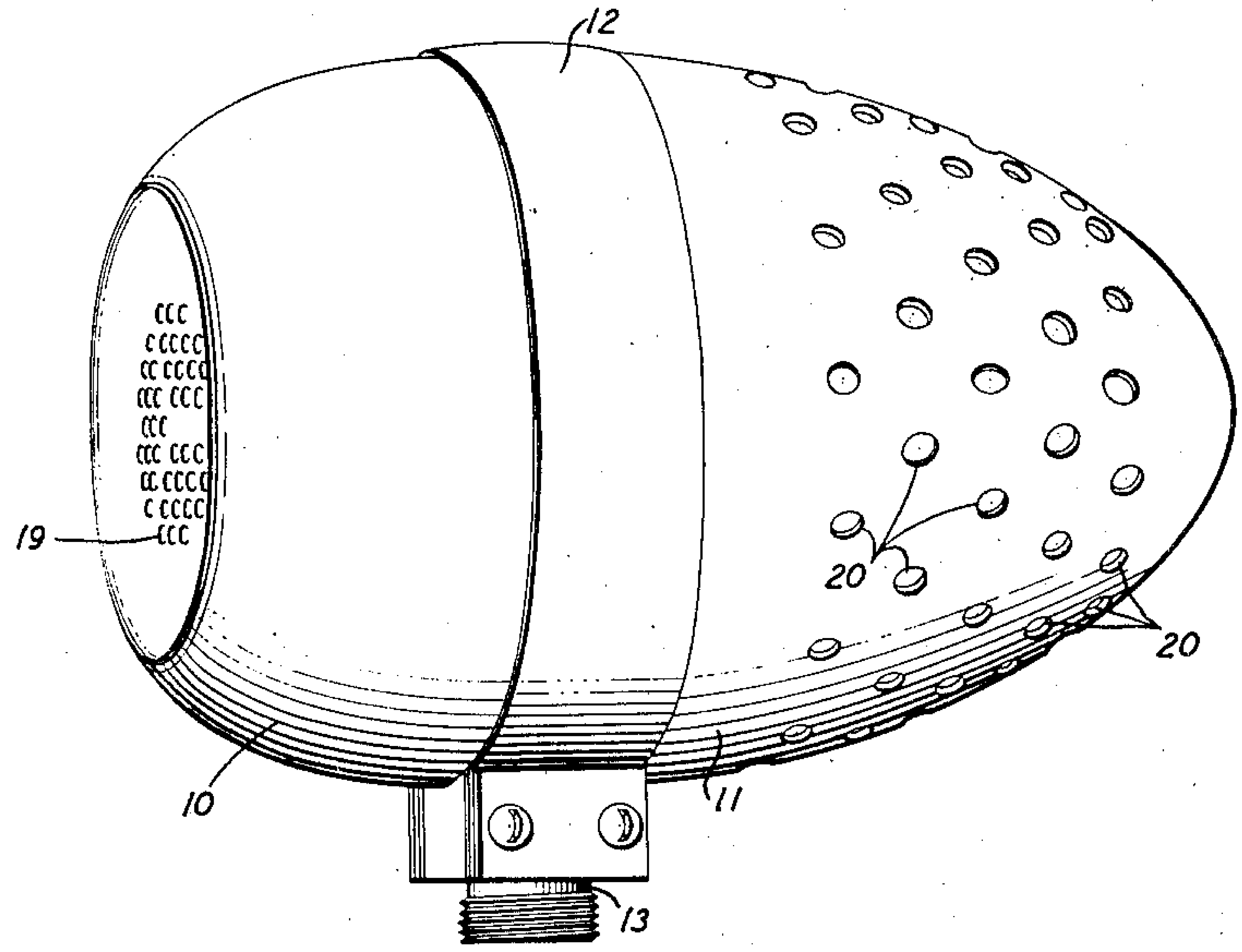

FIG. 1

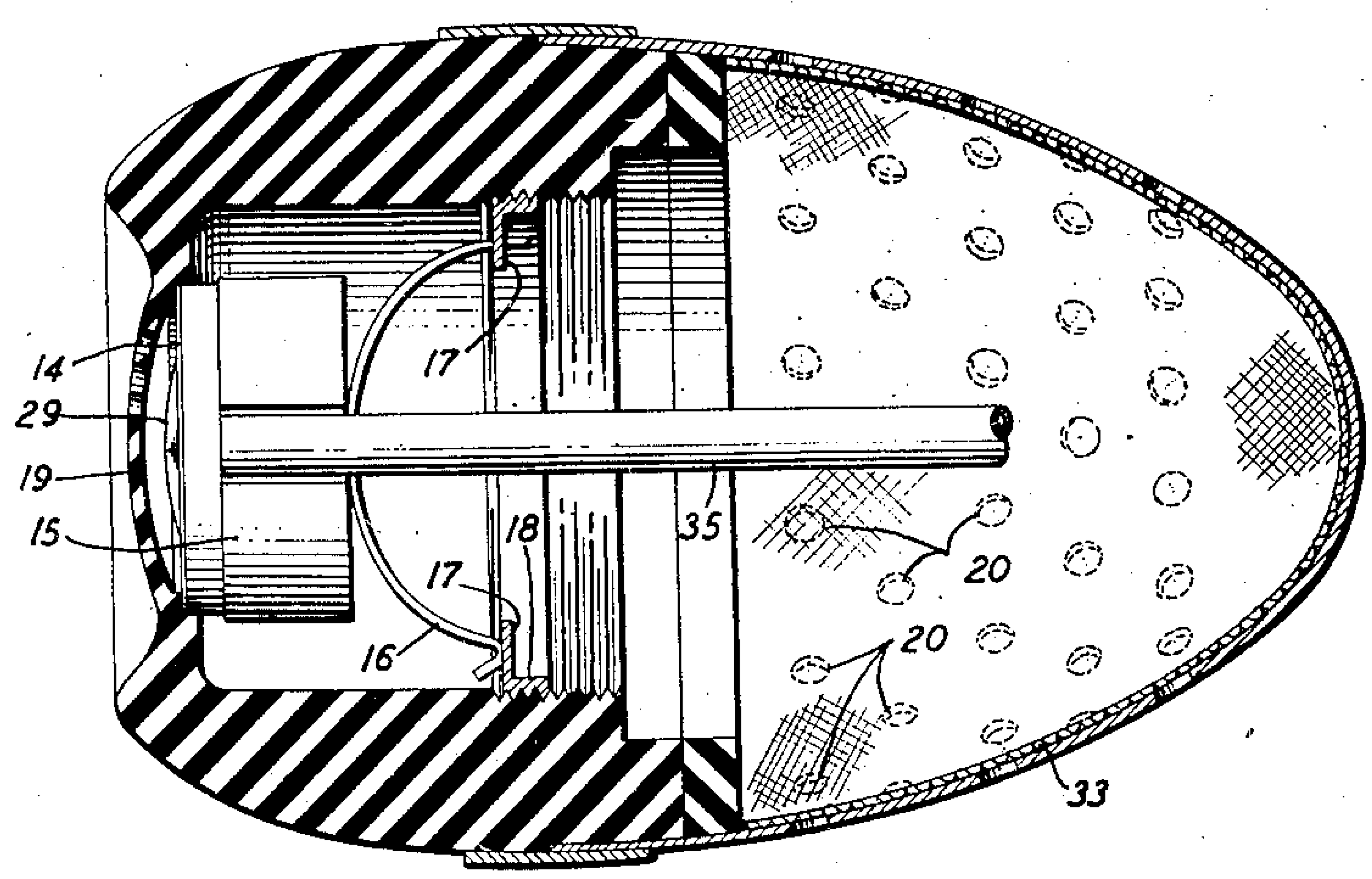

FIG. 2

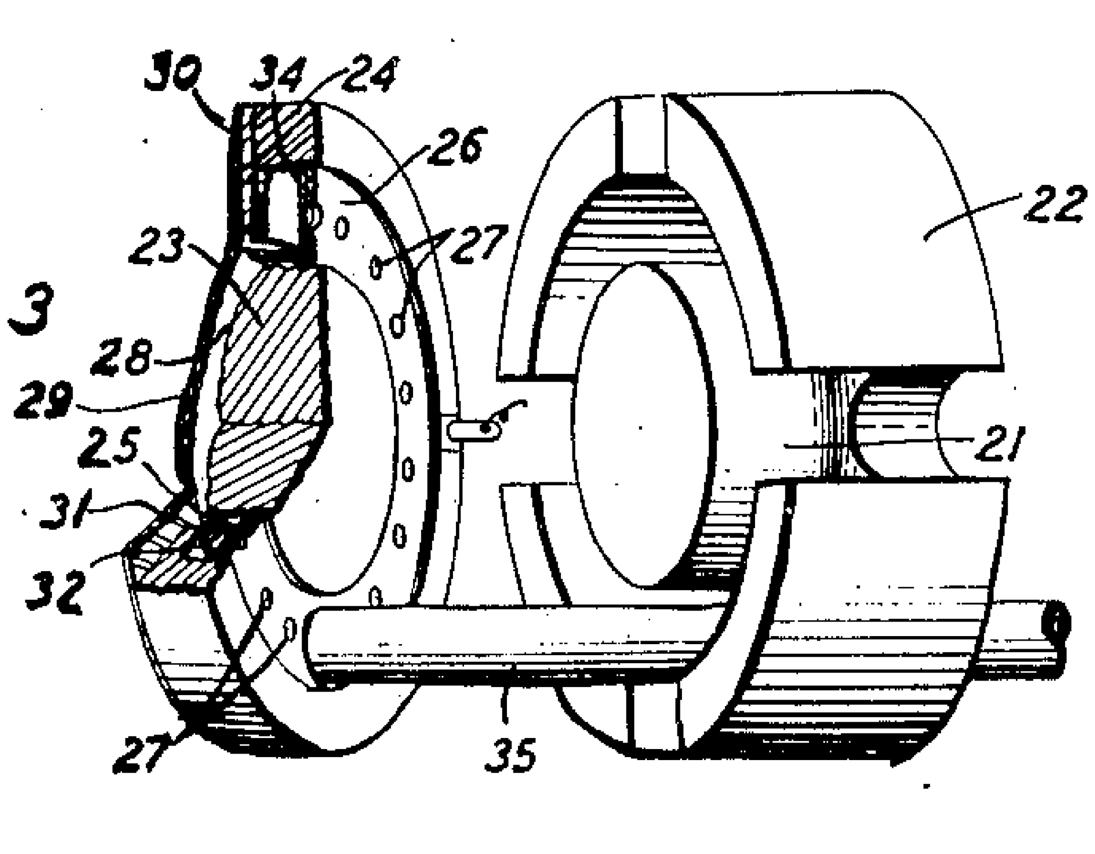

FIG. 3

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FIG. 4

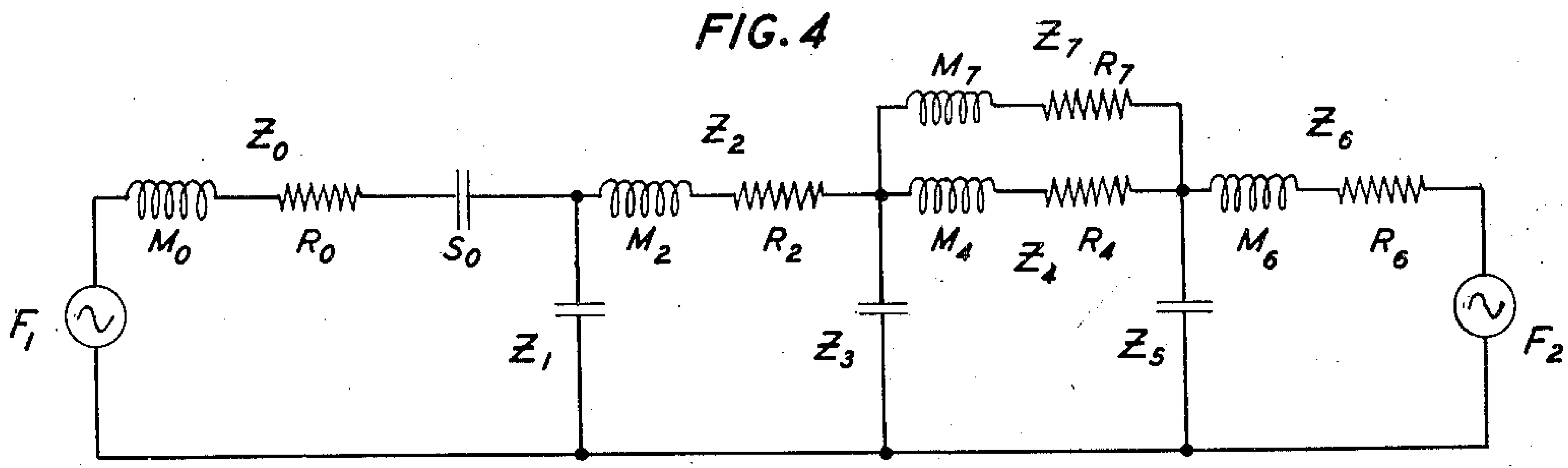


FIG. 5

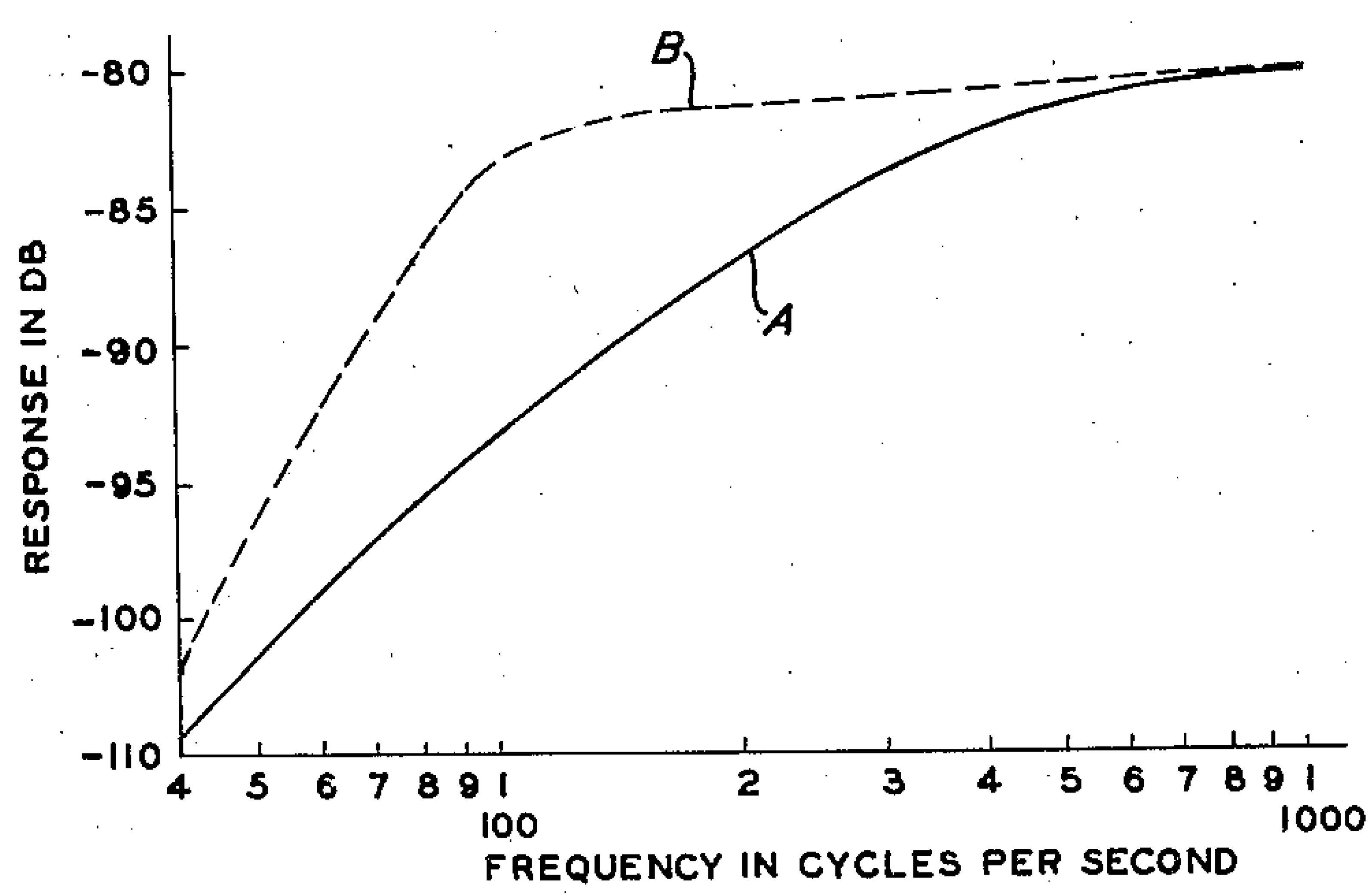
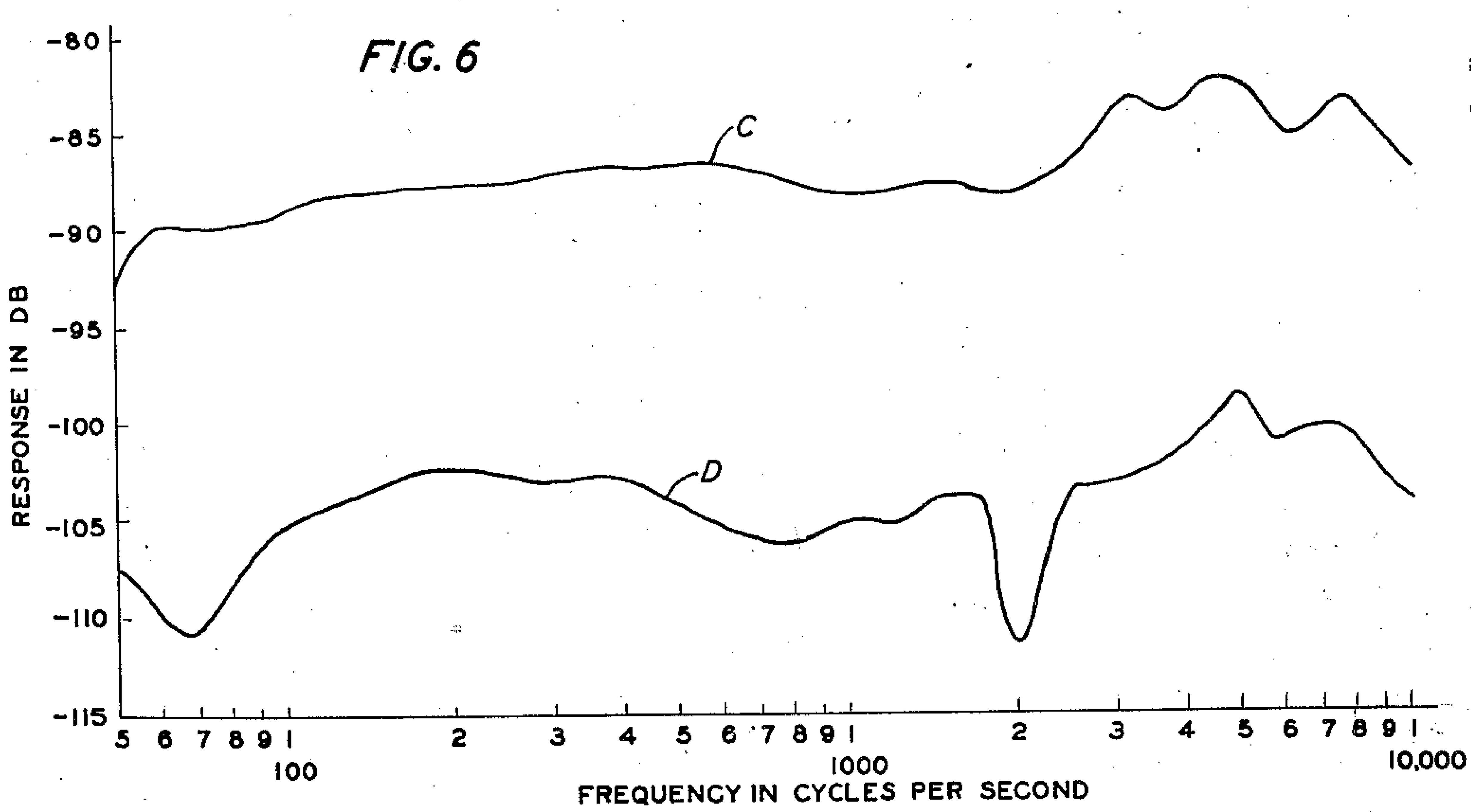


FIG. 6



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UNITED STATES PATENT OFFICE

2,401,328

SOUND TRANSLATING DEVICE

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Application January 16, 1943, Serial No. 472,575

18 Claims. (Cl. 179—179)

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This invention relates to sound translating devices and more particularly to microphones having a marked directional characteristic.

One object of this invention is to assure substantially uniform discrimination by a directional microphone throughout a wide frequency range, for example throughout the range of frequencies from about 50 to 10,000 cycles per second.

Another object of this invention is to obtain a substantially uniform response throughout a wide range of frequencies for a directional microphone.

A further object of this invention is to obtain a high amplitude directional discrimination by a single unit microphone.

Still another object of this invention is to simplify the construction of a unidirectional microphone.

In one illustrative embodiment of this invention, a microphone comprises a single sound translating unit, for example of the moving coil type, mounted within a casing, both surfaces of the diaphragm of the unit being in communication with the atmosphere, one substantially directly and the other by way of an acoustic network defined in part by a chamber bounded by the casing and opening into the atmosphere.

In accordance with one feature of this invention, the communication between the chamber and the atmosphere is established through a multiplicity of restricted apertures arranged in groups spaced different distances from the diaphragm to provide a plurality of sound paths of different lengths between the two surfaces of the diaphragm, the apertures having acoustic resistance material extending thereacross. This enables realization of both directional discrimination throughout a wide frequency range and substantially uniform response throughout this range. This construction enables also attainment of a terminating impedance for the acoustic network associated with the diaphragm, which is composed essentially of only a resistance and a mass and having sufficient resistance to assure a large magnitude of directional discrimination.

In accordance with a further feature of this invention, the resistance and mass components of the terminating impedance are related in such manner that the directional discrimination due to the phase shifting effect of the acoustic network is substantially uniform throughout the range of frequencies below that at which the discrimination due to diffraction effects of the casing becomes substantial.

In accordance with another feature of this

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invention, an acoustic impedance is associated with the diaphragm, this impedance being predominantly mass in character at low frequencies and predominantly resistive in character at high frequencies whereby the response at the low frequency end of the range to be translated is materially enhanced without substantial reduction in discrimination at low frequencies, and substantially uniform response throughout a wide band of frequencies is obtained.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawings in which:

Fig. 1 is a perspective view of a sound translating device illustrative of one embodiment of this invention;

Fig. 2 is a side view mainly in section of the device shown in Fig. 1;

Fig. 3 is a perspective exploded view of the transmitter unit included in the device shown in Fig. 1, a portion of the unit being broken away to illustrate details of construction more clearly;

Fig. 4 is a circuit diagram illustrating the electrical analog of the acoustic system of the device shown in Figs. 1 to 3;

Fig. 5 is a graph illustrating the enhancement of the low frequency response effected in accordance with one feature of this invention; and

Fig. 6 is a graph illustrating the response and the directional character of the device shown in Figs. 1 to 3.

Referring now to the drawings, the microphone illustrated in Figs. 1 to 3 comprises a substantially ovate casing or housing which may be composed of two portions 10 and 11, for example of a phenol condensation product and metal respectively, telescopically fitted together, the casing being fitted in an external band 12 secured to a suitable coupler member 13 for mounting the microphone on a support. The inner wall of the casing portion 10 is formed with an annular seat 14 in which a microphone unit 15 is fitted, the microphone unit being locked in place by a resilient strip 16 bearing thereagainst and sprung into locking engagement with projections 17 on a metallic insert 18 in the casing portion 10. The base 19 of the casing portion 10 is apertured to provide direct communication between the atmosphere and the diaphragm of the microphone unit. The casing portion 11 also is provided with apertures 20 covered with acoustic silk 33, the arrangement and function of which will be described hereinafter.

The microphone unit 15 may be of any of the well-known types or forms. In one particularly satisfactory structure it is of the moving coil or electrodynamic type and of the construction illustrated in Fig. 3. As shown in this figure, the microphone unit comprises a one piece permanent magnet having a central pole 21 and an outer pole 22 comprising four arcuate arms mounted in cylindrical array and encompassing and coaxial with the central pole, the two poles being of opposite polarity. Seated upon the poles 21 and 22 and held thereto by magnetic attraction is a unitary structure including concentric pole-pieces 23 and 24 defining an annular gap 25, and a non-magnetic ring 26 provided with a plurality of restricted apertures 27, all but one of the apertures being covered by acoustic resistance material 34, such as silk. The inner pole-piece 23, which abuts the central pole 21, is provided with a domed surface 28.

A diaphragm is mounted on the magnet structure and comprises a central, bodily vibratile dome portion 29 conforming substantially to the domed surface 28 of the inner pole-piece 23, a marginal portion 30 secured to the outer pole-piece 24, and an intermediate, flexible tangentially corrugated portion 31. Secured to the diaphragm adjacent the periphery of the dome portion 29 thereof is an annular signal coil 32 which is positioned in the gap 25 between the pole-pieces 23 and 24. Vibration of the diaphragm in response to sound waves impinging thereon results in the generation of a corresponding electromotive force in the coil 32.

A tube 35, for example of rubber, the function of which will be pointed out hereinafter, is secured to the non-magnetic ring 26 in alignment with the one of the apertures 27 which does not have the acoustic resistance material 34 extending thereacross.

The device illustrated in Figs. 1 to 3 constitutes an acoustic transducer which may be represented by the multimesh, electrical analog network shown in Fig. 4. In this figure, Z_0 is the diaphragm impedance composed of the mass M_0, resistance R_0 and stiffness S_0, Z_1 is the impedance, substantially entirely stiffness, of the chamber between the diaphragm and the pole-pieces 23 and 24, Z_2 is the impedance of the passage defined by the gap 25, which impedance is composed of a mass M_2 and a resistance R_2, Z_3 is the impedance, substantially entirely stiffness, of the chamber adjacent the diaphragm side of the ring 26, Z_4 is the impedance, composed of a mass M_4 and resistance R_4, of the apertures 27 and the acoustic silk 34, Z_5 is the impedance, substantially entirely stiffness, of the chamber bounded by the housing or casing 10, 11, and Z_6 is the impedance of the apertures 20 and the acoustic silk 33 thereacross. The tube 35 constitutes an impedance Z_7, having a mass M_7 and resistance R_7, in shunt with the impedance Z_4.

The diaphragm of the microphone unit, it will be noted, has both surfaces thereof in communication with the atmosphere, the front surface being exposed directly to the atmosphere through the apertured base 19 of the casing portion 10 and the rear surface being in communication with the atmosphere through a three-section network terminating in the impedance Z_6 of the silk covered apertures 20. Hence, the diaphragm is acted upon by two forces, F_1 and F_2 due to sound waves arriving at the microphone, the force F_2, in general, being in opposition to the force F_1. The magnitude of the resultant force $(F_1—F_2)$ is dependent upon the angle of incidence of the sound waves upon the microphone, as is apparent, and is dependent also upon the length of the air path between the two surfaces of the diaphragm, the length of the path being determinative in part of the phase relation between the two forces F_1 and F_2. Thus, the response of the microphone is dependent upon the angle of incidence of the sound waves and the device has a directional characteristic.

In a device of the character disclosed, directional discrimination is due to two effects, namely, the phase shifting effect of the network behind the diaphragm and the diffraction effect of the casing. In general, the former effect predominates throughout the lower portion, for example, up to of the order of 3,000 or 4,000 cycles, of the frequency range to be translated and the latter effect is predominant at the higher frequencies. The lowest frequency at which the diffraction effect becomes of substantial magnitude, for example of the order of seven or eight decibels, can be determined in ways known in the art from the dimensions and contour of the casing.

The phase shifting effect of the network behind the diaphragm is dependent in the main upon the character of the impedance Z_6, the portions of the network in Fig. 4 to the left of the impedance Z_5 being essentially only response determining impedances. The impedance Z_6, it will be apparent, has both a resistive and a reactive component, the reactive component being essentially a mass. It has been found that an optimum relationship exists between these two components for the realization of large amplitude directional discrimination, substantially uniform throughout a wide frequency range, i. e. up to the frequency at which the diffraction effect becomes of substantial magnitude as noted hereinabove.

Both the resistive and reactive components of the impedance Z_6 vary with frequency, the resistive component, in general, decreasing with frequency from a maximum at zero cycles per second and the reactive component increasing with frequency from a minimum, substantially zero at zero cycles per second, throughout the major portion of the range of frequencies in which the phase shifting effect predominates.

The impedance Z_6 can be expressed in the form $a+jb$ where a and b are the resistive and reactive components respectively, the reactive component being essentially a mass as pointed out heretofore. It can be shown readily from an analysis of the network illustrated in Fig. 4 that maximum discrimination between incidence angles of 0 degrees and 180 degrees obtains when

$$a=\frac{S_5}{\omega}\sin\frac{\omega D}{C} \qquad (1a)$$

and

$$b=\frac{2S_5}{\omega}\sin^2\frac{\omega D}{2C} \qquad (1b)$$

where $S_5=Z_5$, Z_5 being essentially a stiffness as noted heretofore, $\omega=2\pi$ times the frequency, $C=$ the velocity of sound in air, and $D=$ the path length between the two surfaces of the diaphragm.

The optimum relation of the resistive and reactive components results in substantially uniform discrimination at all frequencies in the band up to the frequency at which the diffraction effect becomes of substantial magnitude has been found to obtain when these components are matched at substantially the middle frequency in this band. Thus, for example, if the band extends from zero to of the order of 3,000 cycles per second, the quantities a and b as given by Equations 1a and 1b should be matched at substantially 1,500 cycles.

At low frequencies in this band, the reactive component b is small as is apparent from Equation 1b, and the quantity a is substantially equal to

$$\frac{S_5D}{C}$$

as is apparent from Equation 1a, bearing in mind that for small angles, the angle is substantially equal to the sine thereof. The electromotive force generated in the coil 32, which force is a measure of the response of the device, is directly proportional to the velocity of motion of the diaphragm. At the low frequencies, the diaphragm velocity is directly proportional to the quantity

$$\frac{F_1\left(Z_6+\frac{S_5D}{C}\cos\theta\right)}{Z} \qquad (2)$$

where Z is a function of the mechanical impedance of the device.

As pointed out above, at the low frequencies, the quantity b is substantially zero and the impedance Z_6, therefore, is essentially resistive and substantially equal to

$$\frac{S_5D}{C}$$

Hence, the numerator of Equation 2 can be written in the form

$$\frac{F_1S_5D}{C}(1+\cos\theta)$$

from which it is seen that the directive pattern of the device is cardioidal in form at the low frequencies. It has been found that this pattern is cardioidal also at the higher frequencies.

From what has been said above, it will be seen that the range of frequencies throughout which directional discrimination in the manner indicated is obtainable is dependent upon the path difference D. This in turn is dependent upon the distance between the apertures 20 in the casing and the diaphragm. In general, the greater this distance the narrower is the frequency range throughout which the discrimination is realized, and the upper frequency of this band is that for which the wave-length is comparable with the path difference D. On the other hand, the magnitude of the discrimination is dependent upon the magnitude of the impedance Z_6. Furthermore, the magnitude of the response at the lower frequencies has been found to be dependent upon the path length D and, in general, the greater this length the greater is the response at the lower frequencies.

Thus, it will be seen that the attainment of directional discrimination has two aspects, namely frequency range and magnitude, and that a common factor involved in these two aspects is the path length D. It will be appreciated further that this factor enters into the determination of the magnitude and the frequency range of directional discrimination in different, and in a sense contradictory, ways in that, generally speaking, a wide frequency range dictates the attainment of a short path length whereas high magnitude dictates the use of a long path length. In devices constructed in accordance with a feature of this invention both the desired wide frequency range and high magnitude of directional discrimination are realized.

As shown in Figs. 1 to 3, the housing portion 11 is provided with a multiplicity of silk covered apertures 20. These apertures are arranged in a number, for example four, circular rows, the apertures in the rows being equally or unequally spaced, the rows being equally spaced, and the apertures in adjacent rows being in staggered relation. There are thus provided a plurality of paths of different lengths between the two surfaces of the diaphragm.

For example, the row of apertures 20 farthest from the diaphragm may be spaced therefrom of the order of 10 centimeters and the row of apertures 20 nearest the diaphragm may be spaced therefrom a distance of the order of 6 centimeters. These distances correspond respectively to half wave-lengths of approximately 1,700 and 2,900 cycles per second respectively. The relatively short path length for sound waves passing through the apertures 20 nearest the diaphragm assures substantial directional discrimination, because of the network behind the diaphragm, in the range of frequencies at least up to about 3,000 cycles per second. The other apertures, because of their greater spacing from the diaphragm are particularly effective at the intermediate and lower frequencies in this range and assure a relatively large magnitude discrimination at these frequencies. All of the apertures together constitute the impedance Z_6. Furthermore, it has been found that the arrangement of apertures in the device illustrated in Figs. 1 to 3 constructed to provide the resistance and mass relation for Z_6 as described heretofore results in substantially uniform directional discrimination throughout the frequency range up to about 3,000 cycles per second. This is shown clearly in Fig. 6 where curve C indicates the response of a device of the construction shown in Figs. 1 to 3 for zero degree incidence angle and curve D indicates the response of the same device for incidence angle of 180 degrees.

It may be noted that the construction of the housing member 11 and the arrangement of the apertures 20 therein facilitates the attainment of an impedance Z_6 composed essentially of resistance and mass. The resistance of an aperture covered with acoustic silk is a function of the area of the aperture. Although the requisite resistance might be obtained by the use of a single large area aperture covered with silk, such construction would involve the mechanical problem of mounting the acoustic silk so that it would not vibrate in response to sound waves impinging thereon and thus act as an impedance having a material stiffness component as well as mass and resistance. The use of a large number of small apertures 20 assures not only the attainment of the requisite resistance but also the provision of an impedance Z_6 which is essentially without a stiffness component.

Above about 3,000 cycles, the magnitude of the directional discrimination due to the network behind the diaphragm decreases markedly. However, above this frequency directional discrimination due to diffraction effects becomes pronounced so that, as shown by the curves of Fig. 6, substantially uniform discrimination is obtained throughout the range from about 50 cycles to about 10,000 cycles.

The amplitude of the response of the device shown in Figs. 1 to 3 is dependent largely upon the impedance Z_5, which as previously noted is essentially a stiffness, the terminating impedance Z_6 and the impedances Z_4 and Z_7. Without the impedance Z_7, it has been found that the response of the device falls off rather rapidly at the low frequency end, i. e. at frequencies below about 300 cycles, of the range to be translated.

In general, the response at the low frequency end of the range is directly proportional to the volume of the chamber within the casing 10, 11 and inversely proportional to the resistance R_6. The construction shown in Figs. 1 to 3 allows the use of a fairly large volume chamber so that some enhancement of the low frequency response due to the correspondingly low chamber stiffness is realized. However, practical design considerations and also the requirements for attainment of directional discrimination throughout a wide range of frequencies limit the enhancement of the low frequency response which can be realized by increasing the volume of the chamber. Also, as noted heretofore, realization of maximum directional discrimination entails use of a resistance in the impedance Z_6.

However, the impedance Z_4 can be operated upon to obtain an increase in the response at the low frequency end of the range to be translated without reducing the directional characteristics of the microphone. Theoretically, enhancement of this response would result if the impedance Z_4 were primarily a mass. However, inherently because of the required damping of the diaphragm to reduce the peak due to diaphragm resonance, the impedance Z_4 must have a substantial resistance component. Further, a mass adequate to effect the desired enhancement would result in substantial attenuation of the high frequency response.

The desired enhancement at the low frequency end without substantial attenuation of the high frequencies and without substantial reduction of the directional discrimination is realized by the use of the tube 35. This tube constitutes an impedance element having mass M_7 and resistance R_7, as pointed out heretofore, which is in shunt with the impedance Z_4. The tube is made of relatively large diameter so that the mass M_7 thereof is very large in comparison to the resistance R_7. The resistance R_4, it will be apparent, is large in comparison to the mass M_4. Hence, the impedances Z_4 and Z_7 are essentially a mass M_7 and a resistance R_4 in parallel and the combination of Z_4 and Z_7 is an impedance element which acts primarily as a mass at the low frequencies and primarily as a resistance at high frequencies, and is effective to increase the response at low frequencies without attenuation of the high frequencies.

The effect upon the response in the low frequency range, of the impedance introduced by the tube 35 is illustrated in Fig. 5, wherein curve A indicates the response for a device without the tube 35 and curve B indicates the response of a device with the tube. It is seen from a comparison of curves A and B that the tube 35 results in substantial enhancement of the response at frequencies below about 300 cycles per second so that a substantially uniform response is obtained between about 100 and 300 cycles per second.

An increase in the response below 100 cycles per second to extend the frequency range, wherein a uniform response is realized, can be obtained by appropriate design of the electrical circuit associated with the microphone. Specifically, if, as is usually the case, the microphone is coupled to an amplifier through a transformer, a condenser may be connected between the coil 32 and the primary of the transformer and in series therewith, the condenser having such capacitance that the input circuit to the amplifier is resonant at about 50 or 60 cycles per second.

In some cases standing waves may be produced within the housing 10, 11 in the chamber behind the diaphragm. The production of such waves can be prevented by providing a filling of a material such as lamb's wool in this cavity. Such a filling, from the impedance standpoint, has the character of a distributed resistance and does not affect deleteriously the directional pattern and response of the device.

Although a specific embodiment of this invention has been shown and described, it will be understood that it is but illustrative and that various 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 directional microphone comprising a diaphragm one surface of which is exposed substantially directly to the atmosphere, signal translating means cooperatively associated with said diaphragm, and means defining an acoustic phase shifting network coupling the other surface of said diaphragm to the atmosphere and including resistance means and a chamber having communication with the atmosphere through a plurality of apertures spaced different distances from said diaphragm.

2. A directional microphone comprising a diaphragm having one surface exposed substantially directly to the atmosphere, signal translating means cooperatively associated with said diaphragm, means defining a chamber substantially enclosing the other surface of said diaphragm, said chamber having a plurality of groups of apertures spaced different distances from said diaphragm, and acoustic resistance means extending across said apertures, said acoustic resistance means being constructed in such relation to the stiffness of said chamber that the directional pattern of the microphone is cardioidal.

3. A directional microphone comprising a casing, a diaphragm, within said casing and having one surface communicating substantially directly with the atmosphere through an opening in said casing, signal translating means cooperatively associated with said diaphragm, and an acoustic phase shifting network coupling the other surface of said diaphragm to the atmosphere, said network including a resistive termination and a chamber bounded by said casing, said casing having in the chamber bounding portions thereof a plurality of restricted apertures arranged in groups and each group being spaced from said diaphragm a distance different than each of the other groups.

4. A directional microphone comprising a diaphragm having one surface in substantially direct communication with the atmosphere, signal translating means cooperatively associated with said diaphragm, and phase shifting means coupling the other surface of said diaphragm to the atmosphere, said phase shifting means including a chamber providing a plurality of paths of different lengths coupling said other surface of said diaphragm to the atmosphere and acoustic resistance means in said paths.

5. A directional microphone comprising a casing having an apertured end portion, a diaphragm within said casing and having one surface adjacent said end portion, means associated with said

diaphragm to translate vibrations thereof into electrical variations, said casing having therein a plurality of groups of apertures remote from said end portion, the apertures in each group being spaced a different distance from said end portion than the other groups, and air pervious acoustic resistance material overlying said apertures.

6. A directional microphone comprising an elongated casing having an apertured end portion, a diaphragm within said casing, extending transversely thereof and having one surface adjacent said end portion, said casing bounding a chamber coupled to the other surface of said diaphragm and having therein a plurality of apertures spaced from said end portion, said apertures being arrayed in circular groups each of which is disposed about the longitudinal axis of said casing, each group being spaced from said end portion a distance different than the other groups, acoustic resistance means adjacent said apertures and defining with said chamber a phase shifting acoustic network such that the directional pattern of the microphone is cardioidal, and signal translating means cooperatively associated with said diaphragm.

7. A directional microphone comprising a diaphragm having one surface in substantially direct communication with the atmosphere, means including a chamber and acoustic resistance means defining an acoustic network coupling the other surface of said diaphragm to the atmosphere, said chamber having communication with the atmosphere through a first group of apertures spaced of the order of 6 centimeters from said other surface, a second group of apertures spaced of the order of 10 centimeters from said other surface and apertures between said first and second groups, each of the apertures establishing communication between said chamber and the atmosphere independently of the other apertures, and means for translating vibrations of said diaphragm into electrical variations.

8. A directional microphone comprising an elongated casing having an apertured end portion, a diaphragm within, coaxial with and having one surface adjacent said end portion of said casing, said casing having a plurality of groups of apertures spaced from said end portion, the apertures in each group being in circular array about the longitudinal axis of said casing, said groups being spaced different distances from the other surface of said diaphragm and adjacent groups being substantially equally spaced, the group of apertures nearest said end portion being spaced from the other surface of said diaphragm a distance substantially equal to one-half wavelength of a preassigned frequency in the operating range of the microphone, acoustic resistance means adjacent said apertures, and means for translating vibrations of said diaphragm into electrical variations.

9. A directional microphone in accordance with claim 8 wherein the group of apertures nearest said end portion is spaced of the order of 6 centimeters from the other surface of said diaphragm and wherein the group of apertures farthest from said end portion is spaced of the order of 10 centimeters from said other surface.

10. A directional microphone comprising a substantially ovate casing the larger end of which is apertured, a diaphragm within said casing, extending transversely thereof and having one surface adjacent said apertured end, means for translating vibrations of said diaphragm into electrical variations, said casing having a plurality of apertures therein spaced from said apertured end, said apertures being arranged in circular rows symmetrical about the longitudinal axis of said casing and spaced different distances from said apertured end of said casing, and acoustic resistance silk extending across said apertures.

11. A directional microphone comprising a casing having a predetermined directional diffraction characteristic, a diaphragm within said casing and having one surface in substantially direct communication with the atmosphere through an aperture in said casing, said casing bounding a chamber in communication with the other surface of said diaphragm and having an apertured portion spaced from said other surface, and an acoustic network including said chamber and apertured portion, said network including also an acoustic impedance composed essentially of a resistance and a mass and the resistive and reactive components of which are substantially equal at the frequency substantially midway in the frequency range below the frequency at which the directional diffraction effect of said casing becomes substantial.

12. A directional microphone comprising a casing having an apertured end portion and a predetermined directional diffraction characteristic, a diaphragm within said casing and having one surface adjacent said apertured end portion, said casing defining a chamber opposite the other surface of said diaphragm and having communication with the atmosphere through restricted apertures spaced from said other surface, and acoustic resistance means between said other surface and the atmosphere, said chamber, apertures and resistance means defining an acoustic network the mass reactance and resistive components of which are substantially equal at the frequency substantially midway betwen zero and the frequency at which the diffraction effect of said casing becomes substantial.

13. A directional microphone comprising a diaphragm having one surface in substantially direct communication with the atmosphere, and means defining a phase shifting network coupling the other surface of said diaphragm to the atmosphere, said means including a stiffness defined by a chamber bounded by a casing having walls extending from adjacent said diaphragm and having also a predetermined directional diffraction effect upon the response of said diaphragm, said network including also a terminating impedance composed essentially of a mass and a resistance, and the resistive and reactive components of said impedance being substantially equal at substantially the midfrequency in the band below the frequency at which said diffraction effect is substantial.

14. A directional microphone in accordance with claim 13 wherein said casing has a directional diffraction effect of the order of eight decibels at of the order of 3,000 cycles per second and wherein said resistive and reactive components are substantially equal at 1,500 cycles per second.

15. A microphone comprising a diaphragm, means adjacent one surface of said diaphragm defining a chamber therewith, said means including a member having a plurality of apertures therein, acoustic resistance means extending across all but at least one of said apertures, and a tube having a high mass to resistance ratio communicating with said chamber through an aperture not covered by said acoustic resistance means.

16. A microphone comprising a diaphragm, means for translating vibrations of said diaphragm into electrical variations, means adjacent one surface of said diaphragm defining therewith an acoustic network including a chamber and an acoustic resistance, and means in communication with said chamber defining a predominantly mass impedance in shunt with said acoustic resistance.

17. A microphone comprising a diaphragm, means for translating vibrations of said diaphragms into electrical variations, means including a multiapertured annular member adjacent and coaxial with one surface of said diaphragm defining a chamber therewith, one of the apertures in said member constituting an open passage communicating with said chamber, an elongated tube having a high mass to resistance ratio, one end of said tube being secured to said member in communication with said one aperture, and acoustic resistance material extending across other of the apertures in said member.

18. A directional microphone comprising a diaphragm having one surface in substantially direct communication with the atmosphere, means defining an acoustic network including a chamber coupling the other surface of said diaphragm with the atmosphere, said chamber having communication with the atmosphere through a plurality of groups of restricted apertures spaced different distances from the other surface of said diaphragm, acoustic resistance means included in said network and so constructed and arranged in relation to said chamber that the directional pattern of the microphone is a cardioid, means adjacent said other surface of said diaphragm defining an acoustic impedance having a high resistance component in series with the diaphragm impedance, and means defining a predominantly mass acoustic impedance in shunt with said resistance component.

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