

April 17, 1951

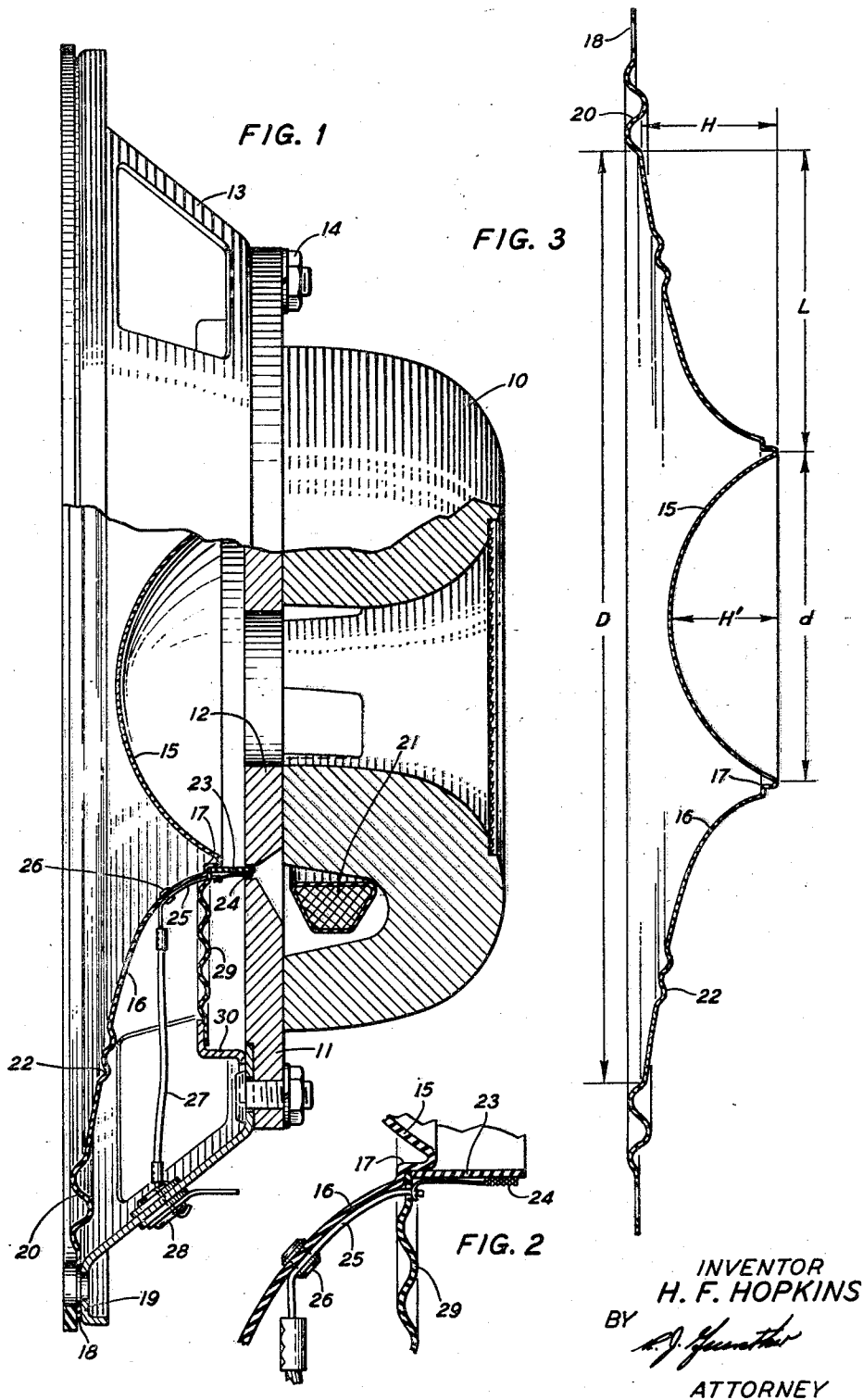
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2,549,091

DIAPHRAGM FOR ELECTROACOUSTIC TRANSDUCERS

Filed Oct. 25, 1946

3 Sheets-Sheet 1



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DIAPHRAGM FOR ELECTROACOUSTIC TRANSDUCERS

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FIG. 4

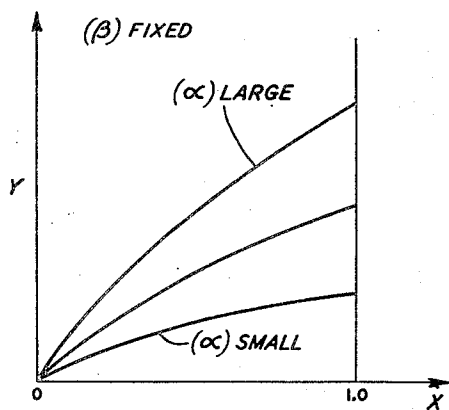


FIG. 5

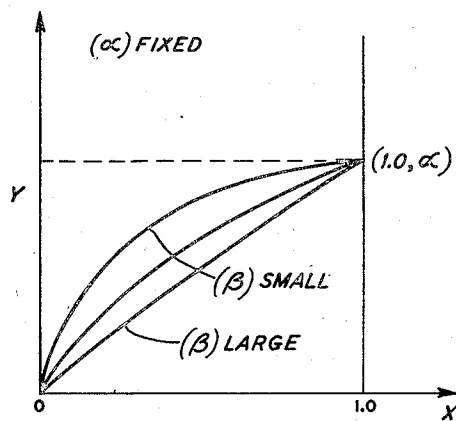


FIG. 6A

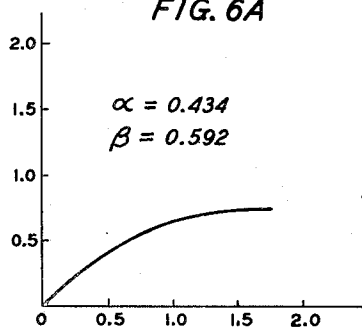


FIG. 6B

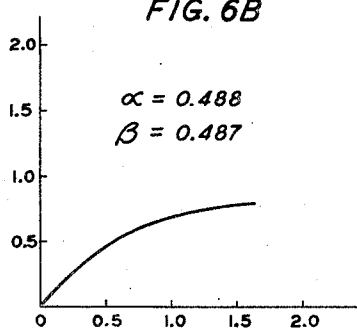
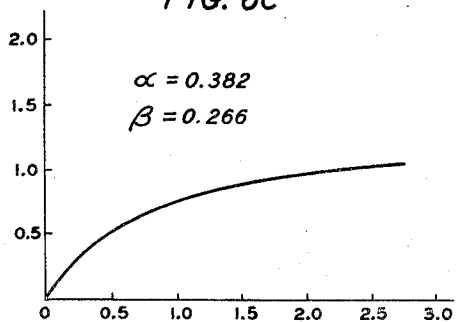


FIG. 6C



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FIG. 7

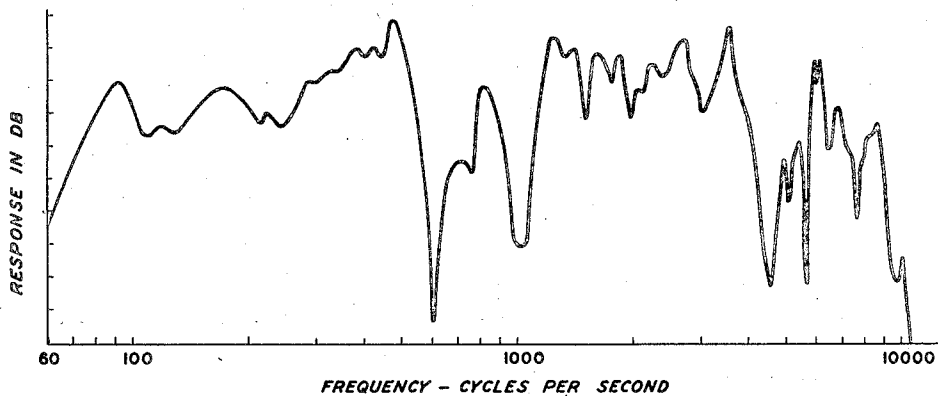


FIG. 8

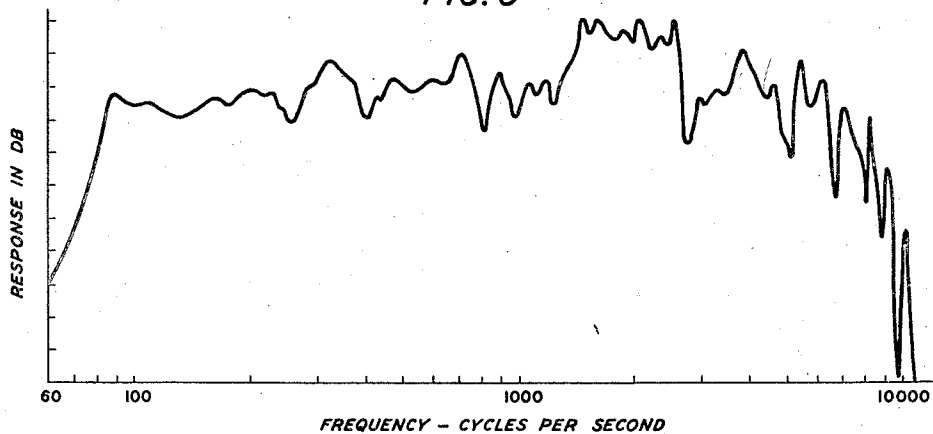
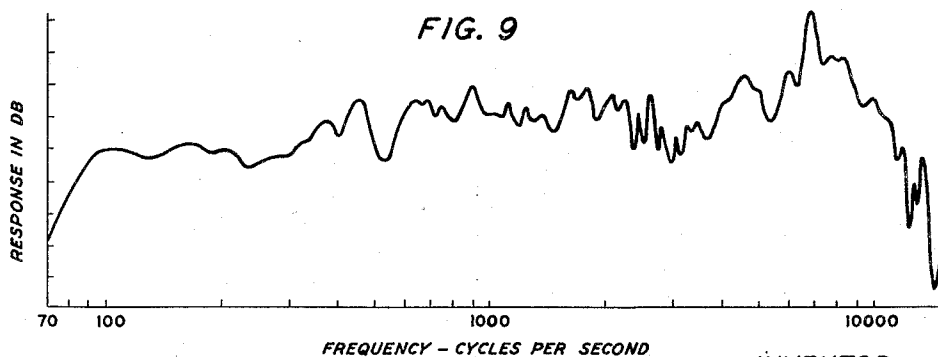


FIG. 9



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15 Claims. (Cl. 181—32)

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This invention relates to electroacoustic transducers and more particularly to direct acting diaphragms especially suitable for use in loudspeakers of the moving coil type.

One object of this invention is to improve the performance of electroacoustic transducers and, more particularly, to reproduce speech and music with high fidelity. More specifically, an object of this invention is to realize, with a single direct acting loudspeaker, essentially uniform translation of electrical signals corresponding to speech and music into acoustic power over a wide range of frequencies, specifically over a range of from the order of 60 cycles to 10,000 cycles.

Criteria for evaluating the performance of a loudspeaker are the acoustic power which can be propagated, the translating efficiency, the frequency range of translation and the relative response throughout this range. Some of the factors and parameters entering into the determination of the performance for any particular loudspeaker, and more specifically for the diaphragm thereof, may be determined fairly readily from fundamental considerations. Other parameters, however, involve complex relationships which do not lend themselves readily to mathematical or even straightforward theoretical or physical analyses.

The acoustic power radiated by a diaphragm in direct acting loudspeakers is a direct function of the effective diaphragm area and the amplitude of diaphragm vibration. The vibrational amplitude practically permissible is limited. Hence, the parameter which can be operated upon primarily to obtain high power outputs is the diaphragm size. High output, generally, involves use of a large diaphragm. Efficient translation of electrical energy into acoustic power dictates the use of a lightweight diaphragm in order that but a small portion of the electrical energy will be expended in overcoming the inherent inertia of the vibrating system. The desideratum of light weight can be realized by use of a thin diaphragm.

Light weight for the diaphragm is desirable also from the standpoint of extent of the useful frequency range, for it enables attainment of a relatively low mass reactance and substantial response at the higher frequencies. In general, decreasing the diaphragm mass results in enhancement of the high frequency response or extension of the range of frequencies which can be reproduced.

Theoretical considerations indicate it to be advantageous from the standpoints of both op-

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erating frequency range and uniformity of response that the diaphragm vibrate bodily analogous to a piston over at least the greater portion of the range of frequencies to be reproduced and that it vibrate in such a manner at the higher frequencies as to reduce the effective mass of the diaphragm. A reduction of mass reactance at the higher frequencies obtains if a reduction in the effective vibrating area of the diaphragm occurs. This connotes a diaphragm of substantial rigidity in the piston like portion. Inasmuch as rigidity is proportional to the cube of thickness, production of such a diaphragm, generally speaking, involves the problem of obtaining the desired stiffness without undue increase of the diaphragm mass and consequent decrease in the operating efficiency.

A partial solution to this problem resides in the expedient of shaping the diaphragm to increase its rigidity, for example by making the diaphragm conical in form or of other non-planar cross-sectional configuration. One design which has been found advantageous is a circular diaphragm of generally W-shaped cross-section. It has been found, however, that even a diaphragm of such advantageous configuration does not result in the uniform and wide range reproduction necessary to satisfy the requirements for high quality reproduction of speech and music. Response measurements of both commercially available and experimental devices have shown that not only does the response thereof fall off rapidly at the higher frequencies but also even at lower frequencies the response is characterized by regions of pronounced irregularity, which result in serious distortion.

One cause of such irregularity and distortion, it has been determined, is non-cophasic vibration of different areas of the diaphragm, which produces serious interference effects and, more specifically, results in substantial cancellation of the radiation from different diaphragm areas at various frequencies. It has been determined further that the principal factors affecting the vibrational character of the diaphragm are the specific form of the outer radiating portion of the diaphragm and the impedance, from the standpoint of radial transmission of energy through the diaphragm, of the edge or support portion of the diaphragm. More specifically, it has been found that in a diaphragm of generally W-shaped section, the configuration of the intermediate or frusto-conical portion of the diaphragm and the character of the edge portion, i. e. the part immediately adjacent the periphery

or outer margin of the intermediate portion, are of prime importance and play a major part in determining the frequency range and quality of reproduction.

In accordance with one feature of this invention, the intermediate and edge portions of the diaphragm are so constructed and arranged that no serious interference effects obtain within the entire frequency range to be reproduced and essentially uniform response at high translating efficiency is realized throughout this range.

In one illustrative embodiment of this invention, a loudspeaker comprises a circular direct acting diaphragm formed, e. g. molded, in one piece of pulp fibre and having a central stiffened, e. g. domed, portion, an intermediate frusto-conoidal portion, a peripheral mounting portion and a flexible edge portion between the intermediate and mounting portions. The generatrix of the intermediate portion is a logarithmic curve of a particular form described in detail hereinafter and this portion is of a maximum height of the order of one-half the wavelength of the mid-frequency in the range of frequencies to be reproduced. Further, this portion is provided with one or more stiffening corrugations intermediate the margins thereof, specifically located substantially sixty per cent of the radial width of this portion from the inner margin thereof.

The edge portion is thinner than the remainder of the diaphragm and is corrugated circularly to provide a low stiffness mount for the radiating portion of the diaphragm whereby substantially unrestrained and large amplitude diaphragm vibrations are allowed and, also, high dissipation of energy transmitted radially through the diaphragm obtains and reflection of such energy is substantially reduced.

Additionally, the flexible edge portion is coated, advantageously upon both faces, with a damping material. A particularly efficacious material is a plasticized cellulose nitrate compound known commercially as Pyralin. This may be dissolved in a solvent, such as acetone, to form a 30 per cent solution which is brushed onto the faces mentioned. But a relatively small amount of this damping material is required. For example, in an illustrative construction, a total effective mass of damping material of the order of two grams has been found adequate for a 12 inch pulp fibre diaphragm having a total effective mass, including air load, of the order of 28 grams. The damping coatings, which do not substantially increase either the effective mass of the diaphragm or the stiffness of the diaphragm edge portion, perform the dual function of substantially suppressing the response peak due to the natural or resonance frequency of the diaphragm and of substantially entirely dissipating the energy transmitted radially through the diaphragm to the edge portion.

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 drawing in which:

Fig. 1 is a cross-sectional view of a loudspeaker illustrative of one embodiment of this invention;

Fig. 2 is a detail view in section and to an enlarged scale of a portion of the diaphragm assembly included in the loudspeaker illustrated in Fig. 1;

Fig. 3 is a dimensioned cross-sectional view of the diaphragm;

Figs. 4 and 5 are graphs showing the configuration of a portion of the diaphragm for several

values of two of the principal dimensional parameters involved;

Figs. 6A, 6B and 6C are plots showing the form of the generatrix for the intermediate portion of several diaphragms of different diameters constructed in accordance with one feature of this invention;

Figs. 7 and 8 are frequency response curves which illustrate, as hereinafter described, the effect of the damping coating upon the edge portion of the diaphragm, provided in accordance with one feature of this invention; and

Fig. 9 is another frequency response curve, for a loudspeaker of the construction illustrated in Fig. 1 and embodying features of this invention.

Referring now to the drawing, the loudspeaker illustrated in Fig. 1 comprises a substantially semi-toroidal magnet 10 of high strength magnetic material, such as "Alnico," to the pole faces of which coaxial, annular pole-pieces 11 and 12, spaced to define an annular magnetic gap, are affixed, as by welding. Disposed within the magnet structure is a cylindrical coil 21 which may be energized to permanently magnetize the magnet 10 after the pole-pieces have been affixed thereto or after assembly of the loudspeaker has been completed.

A shallow housing 13, for example stamped of sheet metal is affixed to the outer pole-piece 11 by bolts 14 and encloses and mounts a direct acting diaphragm. The diaphragm, which will be described in detail hereinafter, comprises a central dished portion 15, an annular, intermediate frusto-conoidal portion 16 joined to the central portion 15 by a flanged, cylindrical step 17, a peripheral mounting portion 18 seated upon and secured to the flange 19 of the housing 13, and a circularly corrugated flexible edge portion 20 intermediate the portions 16 and 18. The frusto-conoidal portion 16 is provided with circular corrugations 22.

As is apparent from Figs. 1 and 3 and as will be brought out clearly hereinafter, the curvature of the generatrix of the frusto-conoidal portion 16 is greatest immediately adjacent the step 17 and decreases as the flexible portion 20 is approached. The corrugations 22 are located at a position where the curvature of the portion 16 is relatively small and most advantageously at a position substantially 60 per cent of the radial width of the portion 16. These corrugations serve to stiffen the diaphragm and thus to prevent breaking up or local vibrations thereof whereby interference effects of the character heretofore discussed are reduced.

Desirably the entire diaphragm is formed in one piece of lightweight material having high internal dissipation, for example molded of deposited pulp fibres, and the flexible portion 20 is made substantially thinner than the central and annular portions 15 and 16, respectively. For example, in one illustrative construction found particularly satisfactory, the diaphragm had a flexible portion 20 twelve inches in outer diameter and 12 mils thick and central and intermediate portions 15 and 16, respectively of the order of 25 mils thick.

The relatively thin and circularly corrugated edge portion 20 mounts the central and intermediate portions 15 and 16 for bodily vibration and because of its small stiffness imposes but little restraint upon axial displacement of the bodily vibratile parts of the diaphragm. Additionally, considered from the standpoint of transmission of energy radially outwardly through the

diaphragm the low stiffness portion 20 presents a low impedance so that reflection of such energy is substantially reduced.

The corrugated flexible portion 20 is coated upon both faces with a damping material of the character heretofore set forth.

Affixed, e. g. cemented, to the step 17 in the diaphragm is a rigid cylindrical coil form or support 23, which extends coaxially into the magnetic gap between the pole-pieces 11 and 12 and carries a cylindrical driving coil 24. The ends of this coil are joined to metallic strips 25, only one of which is shown, affixed to the diaphragm portion 15 by eyelets 26 to which lightweight leading-in conductors 27 are connected. The conductors 27 extend and are connected to terminals 28 insulatingly mounted upon the housing 13.

An annular, circularly corrugated flexible member 29 is affixed to the diaphragm at the step 17 and joined at its periphery to an imperforate shield and support 30 which is mounted upon the outer pole-piece 11 and secured thereto by the bolts 14. The member 29 is of a suitable lightweight material pervious to air but impervious to dust and dirt and serves, together with the support 30, to prevent entrance of foreign particles into the gap between the pole-pieces. This member is constructed and mounted so that it has small stiffness and, hence, does not appreciably affect the diaphragm motion.

Generally, a loudspeaker diaphragm is designed with the acoustic power to be radiated thereby as one of the principal requirements. As has been pointed out heretofore, in order to maintain the vibrational amplitude of the diaphragm within practical or reasonable limits, for a desired acoustic power output a diaphragm of a certain area must be employed. The desired power output, together with other considerations as will appear presently, enters into the determination of the driving coil diameter employed and, thus, to some extent into the determination of the diameter of the central portion 15 of the diaphragm.

As has been set forth also hereinabove, efficient operation and response desiderata dictate or indicate other parameters of the diaphragm. The mass of the diaphragm should be small in order that high efficiency and high frequency response may be realized. The radiating portion should have substantial rigidity and the edge or mounting portion should have low stiffness. Additionally and advantageously, the mass and stiffness of the vibrating system should be correlated so that the natural or resonant frequency of the diaphragm should be approximately equal to or near the lowest frequency to be reproduced.

To recapitulate, upon the basis of the considerations discussed, a number of design parameters are indicated or dictated. Rigidity and mass considerations suggest the use of a diaphragm of generally W-shaped configuration. Power requirements indicate the diaphragm diameter. The latter also enters somewhat into the determination of the diameter of the central portion, i. e., the portion 15 of the diaphragm illustrated in Fig. 1. Mass, stiffness and resonant frequency requirements determine the diaphragm and diaphragm mount thickness and, to some extent, the form of the mount.

It is apparent that an almost infinite number of specifically different diaphragms can be made consistent with the considerations and desirable parameters and relationships indicated

in the preceding paragraphs. Generally W-shaped diaphragms, low mass diaphragms and diaphragms having a low resonant frequency are known and have been known for some time in the art. Yet none of such diaphragms, so far as applicant is aware, has provided the uniform response and wide frequency range of reproduction highly desired and required for high quality reproduction of speech and music. On the contrary, the art generally has considered the capabilities of any single loudspeaker as limited from the standpoint of uniformity and frequency range of response and has resorted, where high quality reproduction is desired, to combinations of two or more loudspeakers, each designed to cover only a limited portion of the audio frequency spectrum, and associated electrical networks, or to complex designs of vibrating systems or acoustic structures.

It has been determined that the performance of a loudspeaker having a diaphragm of generally W-shaped configuration and designed in the light of the considerations heretofore discussed is dependent largely upon certain definite physical parameters of the diaphragm and especially upon the dimensional parameters of the frusto-conoidal portion 16 of the diaphragm, and that by proper correlation of these parameters a uniform response over substantially the entire range of frequencies of importance for the high quality reproduction of speech and music can be attained. For example, in one specific and illustrative construction, a response uniform within ± 5 decibels over the frequency range from substantially 60 to 10,000 cycles has been realized.

The relationships leading to this result will be discussed with particular reference to Fig. 3, which is a dimensioned outline sectional view of the diaphragm included in the device illustrated in Fig. 1.

As has been pointed out heretofore, the diameter D of the effective radiating portion of the diaphragm is fixed or determined by the acoustic power requirements. The general shape of the diaphragm and the thickness also are indicated by considerations discussed hereinabove. The parameters, then, which can be operated upon are the height H' and form of the central portion 15, and the height H and curvature of the frusto-conoidal portion 16.

The generatrix of the portion 16, neglecting the step 17 and the stiffening corrugations 22, is of the form given by the equation

$$\frac{Y}{L} = \beta \log_{10} \left[1 + (10^{\alpha/\beta} - 1) \frac{X}{L} \right]$$

where

X is the coordinate in the horizontal dimension, measured from the periphery of the central portion 15,

Y is the coordinate in the vertical dimension, measured from the plane of the periphery of the central portion 15,

L is the radial width of the portion 16, as indicated in Fig. 3, and

α and β are constants.

The parameter α , which it will be seen is equal to

$$\frac{H}{L}$$

primarily determines the height of the portion 16 whereas the parameter β primarily determines the curvature of this portion. The effect of varying the parameters α and β upon the curvature

and form of the diaphragm portion 16 is illustrated by the graphs of Figs. 4 and 5 in each of which the graph lines show the form of the generatrix for different values of α or β , the other parameter being fixed. Specifically, as shown in Fig. 4, for a given value of β , the height or Y coordinate increases as α increases; as shown in Fig. 5, the curvature decreases as β increases and for large values of β the generatrix approaches or becomes a straight line.

It is manifest that the height H and, hence, the parameter α for any given value of L is important from the standpoint of the rigidity of the diaphragm. In general, inasmuch as has been pointed out heretofore, substantial diaphragm rigidity is essential, it would be desirable that α be large. However, the greater α is, the greater is the departure of the diaphragm from planar form. Such departure, if increased beyond a certain point, results in non-cophasic vibration of different diaphragm areas and consequent deleterious interference with one another of sound or pressure waves originating at spaced areas upon the diaphragm whereby serious non-uniformities in the frequency response characteristic are produced. For these reasons it has been found eminently desirable that the height H be less than one-half wavelength of the mid-frequency in the band to be translated. More specifically, it has been found that for a diaphragm intended to cover the range from 60 to the order of 10,000 cycles per second, and of the order of 8 to 12 inches in diameter, the diaphragm height H should be between 0.75 and 1.25 inches.

It has been determined further that exceptionally good performance is obtained if the parameter α has a value of substantially 0.4. Some variation in both directions from this value is permissible. Tests of actual devices have shown diaphragms having values of α between 0.375 and 0.5 to be satisfactory.

As has been pointed out hereinabove, the parameter β is the main determinant of the curvature of the portion 16. On the basis of rigidity considerations alone, it would appear that β should be large in order to reduce interference effects due to break up or local vibration of this diaphragm portion. However, experimental investigations have demonstrated that this is not the case for diaphragms for which β is large produce frequency response characteristics which are highly non-uniform, fall off sharply at a relatively low frequency, for example, of the order of 5,500 cycles or even lower, and even at intermediate frequencies or bands of such frequencies are so far below the average response or response at other frequencies that distortion clearly beyond tolerance for high quality reproduction obtains.

On the other hand, a small value of β results in decrease in the diaphragm rigidity and may result in intolerable local vibration or breaking up of the diaphragm at a relatively low frequency with consequent degradation of uniformity in the response characteristic.

It has been determined empirically that the value of β should be of the order of 0.43 and that some departure in either direction from this value is permissible without substantial degradation of performance. Devices of the construction illustrated in Fig. 1 including diaphragms for which β lay between 0.25 and 0.625 have been found to enable attainment of response characteristics essentially flat from 60 to 10,000 cycles or higher.

Although it might appear from cursory consideration of the limits for the parameters α and β above set forth that large order variations in the configuration of the portion 16 of the diaphragm are permissible, actually the difference in shape for relatively large differences in the absolute values of these parameters is quite small. This may be seen from Figs. 6A, 6B and 6C which are plots to scale, the same scale being employed in the three figures, of the form of the generatrix for the diaphragm portion 16 in three diaphragms having diameters (up to the outer periphery of the edge portion 20) of approximately 8, 10 and 12 inches respectively and for which α and β were of the values given on each figure. As is seen from these figures the form of the generatrix is substantially the same for the three diaphragms.

The absolute configuration of the central portion 15 of the diaphragm is not very critical. However, this portion should be spherical or substantially so and the height H' thereof should be substantially equal to the height H of the portion 16.

Although construction of the diaphragm portion 16 in accordance with the relationship above given substantially reduces interference effects, further improvements in the response characteristic and performance may be effected, particularly in the case of large diaphragms formed of a material such as pulp fibre and having small thickness. As has been noted heretofore, the diaphragm portion 16 is provided with stiffening corrugations 22. The location of these corrugations is of considerable importance. For example, to cite one case, it was found that a diaphragm of approximately 8 inches in diameter and of the form illustrated in Fig. 1 and above described but wherein the stiffening corrugations were located immediately adjacent the outer margin of the portion 16 had very pronounced irregularities in its frequency response characteristic at frequencies around 280 cycles per second. Such irregularities were not present, however, in the response characteristic of a diaphragm identical to the first except that the stiffening corrugations were located at about 60% of the width of the portion 16 from the inner margin thereof.

The tendency of a diaphragm to break up so that interference effects result is more pronounced the greater the diaphragm diameter, assuming other factors such as diaphragm thickness and stiffening by corrugations, such as corrugations 22, to be equal or comparable. An indication of the irregularities which may be encountered is to be found in Fig. 7 which illustrates the frequency response characteristic of a diaphragm of the form shown in Fig. 1 and having a diameter (outer diameter of the flexible or edge portion 20) of approximately 12 inches and a diameter for portion 15 of 4 inches. It is to be noted from Fig. 7 that substantial response obtains up to at least 8,000 cycles and even higher, which represents an extension of several thousand cycles in the frequency range over prior devices. This substantial and important extension is directly attributable to the particular configuration of the diaphragm portion 16, i. e., a configuration in accordance with the relationships presented above. It will be seen also, from Fig. 7, that although the average response is fairly uniform over the range from about 80 to 8,000 cycles, there are irregularities at several regions, specifically at about 600, 1,000 and 4,600 cycles per second. Such irregularities are substantially elimi-

nated by the provision of damping coatings upon the flexible or edge portion of the diaphragm 20 in accordance with a feature of the invention. A response curve for a diaphragm identical with that having the response characteristic shown in Fig. 7 except that such coatings were provided is illustrated in Fig. 8. From this figure it will be noted that the response is uniform within ± 5 decibels throughout the range from about 80 to 8,000 cycles per second and that the response is free of serious non-uniformities throughout this range.

The upper limit of the range throughout which such uniform response can be obtained is dependent upon the diaphragm diameter. In general, the smaller the diameter, the higher is the upper frequency limit. This is indicated by Fig. 9 which is a response characteristic for a diaphragm of the same construction (including the damping coatings) and configuration as the diaphragm producing the response characteristic of Fig. 8, but being 8 inches in diameter instead of 12 inches and having a central portion 15 2 inches in diameter instead of 4 inches. As is apparent from Fig. 9, the response is essentially uniform throughout the range from about 80 to 12,000 cycles.

It may be noted that the response measurements upon which the curves of Figs. 7, 8 and 9 are predicated were made in an acoustically dead room. Actually, loudspeakers are used mainly, if not almost entirely, in acoustically live rooms. Under such conditions, i. e., in live rooms, the response of the loudspeaker is in effect enhanced at the low frequency end of the range so that when used under these conditions the loudspeakers having the response characteristics of Figs. 8 and 9 would have somewhat higher response at the lower frequencies and effectively an over-all response even more uniform than indicated by Figs. 8 and 9.

Although specific embodiments of the invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of the invention as defined in the appended claims.

What is claimed is:

1. An electroacoustic transducer comprising a diaphragm including a central stiffened portion having a substantially circular periphery, an edge portion and an intermediate dished annular portion surrounding said central portion and having the form in section given by the equation

$$\frac{Y}{L} = \beta \log_{10} \left[1 + (10^{\alpha/\beta} - 1) \frac{X}{L} \right]$$

where

X is the coordinate measured radially outward from said periphery,

Y is the coordinate normal to the X coordinate, measured from the plane of said periphery,

L is the radial width of said dished annular portion,

α is a constant between 0.375 and 0.5, and

β is a constant between 0.25 and 0.625,

means for stiffening said annular portion at a region removed from the outer margin thereof, and means for damping the edge portion of said diaphragm.

2. An electroacoustic transducer in accordance with claim 1 wherein said stiffening means comprises a circular corrugation in and coaxial with said annular portion and located at a region sub-

stantially 60 per cent of the radial width of said annular portion from the inner margin thereof.

3. An electroacoustic transducer in accordance with claim 1 wherein said damping means comprises a coating of cellulose damping material upon said edge portion.

4. An electroacoustic transducer in accordance with claim 1 wherein the maximum value of Y is less than one-half the wavelength of substantially the mid-frequency in the range of frequencies to be translated by the transducer.

5. An electroacoustic transducer in accordance with claim 1 wherein the diameter of said diaphragm is between approximately 8 and 12 inches and the maximum value of Y is between approximately 0.75 and 1.25 inches.

6. A direct acting, circular acoustic diaphragm comprising a domed central portion having a diameter of the order of one-third to one-half the overall diameter of the diaphragm, a logarithmically curved frusto-conoidal portion surrounding said central portion and bodily vibratile therewith, a flexible annular mounting portion surrounding the periphery of said frusto-conoidal portion and of less stiffness than said central and frusto-conoidal portions, stiffening corrugations in said frusto-conoidal portion only at regions removed from the margins thereof, and vibrational energy dissipating means upon said annular portion.

7. An acoustic diaphragm in accordance with claim 6 wherein said energy dissipating means is a coating of a plasticized cellulose nitrate compound upon said annular portion.

8. An acoustic diaphragm in accordance with claim 6 wherein said diaphragm is formed in one piece of compressed pulp fibres and wherein said annular portion is of substantially less thickness than said central and frusto-conoidal portions.

9. A circular direct acting acoustic diaphragm comprising a substantially bodily vibratile inner portion, an outer supporting portion, a highly flexible intermediate portion connecting said inner and outer portions, and a coating of plasticized cellulose nitrate upon said intermediate portion, said inner portion comprising a central part conforming substantially to a segment of a sphere and a frusto-conoidal surrounding part, the generatrix of which conforms substantially to the equation

$$\frac{Y}{L} = \beta \log_{10} \left[1 + (10^{\alpha/\beta} - 1) \frac{X}{L} \right]$$

where

L is the radial width of said frusto-conoidal part, X is the coordinate measured radially from the periphery of said central part,

Y is the coordinate normal to the X coordinate, measured from the plane of said periphery,

α is of the order of 0.4, and

β is of the order of 0.43.

10. A one-piece, direct acting acoustic diaphragm of molded fibrous material comprising a W-shaped, bodily vibratile central portion having a spherically domed central part and a curved frusto-conoidal part surrounding and extending from the periphery of said domed central part, said diaphragm comprising also a circularly corrugated flexible mounting portion surrounding and extending from the periphery of said central portion and of less thickness than said central portion, means for stiffening said frusto-conoidal part only at a region intermediate the margins thereof comprising a circular

stiffening corrugation in said frusto-conoidal part, coaxial therewith and at a region removed from both margins thereof, and a coating of a plasticized cellulose compound upon said mounting portion.

11. A direct acting acoustic diaphragm comprising a generally W-shaped radiating portion of a material having high internal dissipation, and a flexible mounting portion, the outer part of said radiating portion being a surface of revolution, the generatrix of which conforms substantially to the equation

$$\frac{Y}{L} = \beta \log_{10} \left[1 + (10^{\alpha/\beta} - 1) \frac{X}{L} \right]$$

where

L is the radial width of said outer part,

X is the coordinate measured radially outward from the inner margin of said outer part,

Y is the coordinate normal to the X coordinate measured from the plane of said inner margin

$$0.375 \leq \alpha \leq 0.5$$

and

$$0.25 \leq \beta \leq 0.625$$

12. A one-piece, direct acting acoustic diaphragm of fibrous material and comprising a radiating portion having a central dome shaped part and a frusto-conoidal part surrounding said central part, said diaphragm comprising also an annular, integral, flexible mounting portion extending radially outward from the outer margin of said frusto-conoidal part, and said frusto-conoidal portion conforming substantially to a surface of revolution traced by a generatrix of the form

$$\frac{Y}{L} = \beta \log_{10} \left[1 + (10^{\alpha/\beta} - 1) \frac{X}{L} \right]$$

where

L is the radial width of said frusto-conoidal part, X is the coordinate measured radially outward from the inner margin of said frusto-conoidal part,

Y is the coordinate normal to the X coordinate measured from the plane of said inner margin,

α is a constant of the order of 0.4, and

β is a constant between 0.25 and 0.625.

13. An acoustic diaphragm in accordance with claim 12 wherein said dome shaped and frusto-conoidal parts are of substantially equal heights, of the order of one-half the wavelength of the mid-frequency in the range of frequencies to be reproduced.

14. An acoustic diaphragm in accordance with claim 11 wherein the inner and outer parts of said radiating portion are of substantially equal heights and between 0.75 and 1.25 inch and the diameter of the diaphragm is of the order of 8 to 12 inches.

15. An electroacoustic transducer comprising a circular diaphragm W-shaped in section, said diaphragm having a domed central portion of the diameter of the order of one-third to one-half the overall diameter of the diaphragm, a peripheral mounting portion, a longitudinally curved intermediate portion and a flexible annular portion connecting said intermediate and mounting portions, said intermediate portion having circular coaxial stiffening corrugations therein located approximately 60 per cent of the width of said intermediate portion from the inner margin thereof, and coatings of vibration damping material upon both faces of said flexible annular portion.

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