ABSTRACT: A composite diaphragm structure combining a deeply drawn main diaphragm, an inturned compliance ring under the main diaphragm and an elastomer stiffener and damper applied to the front face of the main diaphragm.
The present invention has to do with microphones, and more particularly with diaphragm structures for microphones. While the device of the invention is illustrated as applied to the dynamic, or moving-coil type of microphone, many of the claimed advantages occur also in microphones using other types of transducers. The prime function of a microphone diaphragm is to act as a receptor for acoustic pressure waves and to convert such waves into physical force or motion at the attached transducer, in this case the voice coil in its magnetic airgap. To be most effective the diaphragm must have great stiffness in the plane of its major face so that it will behave as a piston. On the other hand, the means used to support the edge of the diaphragm must be as compliant as possible to permit easy travel of the diaphragm in a direction normal to its major plane. At the same time, the diaphragm and its edge mounting must be quite rigid radially to prevent radial motion of the voice coil and to confine its motion in the axis of the airgap. The diaphragm and its edge mounting must also be resilient enough to return the coil axially to its mid position at the frequency and amplitude of the acoustic waves being treated, due regard being had for the overall mass of the whole moving system. Finally, the diaphragm should be opaque acoustically, since it should not permit the free passage of sound waves and often serves as a divider between various internal chambers within the microphone assembly.

In the diaphragm assembly of the present invention, effective and unique means are provided for achieving optimum performance in a microphone. The several design parameters set forth above are taken into account and means are provided for optimizing each, almost independently of the others. The mass of the diaphragm assembly is kept low through the choice of extremely thin, lightweight plastic sheet of the main portion thereof. Rigidity, which insures pistonlike action, is achieved by designing chosen areas of the diaphragm. Edge compliance is provided by the design of a composite hinge area about the periphery of the diaphragm. The mass of the diaphragm and its performance are further controlled by an additional ply of elastomeric film applied to selected areas, positioned to bridge over from one area to another, and additionally to provide viscous damping which would otherwise occur in chosen areas to suppress unduly accentuated levels in response. An inwardly disposed edge support arrangement substantially reduces the physical diameter of the diaphragm support.

The prime object of this invention is to provide selectively adjustable damping means for smoothing out the frequency response of a microphone.

Another object is the provision of a microphone diaphragm assembly which is mechanically stiffened so that it moves as a piston.

Yet a further object is the provision of a diaphragm and suspension means wherefor, which affords assurance against radial motion while providing extreme compliance normal to the plane of its major face.

These and other objects and advantages will be apparent upon consideration of the following description wherein there is disclosed a preferred embodiment of the invention.

In the drawing:

FIG. 1 is a front elevation of the diaphragm assembly of the present invention;

FIG. 2 is a sectional view of a microphone structure incorporating the diaphragm assembly of FIG. 1;

FIG. 3 is a graph showing a family of response curves which illustrate the operation of the device of the invention.

DETAILED DESCRIPTION

Attention is directed first to FIG. 2 which is a cross-sectional view of a complete microphone structure. Reference numeral 10 indicates a permanent magnet which supplies magnetic flux for the operation of the device. The lower end of magnet 10 fits into a recess 11 in cup 12 which is made of high permeability metal. Outer pole plate 13 is attached to the upper rim of cup 12. The inner rim of pole plate 13 is beveled to a thin edge 14 to provide a magnetic flux gap 15. The lines of magnetic flux generated by the magnet 10 are conducted from its lower end, through the walls of cup 12, through the plate 13 and thence across the gap 15 to return to the top end of magnet 10. This structure is well known in dynamic microphones. A voice coil 16, made of fine copper or aluminum wire, is disposed in the gap 15. Coil 16 is supported on the diaphragm assembly, indicated generally by the reference 20, and its ends 17 shown in broken lines, are brought out to the edge of diaphragm assembly 20 where they are connected to output circuitry in conventional fashion. Disposed on the top surface of plate 13, is a diaphragm mounting ring 22 which supports and retains the diaphragm assembly 20, now to be described in detail.

The diaphragm assembly 20, comprises two general parts, the principal diaphragm 30 and the edge support 40. Principal diaphragm 30 is formed from very thin sheet plastic material, such as 0.001 inch thick polyester for example. It is drawn, under heat and pressure, to include a central dome portion 31, a depressed ring area 32, a peripheral semitoroid corrugation 33, and an outwardly disposed flange 34. The voice coil 16 is attached to the under side of ring area 32. Edge support 40 likewise is formed from sheet plastic, such as 0.005 inch thick polyester film for example. It comprises an outwardly disposed flange 41, a semitoroid corrugation 42 and a downwardly disposed inner skirt 43. Skirt 43 is cemented to the tapered inner circumference of ring 22. Flange 41 extends outwardly of the assembly as shown. Principal diaphragm 30 is placed concentrically over the assembly and its flange 34 is cemented in register with the flange 41 of the edge support 40. Thereupon the voice coil 16 is centrally located in airgap 15.

In addition to the parts 30 and 40 thus far described, a significant part of the present invention is the topper, designated generally by the reference numeral 50. The topper 50 is made of thin sheet elastomeric material, such as medium soft neoprene for example. It is a generally flat disc punched in the shape shown best in FIG. 1, with a circular hole 51 in its center and cutouts 52 cutout of its periphery to leave the four radially extending arms 53. A selected circular area 51', immediately surrounding hole 51, is coated on it under surface with a suitable adhesive and is attached concentrically to the dome portion 31 of diaphragm 30. Selected areas 53', near the ends of arms 53, are similarly cemented to the raised peripheral corrugation 33 as shown in FIG. 2. The topper 50 is thus retained in position with its arms 53 bridging the depressed ring area 32 of diaphragm 30 and with only the areas 51' and 53' secured.

In operation, the mechanical parts of the invention thus described exhibit the following characteristics. The central dome 31, being a spherical section and having appreciable depth with relation to its diameter, is extremely rigid despite its low mass. It resists breaking up into vibrational patterns and moves as a unitary piston when subjected to the pressure of sound waves. The lower rim of central dome 31 adjoining the flat ring area 32, the under side of which provides a surface for attaching voice coil 16. The semitoroidal corrugation 33 is deeply crowned, its vertical depth being almost as great as that of dome 31, and its cross-sectional width being very much less. It thus appears quite stiff in a direction axially of the diaphragm. The crown of its curved upper face and the radially disposed flange 34 at its outer edge combine to afford optimum radial stiffness. The whole corrugation 33 thus is designed to add its effect to that of dome 31 so that the entire upper diaphragm 30 will have substantially a pure piston action.

Edge support 40, being made of much thinner material than upper diaphragm 30, is relied upon to provide the hinge flexibility required to assure highly compliance edge support for
the generally stiff diaphragm 30. The flat edge flange 41 contributes its radial stiffness to diaphragm 30. The semitoroidal corrugation 42, purposely made rather shallow and quite thin, affords both the degree of compliance required to assure proper action of the diaphragm 30 and the degree of elastic resilience required to always return the diaphragm 30 and the voice coil 16 to their neutral position.

The relative degrees of compliance and resilience in edge support 40 may be adjusted, both in the choice of sheet material thickness selected and in the depth of drawing performed in the forming of the corrugation 42. The positioning of the entire edge support 40, underneath the diaphragm 30 and entire inner diameter, achieves substantially greater compliance than is displayed by prior art microphone units of equal overall diameter. This feature, coupled with the choice of two materials of dissimilar thickness for the diaphragm 30 and the edge support 40, combine to achieve some of the objects of the invention.

The multiple effects of the topper 50 include stiffening of the diaphragm, damping of its resonances and some degree of mass loading. These effects are not always identifiable separately, but can be explained broadly as follows. Reference will be had from time to time to the response curves of FIG. 3. The mass effect is minimized by using reasonably thin sheet elastomer and by punching out the sizeable center hole 51 and the edge notches 52. The radial legs 53 contribute radial stiffness across the depressed ring area 52. Although they are flexible at lower frequencies, at higher frequencies they tend to tie together the center dome 31 and the crown of the corrugation 33 and to cause them to move in phase in a direction normal to the general plane of the diaphragm 30.

In a commercial microphone employing the diaphragm assembly of the present invention but without the topper 50, the response illustrated by curve A of FIG. 3 is observed. It will be seen that this curve starts to rise markedly above 1 hertz, rises 10 decibels at 5 hertz and then returns to level at about 7 hertz, beyond which it continues to fall off gradually. This rising response between 1 and 7 hertz is indicative of the center dome 31 having assumed the major portion of the driving function and the decline is output above 7 hertz is caused by an antiresonance which follows a resonance, in this case one occurring about 7 hertz.

When the topper 50 of this invention is properly applied to the same microphone, the response of curve B results. Here the response between 1 and 7 hertz is leveled off to about 2 decibels above that of 1 hertz. This occurs due to the damping of dome 31 by the viscous character of the topper which suppresses resonances of the dome and partially relays the excessive energy of the dome to the less highly excited corrugation 33. This keeps the entire diaphragm 30 operating at substantially linear efficiency over this entire midpoint of the frequency range.

The top surface of topper 50 stands exposed to the same sound waves as all front surfaces of the diaphragm, and doubtless does some direct transmitting of vibrations to both the dome 31 and the corrugation 33. At frequencies above those at which the wavelengths of the sound waves are equal to or less than the dimensions of the center hole 51 or the edge notches 52, the waves appear to act more directly on the diaphragm 30 itself. Also topper 50, at these higher frequencies, becomes effectively hard. The result is a slightly improved level above about 7 hertz, as opposed to the dropping response of curve A.

The slight mass of the topper 50 appears to have little or no effect on the response curve below about 500 hertz. With respect to mechanical vibrations picked up through the body of the microphone, the topper 50 exercises a slight damping effect which is evident subjectively in a noticeably reduced "ringing" sound. This is believed to be due to the slight added resonance effect in the diaphragm by topper 50. However, in the range from 1 hertz, other control effects can be achieved. For example, by substantially increasing the cemented areas 51' and 53' of topper 50, the response of curve C results. An effect intermediate curves A and B results from making areas 51' and 53' smaller than shown in FIG. 1. An additional control over the response characteristics also is in the selection of the hardness grade of material used in the topper 50.

While the response curve B (FIG. 3) is achieved through the use of a preferred grade of medium soft neoprene in the topper 50, the use of a harder grade of the same material results in a noticeably higher level of response in the area of 3 to 4 hertz. This response is preferred by some designers for use in voice communications work, suitable choices of materials for the several parts of the diaphragm and topper are considered to be within the purview of this invention.

There has thus been provided an improved microphone assembly and a system for controlling the response of the same, which accomplishes the objects set forth. By applying a damping topper 50 of this invention to an acoustic diaphragm, its response is selectively chosen to be more or less flat and free of peaks. The effectiveness of topper 50 can be adjusted by changing its thickness, its hardness, or its areas of adhesion to either the dome 31 or the corrugation 33, or both. The two-part edge suspension of the diaphragm 30, comprising the radial flange 34 and the edge support 40, affords good radial rigidity simultaneously with high axial compliance. Both of these characteristics are provided in a topper 50 which has a noticeably smaller outside diameter than prior art devices of equal quality. This reduction in diameter is achieved by disposing the edge support 40 below and inwardly of the outside periphery of the diaphragm 30 and by making its corrugation 42 wider than its depth. The contouring of diaphragm 30 with its dome 31 and its deep corrugation 33, together with the reinforcement and stiffening afforded by topper 50, assure unitary pistonlike action in the diaphragm. The radial stiffness of diaphragm 30 and topper 50, the mutual reinforcement provided by flanges 34 and 41, and the relatively wide radial extent of the edge support 40 assure that voice coil 16 will remain radially centered in air gap 15 and yet will exhibit freedom to move axially in gap 15.

In view of the foregoing it will be apparent to those skilled in the art that I have accomplished at least the principal objects of my invention and it will also be apparent to those skilled in the art that the embodiment herein described may be variously changed and modified, without departing from the spirit of the invention, and that the invention is capable of uses and has advantages not herein specifically described; hence it will be appreciated that the herein disclosed embodiment is illustrative only, and that my invention is not limited thereto.

I claim:

1. A diaphragm assembly for a microphone comprising a diaphragm of formed sheet material having a center spherical dome and a semitoroidal corrugation surrounding said dome and a radially outward extending flat flange surrounding said corrugation, an edge-supporting semitoroidal corrugation of formed sheet material disposed under and inside of said corrugation and having a radially outward extending flat flange positioned in adhered face-to-face relation with said diaphragm flange and an inwardly directed mounting skirt on the second said corrugation, and a voice coil attached to said diaphragm near the juncture of said dome and said corrugation.

2. The diaphragm assembly of claim 1 in which the sheet material of said diaphragm is substantially thicker than the sheet material of the second said corrugation.

3. The diaphragm assembly of claim 1 in which the sheet material of said diaphragm is twice as thick as that of the second said corrugation, and both materials are of the same plastic material.

4. The diaphragm assembly of claim 3 in which the sheet materials of both said diaphragm and the second said corrugation are polyester plastic.

5. The diaphragm assembly of claim 1 in which a sheet of medium soft elastomer, having a center portion and radial arms, is disposed over the surface of said diaphragm, with said center portion adhered to said dome and the ends of said arms adhered to said corrugation.
6. A damper for application to the face of an acoustic diaphragm comprising a central circular body portion of elastomeric material and a plurality of arms extending radially outward of said body portion, an area of said body portion adhered to the midportion of said diaphragm and the extremities of said arms adhered to areas of said diaphragm radially spaced from said midportion.

7. A microphone assembly, comprising a magnetically permeable cup-shaped housing, a magnet within said housing and having an end disposed adjacent to the open end of said housing, a diaphragm overlying said housing open end and subject to the pressure of sound waves, a voice coil secured to and depending from said diaphragm and disposed adjacent to said magnet, whereby vibrations of the diaphragm cause movement of said voice coil in the magnetic field provided between said magnet and said housing, and a flexible member overlying said diaphragm and having at least limited contact therewith, said flexible member damping resonances in said diaphragm and having an opening for exposing at least a portion of said diaphragm directly to said sound waves.

8. The construction of claim 7 wherein said opening is at the center of said flexible member and the latter having radially outwardly extending legs, said flexible member being connected to said diaphragm at its marginal surface surrounding said center opening and at the ends of each of said legs.

9. A microphone assembly, comprising a magnetically permeable cup-shaped housing, a magnet within said housing and having an end disposed adjacent to the open end of said housing, a diaphragm overlying said housing open end and subject to the pressure of sound waves, said diaphragm having a central dome and a peripheral annular bulge surrounding said dome and providing an annular depression said diaphragm between said dome and said bulge, said dome and bulge both projecting in a direction away from said open end of said housing, a voice coil secured to and depending from said diaphragm and disposed adjacent to said magnet, whereby vibrations of the diaphragm cause movement of said voice coil in the magnetic field provided between said magnet and said housing, a flexible member formed of an elastomeric material overlying said annular depression and having a central opening exposing at least a portion of said dome.

10. The construction of claim 9 wherein said flexible material is secured to said dome and said bulge.

11. The construction of claim 10 wherein said flexible member is secured to said dome at its marginal portion surrounding its central opening, and has a plurality of arms each secured to said bulge.
UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3 555 206 Dated January 12, 1971
Inventor(s) Alexander L. Dvorsky

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 36, after the words "plastic sheet", "of" should be---for--.
Column 2, line 46, after the words "coated on," "it" should be---its-----.
Column 3, line 36, after the words "markedly above 1", ---K----should be.
Line 37, after the words "decibels at 3", -----K----should be added and same line after "about 7", -----K----should be added. Line 39, after the word "between 1", -----K----should be added. Same line, after "7" ----K----should be added. Line 41, after the word "decline" "is" should be -----in-----.
Same line after "7"-----K----should be added. Line 43, after "7"-----K----should be added. Line 46, after "between 1", -----K----should be added. Same line after "7", ----K----should be added. Line 47, after "of 1", ----K----should be added. Line 64, after "about 7", ----K----should be added. Line 73, after "from 1", ----K----should be added.

Column 4, line 8, after "3"-----K----should be added. Line 9, after "4"-----K----should be added.

Page 1 of 2 pages
It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Line 10, after the word "work", the comma should be a period, and the word "suitable" should be capitalized. Line 15, after the word "By"----a----should be removed.

Column 5, claim 6, the first word of the claim "a" should be capitalized.

Column 6, claim 9, the first word of the claim "a" should be capitalized.

Line 8, after "depression" the word ----in----should be added.

Signed and sealed this 13th day of April 1971.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR. WILLIAM E. SCHUYLER, JR.
Attesting Officer Commissioner of Patents