April 13, 1948. J. F. MARQUIS 2,439,666

LOUDSPEAKER DIAPHRAGM SUPPORT

Filed Jan. 31, 1944

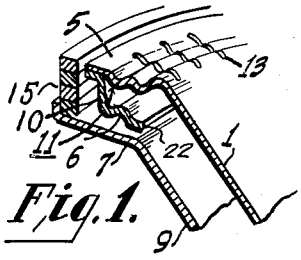


Fig. 1.

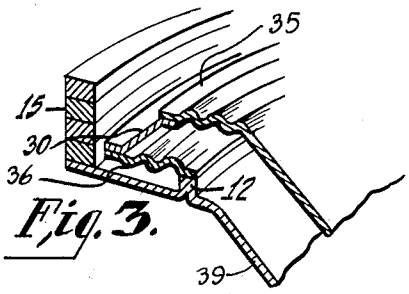


Fig. 3.

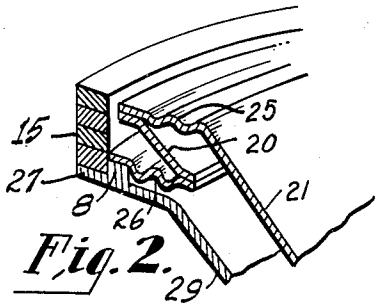


Fig. 2.

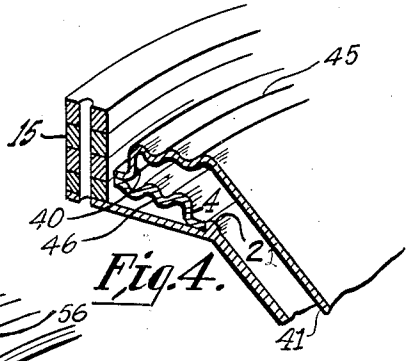


Fig. 4.

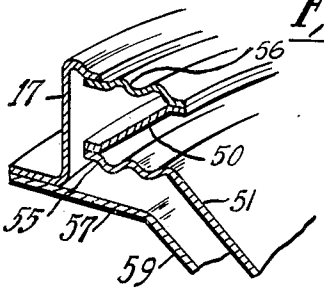


Fig. 5.

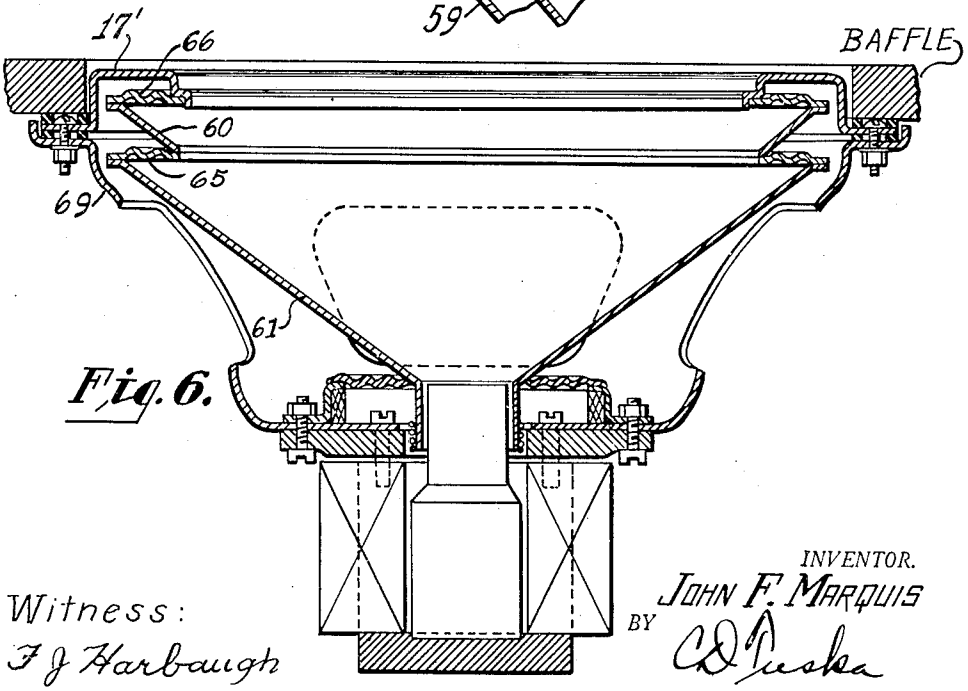


Fig. 6.

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UNITED STATES PATENT OFFICE

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LOUDSPEAKER DIAPHRAGM SUPPORT

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Application January 31, 1944, Serial No. 520,497

2 Claims. (Cl. 181—31)

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This invention relates to sound reproducing devices, and more particularly to loudspeaker diaphragm supports, for use in radio receivers, phonographs, announce systems and the like.

An object of the invention is to increase the power handling capacity of a small speaker, making it comparable to one substantially larger in size in its output of undistorted acoustic energy and fidelity of reproduction of desired low as well as high frequency sound waves.

Another and more specific object of the invention is to provide an improved diaphragm suspension structure in a loudspeaker characterized by a reduction in the effect of the suspension impedance, thus lowering the natural resonant frequency of the speaker of a given size, without increasing the mass reactance of the moving parts.

A further object of the invention is to provide an improved compliant suspension in a limited space for a piston-type loudspeaker diaphragm of small mass reactance whereby the diaphragm is free to vibrate at large amplitude over a substantially extended portion of the lower audio frequency range without amplitude distortion.

A still further object of the invention is to provide an improved and inexpensive construction for substantially reducing the stiffness, or increasing the compliance, in the flexible suspension structure for a loudspeaker piston-type diaphragm while preserving the acoustic sealing functions of the suspension, alternatively to improve the strength and life of the flexible structure without sacrificing compliance.

In accordance with the invention, there is provided an improved dual flexible support for the base of a frusto conical or piston type of diaphragm adapted to move as a whole at low audio frequency and characterized by the fact that greatly increased axial flexibility is obtained with no greater than normal diametrical space requirements. The increased flexibility and efficiency is obtained in certain forms of the invention by arranging in tandem compliant radial sections located in planes, respectively, substantially normal to the axis of the diaphragm. These as well as other features of the invention will become apparent from the following description with reference to the drawings in which:

Figure 1 is an isometric fragmentary view partly in section of a sound reproducing device, more particularly of a flexible suspension for an acoustic diaphragm, embodying the invention;

Figure 2 is a side elevation view in section of a portion of a loudspeaker, more particularly of

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a flexible suspension for an acoustic diaphragm embodying the invention;

Figures 3, 4 and 5 are similar views of a flexible suspension for a loudspeaker illustrating other species of the invention.

Figure 6 is a side elevation view, in section, of a loudspeaker and diaphragm suspension embodying the invention.

Heretofore the usual type of flexible suspension for the base of a frusto conical or acoustic diaphragm has consisted in an annularly corrugated fibrous support rim attached to the base of the diaphragm, as in Bobrovsky Patent 1,862,174, or molded integrally therewith. The purpose of such a suspension has been to provide lateral stiffness to sidewise movement of the diaphragm while allowing freedom of movement in an axial direction, the direction in which the diaphragm is normally driven. The difficulty, particularly with small size speakers, is that there has been too great stiffness in the axial direction, with the result that the range of low frequency response has been limited. Attempts have been made to increase flexibility by increasing the radial dimension of the suspension but this has resulted in unduly large diaphragm housings in the diametrical direction, or has resulted in decreasing the size of a speaker diaphragm for a given size housing. Since the low frequency resonance, below which response falls off rapidly, of a speaker is a function of the mass reactance of the moving structure and the stiffness impedance or compliance, it is essential that the stiffness of the flexible support be reduced to a minimum in order to lower the resonant frequency and hence materially extend the low frequency end of the audible range of reproduction. Increasing the mass in order to lower the range is objectionable because it reduces the effectiveness for the reproduction of higher audio frequencies.

In accordance with the invention, the desired results have been acomplished by dividing the flexible radially extending support member into a plurality of sections connected in series relation and disposed in parallel planes in superposed or overlapping relation, thereby getting the same compliance effect as with a single flexible support of much larger radial extent. This makes possible the use of a larger diaphragm with a given housing and desired amount of compliance in the flexible support. Alternatively, it makes possible the reduction in overall size of a speaker housing in the diametrical dimension for a given size diaphragm.

Referring to Fig. 1, a frusto conical diaphragm

is supported at the base of its central stiffened portion 1 by an annular corrugated flexible rim portion 5 which in turn is supported at its outer periphery by a fibrous member 11, preferably of soft paper, with a compliant flexible section 6 embossed or corrugated as shown, cemented at its lower edge 22 to a metallic support flange 7 of a speaker housing 9. The flexible rim 5 is provided with a plurality of concentric corrugations of conventional design, and is further provided with a plurality of radial slits 13 extending from a region within the stiffened conical portion of the diaphragm to the outer portion of the support rim 5, however, terminating a distance from the outer periphery of rim 5. By reason of the added flexibility of section 6, the overall compliance of the flexible suspension system is substantially enhanced, with the result that a speaker of small size, for example a five inch diaphragm, effectively reproduces lower as well as higher audio frequencies as compared with the usual speaker of this size. By providing the radial slits 13, the low frequency end of the range has been extended considerably for reasons given more fully in my copending application Serial No. 520,496 filed concurrently herewith.

Heretofore attempts have been made to add flexibility in a given radial space using an auxiliary member having compliance structure disposed axially in one or more recumbent folds, wherein the member is compressed and expanded in an axial sense, that is in the direction of diaphragm movement. While such an arrangement has given unusual performance relative to other speakers of its size, it has certain disadvantages, particularly when made in production. I have found that such an auxiliary compliant element results in a non-symmetrical or rectifying effect in that the force required to move the speaker axially from zero position in one direction, e. g. to compress the auxiliary compliance, is quite different from the force required to move it the same distance in the opposite direction, as to expand said compliance. Furthermore, such an auxiliary element has been made of paper that is quite thin in order to have effective compliance, and it has been found that at large amplitudes of vibration this element has deformed and given an objectionable paper noise, although it is quite satisfactory for normal amplitudes of vibration. This type of axially disposed compliance may be referred to as bellows compliance.

Above the low frequency resonance point the diaphragm is mass controlled, while below it is stiffness controlled, and the movement and reproduction of sound falls off rapidly below resonance. Furthermore, distortion is introduced below resonance in that the tops of the waves are flattened, the diaphragm motion being limited by the stiffness of the suspension. While the resonance point can be lowered by increasing the mass, the reproduction of higher frequency waves then suffers, so the solution is to decrease the stiffness. With small diaphragms of low mass, the stiffness of the flexible suspension must be quite low, or the compliance thereof high, and the compliance should have substantial linear characteristics to permit a substantial excursion of the diaphragm in a baffle to efficiently radiate low frequency energy. Whereas a large area diaphragm need vibrate thru only a small excursion to move a given volume of air for low frequency reproduction, a relatively small diaphragm must move a large distance. It is also essential that such a flexible suspension have sufficient strength and toughness to function efficiently as a seal acoustically, and have endurance against fracture particularly as it ages.

In accordance with the present invention, the above mentioned disadvantages of the auxiliary bellows compliance member have been overcome by making the compliant section 6 in the form of an annulus with a circumferentially embossed corrugation to add compliance and located in a plane substantially parallel to that of the flexible rim 5. The outer periphery of rim 5 is coupled to the compliant corrugated section 6 by means of a lightweight frusto conical section 10, integral with section 6, having substantially no compliance with regard to the forces and frequencies involved. Being of light weight, it does not add substantially to the mass of the moving structure. The total compliance is, therefore, that of flexible members or sections 5 and 6 effectively in series relation, connected at one end of the series to the diaphragm and at the other end of the rigid support structure 7 of the housing 9. It is apparent that such an arrangement is substantially symmetrical in either direction of vibration with respect to applied driving forces, there being no bellows type compliance, and that substantially no sacrifice has been made in desired lateral stiffness for properly centering the diaphragm structure. The flexible supporting structure is protected as in the case of Fig. 1 by means of a stack of pasteboard rings 15 which are spaced radially to provide clearance from the flexible structure and which extends forwardly of the base of the diaphragm so that when mounted against a baffle there is at all times proper clearance provided. The annular coupling member 10 is provided at its upper edge with a flange disposed in parallel relation to the base of the diaphragm for cementing to a similar flange or marginal edge on the flexible rim element 5.

Referring to the modification in Fig. 2, I have shown a way of increasing the compliance by making the auxiliary compliant element in two parts 26 and 20, the portion 26 having a greater radial extent and greater number of compliant corrugations. The outer periphery of rim 25 is coupled to the inner periphery of flexible element 26 by means of an element 20 having the functions of part 10 in Fig. 1. In the assembly of the different elements, it is preferable that elements 26 and 20 be joined first and then joined as a unit to element 25 with appropriate annular pressing dies. The diaphragm 21 and carrying elements 25, 20 and 26 as a unitary structure are dropped into place in the housing 29 and the outer periphery of element 26 is cemented to a raised portion 8 on flange 27, being pressed in placed by appropriate tools. Finally, the protective cardboard rings 15 are cemented and stacked in place as shown.

Referring to Fig. 3, the outer marginal edge of flexible support member 35 is cemented to non-compliant coupling member 30, as in Fig. 2; however, this member 30 is inclined outwardly from the periphery of member 35. An auxiliary compliance member 36 is attached at its outer marginal edge to the lower flange of frustoconical element 30 and is cemented at its inner marginal edge to a boss 12 on the housing 39. In effect, the non-compliant member 20 of Fig. 2 has been inverted and made larger in diameter, in applying it to the structure of Fig. 3. This arrangement gives a greater amount of overall compliance than Figs. 1 and 2, although it has the disadvantage of occupying slightly more space

for a given size diaphragm. However, it can be made to occupy about the same space by so making the element 30 as to lie closely parallel, in section, to the dynamic axis of the cone diaphragm. In assembling this structure for production, the upper flange of element 30 is first cemented to the marginal edge of element 35 prior to assembly of the diaphragm on to the housing. Element 36 is cemented at its inner edge to the boss 12 on the housing prior to the assembly of the diaphragm. Next, the diaphragm is assembled on to the housing with the driving coil, not shown, centrally positioned in the air gap of the magnetic structure, as shown in Fig. 6, and the outer marginal edges of elements 30 and 36 are cemented together by appropriate dies. Finally the protective annular structure 15 is assembled into place as in Fig. 1.

Referring to Fig. 4, the structure shown here is basically similar in nature to that of Fig. 3, although simplified. The diaphragm 41, preferably of the one piece molded type made, for example, by a process disclosed in Pare Patent 2,288,832, is provided with an integral corrugated rim member 45, as in the preceding figures, but the non-compliant element of the previous figures is made integral with the diaphragm structure as shown at 40. Attached to the marginal flange on element 40 is an auxiliary compliant support member 46 which differs from the corresponding member in Figs. 2 and 3 by having a substantially noncompliant extension 4 below the plane thereof and provided with a lower flange for cementing to the inner section of flange 47 of the speaker housing. A small bead 2 is preferably struck out on the housing to assist in centering member 46. The same arrangement as shown at 12, in Fig. 3, may, however, be employed in Fig. 4. The assembly of this species is quite simplified and is preferred to Figs. 2 and 3. The element 46 is cemented in place on the housing prior to assembly of the diaphragm. The diaphragm is then assembled and centrally located, and the outer marginal flange of 40 is cemented to the similar portion on element 46, with the help of a split die which is slipped into place underneath the outer marginal flange of 46 and the top of the housing flange 47. Finally, the protective element 15 is secured in place as in the other figures. In Fig. 4, I have made the coupling member 40 integral with the flexible rim of the diaphragm, whereas in Fig. 1, member 10 has been made integral with the auxiliary compliant member 6.

Referring to Fig. 5, I have shown an arrangement wherein the non-compliant member 50 and the auxiliary compliant member 56 are secured together and in turn to the outer marginal edge of the integral compliant element 55 on the base of the diaphragm 51 and located forwardly of the base of the diaphragm. The flexible support structure is attached to the housing by means of an annular metallic member 17 that is cemented to the outer marginal edge of element 56 and is bolted to the outer margin of housing flange 57 of housing 59. The member 17 performs the double function of protecting the flexible support structure and serving as a rigid supporting element of the housing.

Referring to Fig. 6, I have provided, in accordance with the invention, an improvement over the structure shown in Seabert Patent 2,329,560, September 14, 1943. Reference is made to this patent for a description of the rest of the speaker construction. While Seabert has made a worthwhile contribution to the art by a novel arrangement for increasing the area of a diaphragm and the flexibility of the diaphragm support, without increasing the size of the housing, it has the disadvantage that the housing support member extends inwardly of the diaphragm a sufficient distance to reduce somewhat some radiation of waves of certain frequencies. In accordance with the present invention, I have provided an arrangement for obtaining a similar degree of flexibility as in Seabert patent in a smaller space radially inward of the diaphragm base. The flexible rim element 65 is cemented at its outer marginal edge to the base of diaphragm 61 and at its inner marginal edge to the lower end of the frusto conical non-complaint support member 60. The auxiliary corrugated complaint member 66 is attached to the upper end of member 60 at its outer periphery and the inner marginal edge of 66 is cemented to a metallic housing member 17', generally similar to element 17 of Fig. 5 in function. Member 17' has the function of preventing undesired radiation of out of phase sound waves from the flexible support structure. A further advantage of this arrangement is that there is less tendency to interference between adjacent portions of diaphragm 61 and compliant member 65 in that the latter occupies less area than the flexible support element of Seabert. It will be noted that for purposes of assembly, the inner diameter of element 66 is smaller than that of elements 65 and 60, making it possible to drop a die through 65 on to the inner marginal edge of member 66 for cementing it to element 17' prior to assembly with diaphragm 61. The diaphragm and members 65, 60, 66 and 17' are assembled prior to assembly with the housing 69.

In the figures the diaphragm and flexible suspension structure have been shown as having considerable thickness, although it will be understood that this thickness in the drawings has been exaggerated. The material is of paper varying in thickness with different size diaphragms, e. g. from 5 to 15 mils, averaging around 8 mils, and the flexible suspension is ordinarily around half the thickness of the remainder of the diaphragm.

In all of the above modifications, the compliance is preferably further enhanced by providing compliant paths transverse to the circumferential ones, e. g., radial corrugations for increasing the circumferential compliance as disclosed and claimed in my copending application above referred to, for the purpose of lowering the resonant point and improving linearity. By way of illustration of a form of this arrangement, I have shown the radial slits in the flexible annular rim extending into the base of the diaphragm in Fig. 1. The circumferential compliance may be used in auxiliary compliant element 6 and in the other modifications, produced as by means of the radial corrugations or embossings. The linearity may be improved still further in the above modifications, e. g. in Fig. 6, by making members 65 and 66 of lightweight and thin resilient metal such as Duralumin, thereby eliminating a mechanical hysteresis effect known to be inherent in fibrous suspensions.

By reason of the increased compliance of the dual suspension, particularly when supplemented by the means providing circumferential compliance, a compliant suspension having a greatly improved linear characteristic has been provided, free from non-symmetrical movement in for-

ward and rear movements of the diaphragm. This linearity is particularly desirable at or below resonance. Below resonance the stiffness of the suspension system controls the motion of the vibrating system. The following is quoted from 1938 and 1939 engineering reports of H. F. Olson, a well known expert in the art. "A cone below its resonance frequency produces flat top waves for sinusoidal input . . . The motion of the cone is limited and therefore flat top waves are produced in the output. The distortion is due to the non-linear characteristics of the suspension system. Considerable work has been carried out on suspension systems with the object of developing a system with linear characteristics. Apparently the problem is not easily solved. Since a linear suspension is not available, the distortion may be reduced by reducing the effect of the suspension impedance."

It will be apparent to those skilled in the art that other arrangements and combinations within the spirit of the invention are possible. It is not intended, therefore, that the invention should be limited to the precise modifications shown.

I claim as my invention:

1. In an acoustic mass controlled device of the direct acting type, a conical type diaphragm having a base and small end, a support housing having a rigid annular flange adjacent said diaphragm base and external to the space enclosed by said diaphragm, highly compliant low frequency suspension system for said base and small end, respectively, comprising an annular flexible rim member attached to said base and extending radially, a second annular flexible rim member attached to said housing flange and extending radially in overlapping relation with respect to said first named member, a relatively short frusto conical non-compliant coupling member of fibrous sheet material peripherally attached to the outer periphery of one of said members and to the inner periphery of the other of said rim members for spacing said members closely in parallel planes and cross connecting them in series compliant relation between said diaphragm base and said housing flange to substantially decrease resistance to axial driving forces, a concentrically corrugated suspension member for

said small end and acoustic driving means attached to said diaphragm small end and supported entirely by said suspension system.

2. In a sound reproducing device of the direct acting type, a housing having a rigid support flange, a dished type mass controlled acoustic diaphragm of fibrous material having a base adjacent said flange a flexible suspension system connected from said housing flange to said diaphragm in space external to said diaphragm, said system being divided into two annular highly compliant sections located in superposed overlapping relation in different planes substantially normal to the axis of movement of said diaphragm, non-compliant means comprising a relatively short annular frusto-conical member of thin material coupling said sections in additive series relation between said diaphragm and said housing, the larger end of said frusto-conical member being joined to the outer periphery of one of said sections and the smaller end of said member being joined to the inner periphery of the other of said sections, said sections being equivalent to a single flexible suspension of much larger radial extent while occupying substantially less space radially.

JOHN F. MARQUIS.

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