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J. F. MARQUIS

2,439,665

SOUND REPRODUCING DEVICE

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Fig. 1.

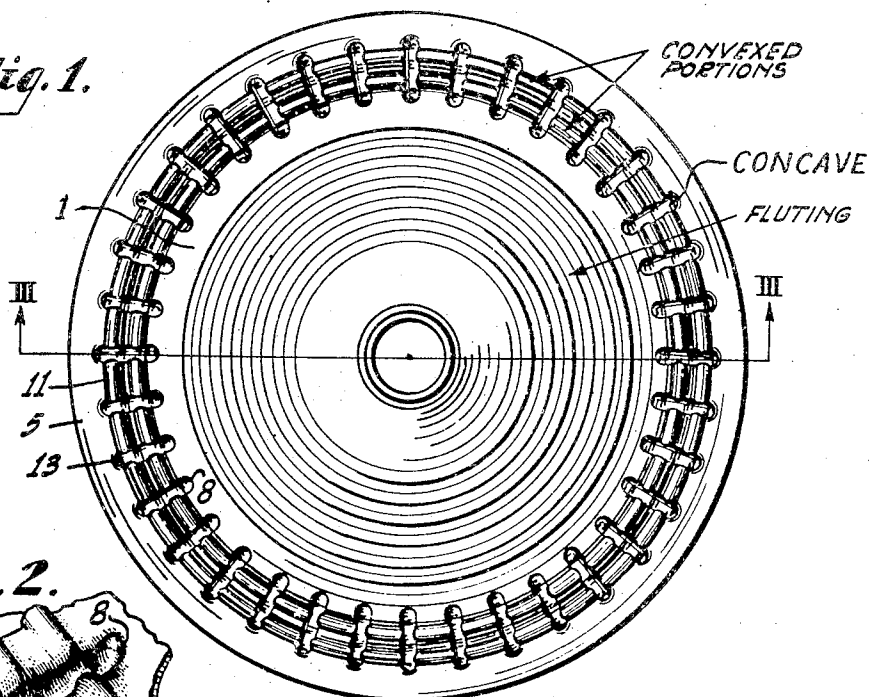


Fig. 2.

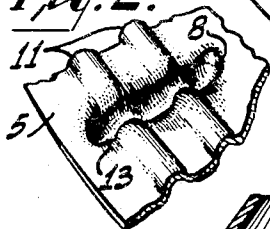


Fig. 3.

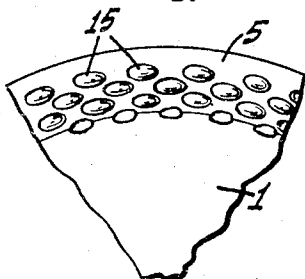
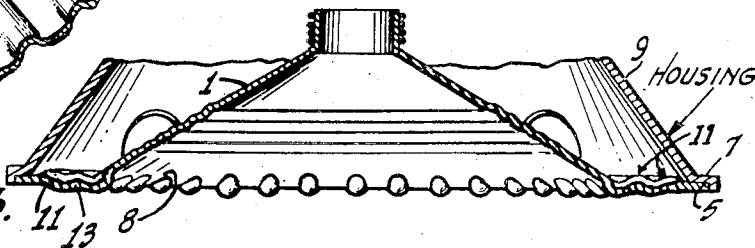


Fig. 4.

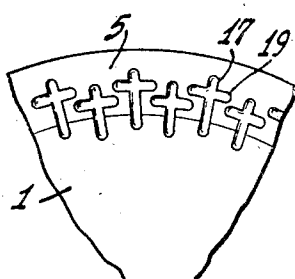


Fig. 5.

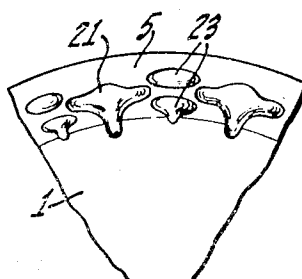


Fig. 6.

Witness:

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SOUND REPRODUCING DEVICE

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2 Claims. (Cl. 181—31)

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This invention relates to sound reproducing devices, and more particularly to flexible mountings for direct acting diaphragms in loudspeakers.

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 of 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.

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 a plan view of the underneath or rear convex side of a conical diaphragm of a loudspeaker, embodying the invention;

Figure 2 is an enlarged section of a portion of the base and rim of the diaphragm as viewed from the rear side;

Figure 3 is a side elevation view in section taken on lines 3—3 of Figure 1;

Figures 4, 5 and 6 are plan fragmentary views of modified forms of the invention.

In accordance with the invention there is provided a simplified and inexpensive construction of an annular flexible base-supporting portion for the stiffened central portion of an acoustic diaphragm, effecting sufficient circumferential as well as radial freedom of expansion and contraction of the support portion in a small area to permit the diaphragm to vibrate at large ampli-

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tudes with a minimum of energy loss in the supporting portion. The nature of the present invention will be better understood by reviewing the constructions in the prior art, over which the present invention is an improvement.

Prior to 1930 there was developed for phonograph sound-boxes and horns, a conical piston-type aluminum diaphragm having an integral flexible base suspension constructed to provide freedom of expansion and contraction both radially and circumferentially. The suspension was provided circumferentially with diamond shaped corrugations. Around that period, in the loudspeaker art, in large direct acting conical diaphragms, it was common practice to use leather or other such pliable material for the flexible base suspension. It was proposed to use a modified form of the above mentioned soundbox diaphragm suspension for supporting large direct acting diaphragms, but the construction is somewhat complicated, particularly in regard to dies, and its use was largely confined to microphones and small diaphragms for horns, as in phonographs. Furthermore, the suspension comprised a plurality of flat surfaces which have objections acoustically in the case of large diaphragms.

For many years the usual type of construction has consisted in a circumferentially corrugated, fibrous support rim attached to the base of the conical diaphragm or molded integrally therewith. This arrangement has been adopted because of simplicity and adaptation to low cost production. While such a construction has provided a certain amount of freedom of movement in a radial sense of flexibility, it has been relatively stiff in a circumferential sense, with the result that the base suspension has been relatively stiff. Since the low frequency resonance or cut-off characteristic of a speaker is a function of the mass or the moving structure and the stiffness or compliance, difficulty has been encountered in the effective reproduction of the low audio frequencies with small diaphragms of small mass, although using a baffle of sufficient area. There is a general conception that if the baffle is large enough, or infinite, any desired low frequency reproduction can be realized, but this is not true. While the baffle area must be above a certain size, as taught for example by Rice and Kellogg in *The Journal of the American Institute of Electrical Engineers*, September 1925, "Note on the development of a new type of hornless loudspeaker," for a desired lower frequency limit of reproduction, it is just as essential that the low resonant frequency peak of the speaker be

below the limit, or, as in practice, immediately above it.

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 through 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.

The problem is to obtain maximum flexibility in the support rim in a limited space between the base of the stiffened central portion, or conical section, of the diaphragm and the annular outer stationary support so as to get the maximum radiating diaphragm area within a given size housing. If the flexible rim were increased in area to improve flexibility for a given size of useful diaphragm area, the housing size would be unduly increased, and undesired effects caused by radiation of sound from the rim in out-of-phase relation would noticeably increase.

A worthwhile improvement was made in the thirties in a high fidelity speaker, used in sound systems, wherein was provided circumferential as well as radial flexibility in a diaphragm base suspension by constructing it of spaced tangentially corrugated segments, the spaces being sealed by felt to preserve an acoustic seal. Such an arrangement had the disadvantage, however, of being expensive and lacking simplicity. An attempt to solve the problem was made later by proposing to make a molded diaphragm corrugated suspension with a plurality of radial weakened thin areas, but it is apparent that such areas have disadvantages, acoustically and structurally.

In accordance with the present invention, a novel flexible base suspension is provided for obtaining the desirable characteristics sought by others, as well as other advantages, with a greatly simplified and inexpensive construction. The invention makes possible the reproduction of given low frequency sound waves and greater undistorted power output with a smaller than usual speaker, and of course improves the characteristics of large speakers.

Referring to Fig. 1, a frusto conical acoustic diaphragm, or other type having its central main portion dished or otherwise curved to stiffen it, is suspended at the base of its central stiffened portion 1 by an annular flexible rim portion 5, cemented or clamped at its outer peripheral or marginal edge to a conventional stationary metallic support flange 7 of a speaker housing 9 shown in Fig. 3. At its inner periphery, the flexible rim suspension may be cemented to the base of the cone portion, as in Bobrovsky Patent

1,362,174, June 7, 1932, although it is preferably integral therewith, as shown. An intermediate zone of the rim portion is provided with concentric embossings, such as consecutive adjacent corrugations 11 of conventional design, running circumferentially around the rim in parallel relation for increasing radial flexibility of the rim. In accordance with the invention, a plurality of spaced radial corrugations 13, intersecting the circumferential corrugations, extend from the outer corrugated portion of 5 of the support rim a short distance into the base of the cone diaphragm where they taper out at 8. The latter corrugations can, with good results, extend outwardly with a departure from a radial direction. The groups of consecutive corrugations 11, between adjacent radial ones 13 may be linear as in Fig. 5, as well as tangential, the group arranged in polygonal formation about the diaphragm, in alternating relation with the radial corrugations.

In my early developments, I obtained a similar result in the way of circumferential compliance by providing the base rim structure with a plurality of thin slits positioned like the radial corrugations. This is shown in my copending application, Fig. 1, filed concurrently herewith. I found subsequently that I could obtain similar results by means of corrugations which had the advantage over the slits of preserving the acoustic seal. The radially directed corrugations 13, while straight, as appearing in a plan view of the diaphragm, are not straight when viewed in section, as in Fig. 3, but follow the contour of the circumferential corrugations 11. This is not to be confused with an old arrangement in small aluminum type diaphragms wherein a circumferentially corrugated rim was provided with radial corrugations which were linear in both plan and elevation views and for different purposes, inherently stiffening radially. The nature of my radial corrugation is shown more clearly at 13 in Fig. 2.

By having the radial corrugations follow the contour of the circumferential corrugations, they do not tend to stiffen the base suspension radially. There is, therefore, no linear path, in all dimensions, between the base of the cone and periphery of the rim portion. In an actual sample, made in accordance with the invention, a one-piece molded diaphragm, preferably made by a felting process, e. g., as disclosed in Pare Patent 2,288,832, July 7, 1942, having an outer diameter of $4\frac{3}{4}$ " measured to the periphery of the rim flexible support, and an inner diameter of 4" measured at the base of the frusto conical section, was provided with radial corrugations spaced $\frac{1}{4}$ " as measured circumferentially midway of their length. The corrugations were about $\frac{3}{16}$ " deep and substantially semi-circular in cross section. The flexibility was improved sufficient to lower the natural period from around 135 cycles to 85 cycles for one type of speaker. The power handling capacity was increased about twenty percent with a substantial reduction in amplitude and harmonic distortion, particularly that caused by subharmonics. The invention is equally applicable to elliptical and "morning glory" type diaphragms.

Referring to Fig. 4, the base rim suspension 5 is provided with a plurality of discrete embossings or dimples 15 so arranged in overlapping relation that there is no straight path line from the inner to the outer portion of the rim.

Referring to Fig. 5, the intermediate rim por-

tion of 5 is provided with a plurality of embossed cross-like corrugations, the radially directed portions 17 of the crosses corresponding to the radial corrugations of Fig. 1, and the tangentially directed portions 19 of the crosses corresponding to the circumferential corrugations of Fig. 1 in function and arrangement. It will be observed that the lower portions of the crosses extend a desired distance into the base of the conical diaphragm portion 1 to impart circumferential compliance thereto.

Fig. 6 shows a combination of the embossed elements of Figs. 4 and 5, the element resembling the cross-like embossing of Fig. 5 being shown at 21, and that resembling the dimples of Fig. 4 being shown at 23. In all the above figures, it will be observed that nowhere is there a straight line path, in all dimensions or planes from the inner periphery to the outer portion of the support structure, particularly as viewed in cross-section thereof, with the result that both radial and circumferential freedom of expansion is provided.

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.

While I have disclosed my invention in connection with a flexible suspension for the base of a diaphragm, it can also be applied to the centering structure for the small end and voice coil of a dynamic speaker, where an outer corrugated disc is ordinarily used, as in Boudette 1,893,049, January 3, 1933, although the improvement would be more apparent in the case of an inner centering disc as in Wunderlich Patent 2,038,401, April 21, 1936, where there is a problem of getting much compliance in a small area.

In either case, of a diaphragm base or small end flexible suspension, I have provided a suspension characterized by substantially low resistance to driving force applied perpendicularly to the plane of the diaphragm base, or in other words parallel to the diaphragm axis, but offering high resistance to forces parallel to the diaphragm base.

While the invention has been largely disclosed for the purpose of improving and extending the useful low frequency range of reproduction, it is equally useful in substantially improving the structure characteristics and useful life of a speaker diaphragm suspension, particularly in cases where it is unnecessary to extend the lower end of the audio range of reproduction. For example, in relatively small size radio cabinets the effective baffle area is too small to reproduce low frequency waves with any kind of speaker, and in such cases the requirement is that the speaker resonance occur at a frequency a little below that of the cabinet baffle. Even in such cases it has been difficult to design small speakers having low enough frequency response and

with desired structural characteristics for long life. The flexible rim suspension has been made of thin material and of large radial extent. The material tended to fracture with age and the tolerances were difficult for production. As a result of the present invention the rim can be made of sufficiently heavy material to materially increase its useful life and the radial expanse of the rim can be lessened, thereby giving a larger diaphragm area for a given size housing. Being of thicker material, it is much easier to obtain uniformity in production as to acoustic characteristics in that a given variation in thickness is a much smaller percentage of the whole than in the case of thin material for the rim.

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 a mass controlled sound reproducing device of the direct acting type, an acoustic diaphragm of fibrous material having a stiffened central conical surface portion, a peripheral clamping portion and an intermediate flexible portion integral with the other of said portions and comprising a plurality of embossings extending at least in part in circumferential relation to said central portion for increasing the compliance of said intermediate portion in a radial sense, and a plurality of spaced radial embossings for increasing the circumferential compliance of said intermediate portion at its inner periphery, said radial corrugations each being non-linear in a plane normal to said intermediate portion, said flexible portion constituting a relatively small proportion of the total area of said diaphragm although characterized by a high degree of compliance in the suspension of the base of said central conical surface portion.

2. The invention as set forth in claim 1 wherein said radial embossings extend from said intermediate portion a short distance into the base of said central portion for increasing the circumferential compliance thereof.

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