Jan. 15, 1963 J. C. BLEAZEY ETAL 3,073,411

ACOUSTICAL APPARATUS

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Fig. 1.

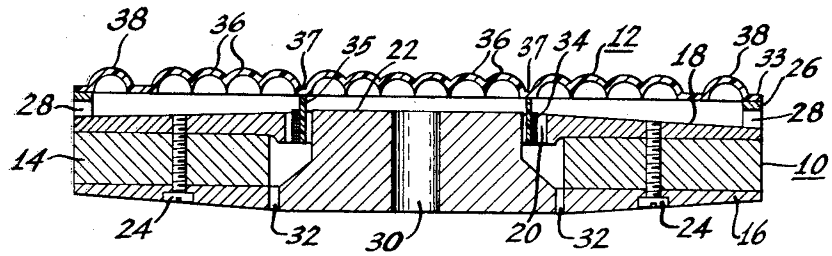
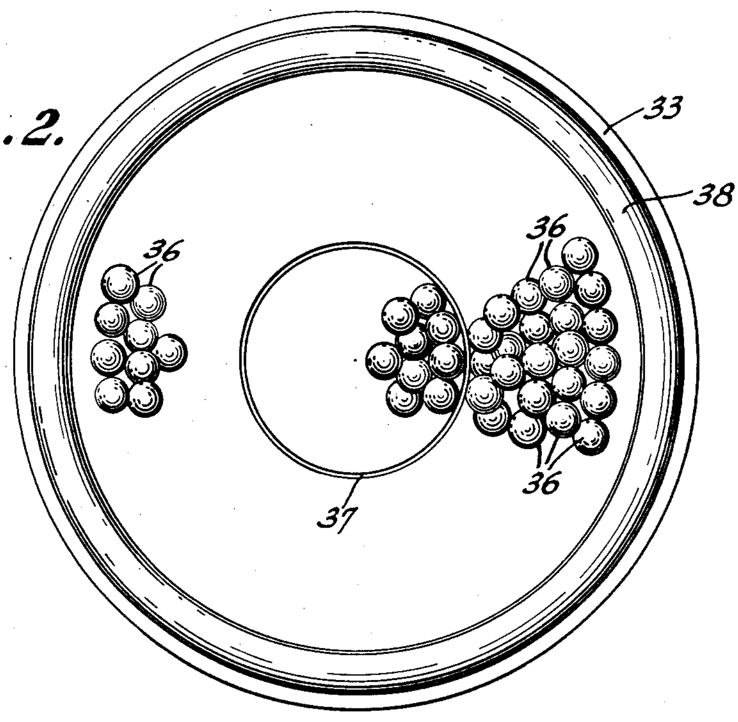


Fig. 2.



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ACOUSTICAL APPARATUS

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The present invention relates to acoustical apparatus, and more particularly to acoustical diaphragms suitable for use in loudspeakers and microphones.

The present invention is especially suitable for providing an acoustical diaphgram of miniature size. Miniature acoustical diaphragms are necessary for smaller loudspeakers used in miniature or personal radio receivers, some of which are no larger than a conventional pack of cigarettes.

Miniature loudspeakers have been constructed from conventional component parts which are reduced in size. Such reduction in size often results in a proportional reduction in efficiency and performance. In loudspeakers for personal radio receivers, such loss in efficiency and performance resulting from loudspeakers miniaturization is undesirable, since the output power from the radio receiver circuits is ordinarily less than from circuits of conventional size.

It has been recognized that the performance of a loudspeaker is related to the size of the diaphragm of the loudspeaker. From the standpoint of optimum output, a large diaphragm would seem to be desirable. However, in radio receivers where space is limited, resort is frequently had to flat diaphragms. However, flat diaphragms ordinarily have insufficient stiffness to vibrate uniformly over a frequency range wide enough to provide sound reproduction with good fidelity. While a flat diaphragm can be stiffened by making it heavy or thick, this results in a loss in efficiency of operation. It has also been proposed to impart stiffness to a flat diaphragm by the use of surface corrugations, indentations or other surface distortions. For example, a patent to English, No. 728,382, issued May 19, 1903, describes a diaphragm for phonographs having a plurality of indentations arranged in some orderly or geometrical manner. Such diaphragms are unsatisfactory, however, since adjoining indentations and distortions thereon define discrete lines or circles therebetween by reason of the regular or orderly arrangement of the indentations. Such lines and circles establish nodes of vibration at comparatively low frequencies in the operation of the loudspeaker. Thus, a loudspeaker or microphone using such a diaphragm is insufficient to translate signal energy to or from sound, as the case may be, with good fidelity.

Accordingly, it is an object of the present invention to provide an improved acoustical diaphragm which will not be subject to the aforementioned and other difficulties characteristic of small diaphragms heretofore known.

It is another object of the present invention to provide an improved acoustical diaphragm of substantially flat shape so that it will occupy a minimum of space.

It is still another object of the present invention to provide an improved acoustical diaphragm of minimum size which can be operated to reproduce sound with good fidelity.

It is a still further object of the present invention to provide an improved acoustical diaphragm of relatively thin, flexible material having sufficient stiffness to provide satisfactory translation of sound without, however, being subject to undesirable nodes of vibration.

Briefly described, an acoustical diaphragm provided in accordance with the present invention may be a relatively thin, flexible sheet having a multitude of protuberances thereon. These protuberances, in one form, may be spherical surfaces extending from the sheet. The protuberances are arranged adjoining each other to define lines of random curvature therebetween. Thus, the protuberances impart stiffening to the sheet without defining lines or circles which establish nodes of vibration on the diaphragm when it is operated in a sound transducer. More particularly, the protuberances may be arranged in adjoining rows in unsymmetrical arrangement with respect to any line across the sheet.

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The invention itself, both as to its organization and method of operation, as well as the foregoing and other objects and advantages thereof, will become more readily apparent from a reading of the following description in connection with the accompanying drawing in which:

FIG. 1 is a central, sectional view of a loudspeaker provided with one form of diaphragm according to the present invention; and

FIG. 2 is a plan view of the loudspeaker of FIG. 1.

Referring, now, more particularly to the drawings, there is shown a loudspeaker having a magnetic structure 10 and an acoustical diaphragm 12 constructed in accordance with the present invention. While a loudspeaker is illustrated herein, it will be appreciated that the diaphragm provided by the invention may be used in a microphone or other acoustical apparatus which requires a vibratile element. The loudspeaker is shown on an enlarged scale in the drawing. For example, the illustrated loudspeaker may be approximately 1⅝ inches in overall diameter and 9/32 inch in thickness.

The magnetic structure includes a permanent ring magnet 14. The permanent magnet 14 may be any grain oriented magnet commercially available and providing a high magnetic flux output. A bottom plate 16 of soft magnetic material and a top plate 18, also of soft magnetic material, sandwich the permanent magnet 14. A center pole portion 22 extends from the bottom plate 16 into a central opening in the plate 18. An annular air gap 20 is defined in the field structure between the top plate 18 and the pole portion 22. The top plate 18, the bottom plate 16 and the magnet 14 are fastened together by means of screws 24. An annular ridge 26 projects upwardly from the top plate 18. A plurality of openings 28 may be provided in this ridge. The pole piece 22 also has an axial opening 30 therethrough. Other openings 32 are provided in the bottom plate 16 circumferentially around the pole piece 22. The openings 32 connect the ambient with the air gap 20. The openings 28, 30 and 32 serve to relieve the pressure behind the diaphragm 12 and improve the frequency response of the loudspeaker.

The diaphragm 12 is secured along its marginal flange or rim portion 33, as by being cemented, to the top of the ridge 26. A voice coil 34 is mounted on a form 35 which may be cemented to the diaphragm 12 along a flat, circular portion 37. The voice coil 34 extends downwardly into the air gap 20. A pair of leads (not shown) are connected to the voice coil. Electrical signals may be applied to these leads to operate the loudspeaker.

The acoustical diaphragm 12 is a sheet of relatively thin material such as plastic, metal, pressed or felted paper, or the like. A single corrugation 38 is provided in the marginal portion adjacent the marginal flange or rim 33 of the diaphragm. This corrugation 38 provides a compliant suspension for the diaphragm 12.

The acoustical diaphragm 12 is essentially flat in shape and provides maximum radiating efficiency in a minimum volume of space. The efficiency of a loudspeaker is given approximately by the general mathematical expression

$$\mu = \frac{(Bl)^2 r_{MA}}{r_{EC}(X_{MA}+X_{MC})^2} \times 100$$

where

B=flux density in the air gap, in gausses,

l=length of the conductor in the voice coil, in centimeters,

r_{MA}=mechanical resistance of the air load, in mechanical ohms,

r_{EC}=damped electrical resistance of the voice coil, in abohms,

$X_{MA}=\omega m_A$=mechanical reactance of air load, in mechanical ohms, and

$X_{MC}=\omega m_C$=mechanical reactance of the voice coil and diaphragm, in mechanical ohms.

The efficiency of the loudspeaker is therefore determined by the term "X_{MC}" which is a function of the mass of the diaphragm and the voice coil. It follows that a heavy, thick diaphragm will produce a loss in efficiency. In order for the diaphragm to vibrate uniformly throughout a relatively wide frequency range, the diaphragm must have considerable stiffness. It has been found, in accordance with the invention, that great stiffness can be imparted into the diaphragm without excessive mass by forming a multitude of adjoining protuberances **36** in the sheet of thin material constituting the diaphragm. The protuberances **36** may be formed as partial spheres, ellipsoids, or the like, and they are arranged relative to each other in a manner more particularly described hereinafter. The use of protuberances of hemispherical shape, as illustrated in the drawings, is especially suitable in providing an extremely stiff, substantially flat diaphragm.

The arrangement of the protuberances **36** in the illustrated diaphragm also precludes mid and high frequency "break up" of the diaphragm. A diaphragm "breaks up" when it vibrates on a vibration node so that the inside and outside portions of the diaphragm are out of phase. This reduces the sound output of the diaphragm over a large portion of its frequency range and therefore deteriorates the loudspeaker response and performance. Flat diaphragms and proposed heretofore ordinarily have arrangements of either indentations or embossments for imparting stiffness which define a plurality of straight lines or circles on the surface of the diaphragm. These lines or circles act as vibrational nodes. Thus, the diaphragm would "break up" in the mid and high frequency ranges. It follows that such diaphragms are not suitable for use in loudspeakers and microphones, as well as in many other types of acoustical apparatus.

The protuberances **36** formed in the diaphragm **12** are arranged in a non-uniform or unsymmetrical manner, as hereinafter more fully set forth, such that straight diameters and uniform circles are not formed at the adjoining hemispheres providing the protuberances. The lines defined by the adjoining hemispherical protuberances are, in fact, of random curvature. The diaphragm **12** is, therefore, without straight lines or uniform circles which would act as vibrational nodes. Thus, the diaphragm **12** does not "break up" within a wide frequency range. It follows that a loudspeaker having a diaphragm according to the present invention will operate to transduce electrical signals into sound with high efficiency and over a wide frequency range. Thus, the loudspeaker is especially suitable for use in radio receivers, particularly of the personal or the transistor variety.

The diaphragm **12** may be formed between a pair of cooperating dies as in the case of known loudspeaker cones. Different ones of the dies may be machined with indentations and protuberances thereon so as to accurately form the diaphragm therebetween. The protuberances in the illustrated diaphragm are hemispherical in shape and are arranged in generally circular rows. The protuberances in different rows are offset from each other non-uniformly and in such manner that some adjacent protuberances are spaced from each other, some are just tangent to each other, and some overlap each other in different degrees, both within a given row and in adjoining rows. This non-uniform and more or less haphazard

arrangement of protuberances imparts extreme stiffness to the overall diaphragm surface without defining straight lines across, or circles around, the diaphragm which will result in diaphragm "break up" within the operating range of the loudspeaker.

From the foregoing description, it will be apparent that there has been provided, in accordance with the invention, an improved acoustical diaphragm which is especially useful in transducers of small size. This diaphragm provides greater efficiency of operation in a smaller space than previous diaphragms. While only a single loudspeaker incorporating a diaphragm in accordance with an illustrative embodiment of the invention has been shown and described herein, variations in the diaphragm, all coming within the spirit of the invention, will, no doubt, readily suggest themselves to those skilled in the art. Hence, it is desired that the foregoing shall be considered merely as illustrative and not in any limiting sense.

What is claimed is:

1. A vibratile element which comprises a sheet of flexible material of substantially uniform thickness having a plurality of protuberances on one side thereof, said protuberances being arranged in substantially random, adjoining relation.

2. An acoustical diaphragm which comprises a sheet of flexible material of substantially uniform thickness, at least a portion of said sheet having a plurality of protuberances on one side thereof for imparting stiffening to said portion, said protuberances being arranged in random, adjoining relation to each other so that said sheet is free from nodes of vibration.

3. An acoustical diaphragm which comprises a sheet of flexible material of substantially uniform thickness having a plurality of protuberances on one side thereof, said protuberances being arranged adjoining each other in substantially random relation to define on said sheet lines of random curvature extending along said protuberances.

4. An acoustical diaphragm which comprises a vibratile element of substantially uniform thickness having a multitude of protuberances on one side thereof, said protuberances being disposed in substantially random, adjoining relation in an unsymmetrical arrangement to impart stiffening to said element without defining nodes of vibration thereon.

5. An acoustical diaphragm which comprises a vibratile sheet of substantially uniform thickness having a plurality of partially spherical surfaces thereon extending out from one side of said sheet, said surfaces being arranged in substantially random unsymmetrical relation with respect to each other, at least some of said surfaces overlapping each other.

6. An acoustical diaphragm which comprises a sheet of flexible material of uniform thickness having a plurality of protrusions on one side thereof, said protrusions being arranged substantially at random in adjoining rows and in unsymmetrical arrangement with respect to any line across said sheet.

7. An acoustical diaphragm which comprises a sheet of flexible material of uniform thickness having a plurality of partially spherical surfaces thereon extending out of one side of said sheet, said surfaces being disposed in rows and being of substantially equal diameter, adjoining ones of said surfaces in different rows being offset from each other in substantially random relation.

8. An acoustical diaphragm which comprises a sheet of flexible material of uniform thickness having a marginal portion for suspending said sheet, said sheet also having a region spaced from said marginal portion including a plurality of adjoining, partially spherical surfaces extending from one side of said sheet, and at least some of said surfaces being disposed in substantially random, overlapping relation.

9. An acoustical diaphragm comprising a sheet of flexible material of uniform thickness having a plurality of protuberances extending from one side of said sheet and

arranged randomly thereon with at least certain adjacent ones of said protuberances substantially tangent to each other, and certain of said protuberances overlapping each other.

10. An acoustical diaphragm comprising a sheet of flexible material of uniform thickness having a plurality of protuberances extending from one side of said sheet and arranged randomly thereon with at least certain adjacent ones of said protuberances substantially tangent to each other and certain of said protuberances overlapping each other, said last named certain protuberances comprising adjacent pairs of protuberances which overlap each other in different degrees.

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