This invention relates to loudspeaker diaphragms, and more particularly refers to a diaphragm having a short axial dimension.

Except for the smallest units, loudspeaker diaphragms have traditionally been constructed in conical form. The conical form has been used since it increases the rigidity of the diaphragm, while at the same time permitting thin light-weight material such as paper to be used in its fabrication. One of the disadvantages of conical diaphragms is that they require relatively large drivers.

Fig. 4 shows how flat diaphragms have been made to reduce the axial dimensions of loudspeakers in order that thin acoustical enclosures which are more compatible with modern furniture design might be used to house the speakers. As a means for reducing the axial dimensions, flat diaphragms have to some extent been utilized, even for speakers designed to reproduce low frequency sound. However, when flat diaphragms are driven in the usual manner by a voice coil mounted at the center of the diaphragm, it has been found that the vibrating diaphragm breaks up into several vibrational modes, with the end result that severe distortion is introduced.

It is an object of the invention to provide a loudspeaker diaphragm which, being composed of two substantially flat parts, is substantially flat but which, nevertheless, will reproduce sound without undue distortion.

It is a further object to provide such a diaphragm which can be used with speakers having small axial dimensions.

It is a further object to provide such a diaphragm which is light in weight and yet rigid.

It is further an object to provide a flat diaphragm which vibrates as a piston without breaking up into several vibrational modes.

It is still further an object to provide a diaphragm as described which is relatively simple and inexpensive to produce.

Other objects and advantages of the invention will become apparent from the following discussion and the accompanying drawings in which:

FIG. 1 is a cross-sectional view of a diaphragm embodying the present invention;

FIG. 2 is a cross-sectional view of a diaphragm according to the invention utilizing a somewhat modified voice coil attachment;

FIG. 3 is a cross-sectional view of an alternative embodiment of the invention, and

FIG. 4 is a rear view of a portion of the structure shown in FIG. 3.

According to the invention it has been found that a relatively flat and rigid air-moving means which will vibrate as a piston without breaking up into several vibrational modes may be provided by utilizing a compound diaphragm having a flat main air-moving diaphragm member cooperating with an auxiliary driving member affixed thereto at the periphery. The auxiliary driving member operates to transmit vibrations from the voice coil, which is mounted at the axis of the driving member, to the periphery of the flat diaphragm member.

Referring to FIG. 1, the diaphragm 1 is shown in the form of a planar disc. At the periphery of the diaphragm 1 and at the side thereof is a raised shoulder 2. A substantially flat driving member 3 is arranged to transmit motion to the periphery of the diaphragm member through the shoulder 2. The functions of the shoulder 2 are to maintain the major portion of the inner surface of the diaphragm 1 spaced apart from the major portion of the surface of the driving member 3, and to provide a means for transmitting driving force to the diaphragm from the driving member. A flexible annular ring 4 may be mounted between the diaphragm 1 and the driving member 3 at the peripheral shoulder to support the diaphragm assembly. The periphery of the annular ring 4 is in turn affixed to the loudspeaker frame, not shown.

Mounted centrally at the axial aperture 3' of the driving member 3, as by cementing, is a voice coil bobbin 5 having a voice coil 6 mounted thereon. A channel 7 connects the voice coil opening with the space 1a between the diaphragm 1 and the driving member 3.

The structure of the peripheral portion of the diaphragm assembly may have a somewhat altered arrangement. Instead of having the shoulder at the periphery of the diaphragm for the application of the driving force, the diaphragm periphery may be flat and a separate ring may be cemented to and positioned between the diaphragm and the annular ring 4, or the annular mounting ring may itself serve to provide the driving connection between the two members. Alternatively, the annular ring 4 may be directly affixed to a flat diaphragm and an extension of the driving member used to separate the diaphragm from the driving member. Whatever arrangement is used, it is important that the driving force be applied to the diaphragm at an annular area near its periphery to avoid the breaking up of the diaphragm into separate vibrational modes.

A somewhat modified form of the compound diaphragm assembly is shown in FIG. 2. Here, as in FIG. 1, the diaphragm 8 is driven at its periphery by a substantially flat driving member 9. An annular supporting ring 11 is inserted between the two parts in a manner similar to that of FIG. 1. In this arrangement, the driving member 10, instead of having an axial opening or channel connecting with the space 1a between the diaphragm and driving member, as in FIG. 1, has only a shallow well 10' provided therein into which the bobbin 12 supporting the voice coil 13 is cemented. The operation of this structure is similar to that of the device of FIG. 1, except that here the air between the diaphragm and the driving member is entrapped to form an elastic cushion with damping qualities.

Among the materials contemplated for use in the present invention are the class of materials known in the art as rigid plastic foams or rigid expanded plastics. Such materials are prepared by incorporating a small amount of "blowing agent into a fusible or liquid plastic or resinous material, either while the material is in the liquid stage, or, in the case of bead-form materials, by causing the blowing agent to be absorbed into the individual beads. Under the proper conditions the blowing agent causes the plastic material to expand by the reacting therewith or with water liberated therefrom to form a gas, by reaction of two or more components of the blowing agent, or by the vaporization or decomposition of the blowing agent into a gas whereas the temperature of the foamy material is raised. After the plastic material has been caused to expand to the desired density, it is solidified, either by cooling, as in the case of thermoplastic materials, or by curing or setting in the case of thermosetting materials. The resulting product has a structure comprised of a multitude of very fine, uniformly discrete closed cells, each being a miniature bubble with a very thin plastic wall which is common to that of adjacent cells.

Examples of the various plastic or resinous materials...
which may be used to prepare rigid foams suitable for the present invention are: polystyrene, polyethylene, polyvinyl chloride, phenol-formaldehyde condensation products, various polyurethane resins, and many others. Suitable foaming agents for each of these materials are well known in the art. Thermosetting plastic foams are entirely suitable for the practice of the present invention. Preliminary tests indicate that plastic beads suitable for use in the present invention are commercially marketed by Koppers Company, Inc., under the trademark Dylite. This material is more fully described in British Patent #756,654, the disclosure of which is herein incorporated by reference.

The plastic beads may be fabricated by placing the required amount of polystyrene beads in a mold and applying heat by means of steam. The beads are caused to expand and to fill the molding form. Alternatively, the beads may be extruded into a flat sheet and the flat diaphragm then directly cut from the sheet.

As an alternative to the use of plastic foam for the diaphragm assembly, the diaphragm, as well as the driving member, may be fabricated from paper or other sheet form material which is stiffened by means of a resin or sizing agent. In the case of the driving member, increased rigidity is attained by molding radially ribbed body. Such a structure is illustrated in FIGS. 3 and 4. Here the diaphragm 14 is comprised of a flat sheet of paper which is made rigid by impregnation with a lacquer. The diaphragm 14 is driven at its periphery by stiff substantially flat driving member 16 which is composed of a felted and lacquered paper having radial ribs molded therein. The paper used for the supporting ring 18 is also preferably impregnatd with a lacquer, as by dipping.

A voice coil bobbin 19 bearing a voice coil 20 is inserted into the driving member 16.

Various combinations of the structures shown in the drawings may be used. For example, a foamed plastic driving member may be used with a stiffened paper diaphragm, or with a molded foam diaphragm; or a paper driving member may be used with a paper diaphragm or a flat plastic diaphragm. In every case, because the diaphragm is driven substantially at its periphery, it does not break up into vibrational modes.

The driving member itself, because it is driven near its center and is substantially flat, will tend to break up into vibrational modes to a limited degree. However, this effect is substantially damped out and, in any event, does not manifest itself in the sound reproduced by the diaphragm unit because the diaphragm, being driven only at its periphery by the peripheral portion of the driving member, does not to any appreciable degree break up into vibrational modes. Moreover, the sound waves from the back of the driving member are substantially attenuated by the acoustic enclosure in which the speaker is mounted.

Other rib or reinforcement patterns may be used as alternatives to the pattern shown in the drawings, the primary requirement being maximum radial stiffness of the driving member.

The double diaphragm assembly of the present invention has a number of advantages over conical diaphragms. First, it has small axial dimension, permitting unusually slim cabinetry to be utilized. Second, because the radia forer the form of a flat plate, the diaphragm is effective for efficient sound production and radiation. Third, because the piston-like diaphragm is driven at least mainly at its periphery, the tendency for the diaphragm to vibrate in spurious vibrational modes is suppressed. The diaphragm assembly is sturdy, light and rigid. It provides excellent efficiency and improved transient response. It has good tonal range and balance and is free from coloration.

In addition to its excellent response characteristics, the compound diaphragm assembly of the invention is relatively simple and inexpensive to produce, and its parts may be readily molded from expandable plastic beads available on the market or from readily available fabrics and resins.

Although the invention has been illustrated by only a few examples, variations may be practiced by those skilled in the art. It is to be understood that the spirit and scope of the invention as defined in the appended claims.

Invention is claimed as follows:

1. A compound loudspeaker diaphragm assembly comprising a substantially flat and rigid diaphragm, a rigid substantially flat driving member spaced except at the periphery thereof from said diaphragm, and having its periphery affixed to said diaphragm only at substantially the periphery thereof, and a voice coil coaxially mounted on said driving member, the diameter of said voice coil being substantially smaller than the diameter of said diaphragm.

2. A compound loudspeaker diaphragm assembly according to claim 1 wherein said diaphragm is composed of a rigid expanded plastic.

3. A compound loudspeaker diaphragm assembly according to claim 1 wherein said driving member is composed of a rigid expanded plastic.

4. A compound loudspeaker diaphragm assembly according to claim 1 wherein said driving member is composed of a rigid plastic diaphragm.

5. A compound loudspeaker diaphragm assembly according to claim 4 wherein said plastic is polystyrene.

6. A compound loudspeaker diaphragm assembly according to claim 1 wherein said driving member is composed of a fibrous sheet impregnated with a resinous rigidizing material, and having radial reinforcing ridges molded therein.

7. A compound loudspeaker diaphragm assembly according to claim 1 wherein said driving member is composed of fibrous sheet material impregnated with a resinous rigidizing material, said driving member having radial reinforcing ribs molded therein.

8. A compound loudspeaker diaphragm assembly comprising a substantially flat and rigid diaphragm, a substantially flat and rigid driving member spaced except at the periphery thereof from said diaphragm and having its periphery affixed to said diaphragm only at substantially the periphery thereof, a voice coil mounted on said driving member coaxially therewith, the diameter of said voice coil being substantially smaller than the diameter of said diaphragm, and a flexible annular suspension member affixed to said diaphragm assembly at the periphery thereof.

9. A compound loudspeaker diaphragm assembly comprising a substantially flat and rigid diaphragm, a substantially flat and rigid driving member spaced except at the periphery thereof from said diaphragm and having its periphery affixed to said diaphragm only at substantially the periphery thereof, said driving member having a channel therein coaxial therewith, a voice coil bobbin secured to said driving member in said channel, and a voice coil mounted on said bobbin, the diameter of said voice coil being substantially smaller than the diameter of said diaphragm.

10. A compound loudspeaker diaphragm assembly comprising a substantially flat and rigid diaphragm, a substantially flat and rigid driving member spaced except at the periphery thereof from said diaphragm and having its periphery affixed to said diaphragm only at substantially the periphery thereof, said driving member having a well extending thereinto coaxially therewith, a voice coil bobbin extending into said well and affixed to said driving member, and a voice coil on said bobbin, the diameter of said voice coil being substantially smaller than the diameter of said diaphragm.

11. A compound loudspeaker diaphragm assembly comprising a substantially flat and rigid diaphragm, a substantially flat and rigid driving member having its peripher-
ery affixed to said diaphragm at the entire periphery thereof but being spaced apart from said diaphragm throughout the major portion of the area thereof to define a closed space therebetween, and a voice coil coaxially mounted on said driving member, the diameter of said voice coil being substantially smaller than the diameter of said diaphragm.

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