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SOUND-REPRODUCING DEVICE

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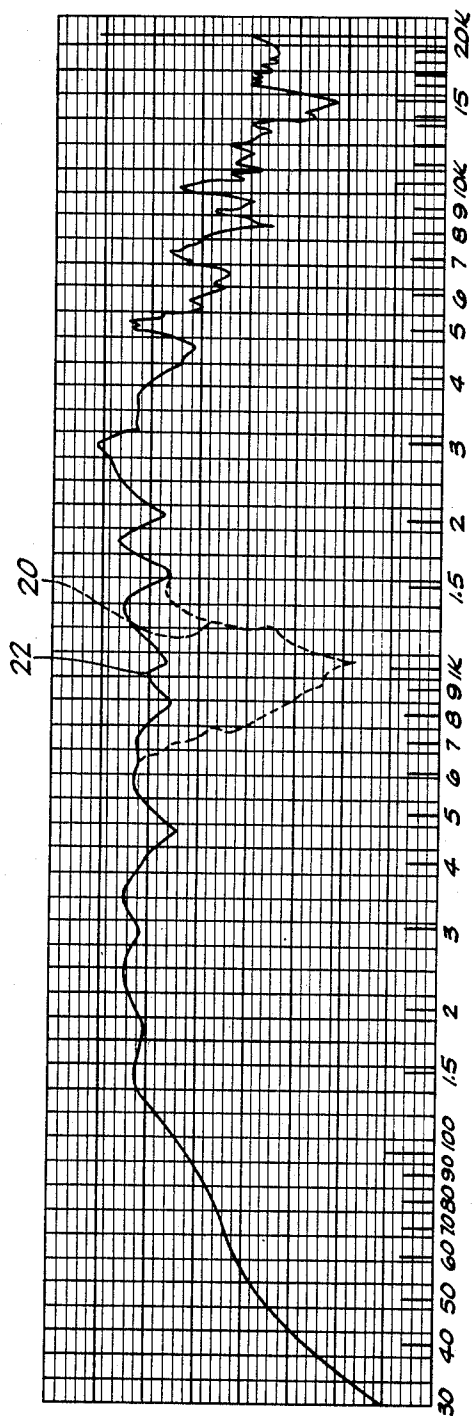


FIG. 3.

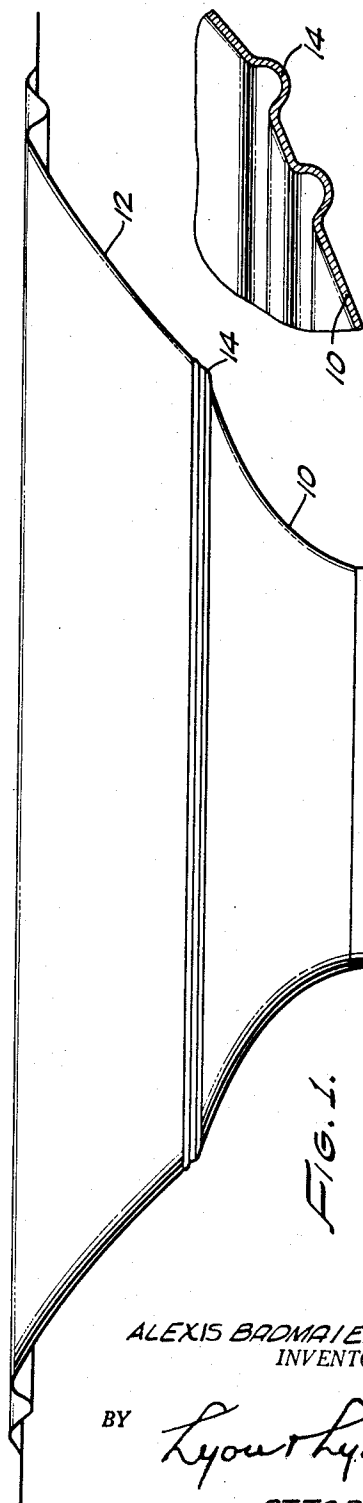


FIG. 2.

FIG. 1.

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SOUND-REPRODUCING DEVICE

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6 Claims. (Cl. 181—32)

This invention relates to loudspeakers and, more particularly, to an improvement in the construction of diaphragms for loudspeakers.

One of the simplest forms of transducers for transforming electrical energy into acoustical radiation is the cone-type loudspeaker. The familiar, single-cone speaker usually consists of a radiating paper cone driven by a voice coil attached at the apex of the cone. The frequency range of these speakers is quite limited, however, when they are built at a lower cost. Although the frequency range may be extended by the use of additional refinements and a smoother response achieved also, there is, however, a limit to the range of frequencies which may be reproduced, despite the ingenuity of the various refinements. Accordingly, compromises must be made between low- and high-frequency reproduction when a single cone is to be employed for the purposes of attempting to reproduce the full-frequency range.

For the purpose of extending the spectrum of frequencies being reproduced in order to provide more faithful reproduction, the present practice is to use more complex speaker systems, usually comprising two units. In these two units, a speaker which is designed for low frequencies is employed, and another speaker for reproducing the high frequencies. These are commonly known as the woofer and tweeter speakers. An electrical crossover network is usually used to divide the sound-frequency spectrum between the two speakers. It will be appreciated that these two-way loudspeaker systems are much more costly than the single-cone speaker.

An object of the present invention is to provide a novel single-cone loudspeaker arrangement which has an extended frequency range of reproduction.

A further object of the present invention is to provide a single-cone speaker which is relatively inexpensive and can reproduce an extended range of frequencies.

One way to achieve the performance of a double-cone loudspeaker with a single cone is to effectively split the single cone so that it contains a smaller cone which can reproduce high frequencies and an additional peripheral extension of the small-cone area which can be coupled to the smaller cone so that together there is provided a large cone for the purpose of reproducing the middle and low frequencies. This can be accomplished by introducing a compliance in the middle section of a large cone. The compliance permits the outer portion of the speaker to become decoupled at high frequencies, in which region the inner area becomes free to vibrate without carrying the mass of the outer area. The accomplishment of this by corrugating a ring in the diaphragm or cone of the loudspeaker is known. However, certain difficulties arise when this type of compliance is used, as a result of which there has not been widespread use of this device in loudspeakers for reproducing an extended range of frequencies. The reason is that in the region where there is a crossover, that is, where the system goes from the high-frequency reproduction to the

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low-frequency reproduction, disturbances occur due to shift in the relative phase of the velocities of the high-frequency and low-frequency cone portions, which result in a severe reduction in output at the crossover frequency region which has been termed a "hole" in the frequency spectrum.

Accordingly, a further object of the present invention is the provision of a novel loudspeaker containing a single cone which can reproduce the full-frequency range and in which there are substantially no disturbances obtained at the region of crossover.

These and other objects of this invention are achieved by providing a single-cone loudspeaker having a double corrugation in the cone at a distance from the center and by applying a layer of viscous damping liquid to both sides of the cone at the corrugation region. This effectively increases the resistance of the mid-compliance section of the cone. As a result, the phase difference of the two cone sections which are the cause of disturbances at crossover are minimized considerably. This results in substantially eliminating the dip in the frequency spectrum. To further reduce irregularities in the over-all response characteristic of the speaker, the magnitude of the mechanical resistance at the rim of the cone is raised by a damping layer to thereby prevent reflection from the edge of the cone. The wave motion, as it travels from the center of the cone out to the rim, is substantially absorbed by the mechanical resistance of the damping layer and thus is prevented from being reflected back.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

Figure 1 is a section of a loudspeaker cone made in accordance with this invention;

Figure 2 is a detail of the corrugation employed in the speaker; and

Figure 3 shows the frequency response obtained with a 12" speaker before and after the employment of this invention.

As was pointed out previously, a relatively large cone is necessary for the radiation of reasonable amounts of power at low frequencies, but large mass limits effectiveness at high frequencies. A small mass, such as a 6" cone, may have excellent high-frequency characteristics, but very little power can be radiated at low frequencies by such a small radiating area. The combination of a small cone with a large cone, if incorporated in one speaker, would considerably reduce the cost, because such a structure would be driven by one voice coil and simultaneously would retain the simplicity of a single-cone construction. The introduction of a compliance in the middle section of a large single cone has the effect of permitting the outer-cone portion to become decoupled at high frequencies, in which region the inner-cone portion becomes free to vibrate without carrying the mass of the outer-cone portion. Thus, as shown in Figure 1, which is a drawing of an embodiment of the invention, there is a speaker cone which has an inner- or small-cone area 10, and outer-cone area 12, and a mid-compliance 14 consisting of a corrugation ring. Such mid-compliance may be designed to have a stiffness so that it places the "crossover frequency," for example, at 1,000 cycles. The compliance 14, as may be seen in detail in Figure 2, consists of two concentric corrugations in the cone. These terminate the smaller-cone area and act as its edge compliance. Above 1,000 cycles, the smaller-cone area 10 alone is driven by the voice coil and effectively radiates the high frequencies while the outer area of the cone 12 is essen-

tially motionless and acts as a baffle for the smaller one. A curved contour is given to the outer area of the cone to further improve the high-frequency response because of the avoidance thereby of difficulties arising from close-by irregularities which may be present in the normal cabinet baffle surface. At frequencies below 1,000 cycles, the inner- and outer-cone areas move in unison and constitute an effective low-frequency radiator.

The real difficulties arise, however, in the region of crossover. From analysis, it may be shown that disturbances occur in the region of crossover due to the shift in the relative phase of the velocities of the two cone members. Actual tests of a cone containing the simple mid-compliance described thus far fully confirms this expectation.

An analysis employing the electrical analog of the system represented by the cone and its corrugation shows the drive for the outer portion of the cone comes through the corrugation. In the region of the crossover, if the compliance, which is formed by the corrugations, acts effectively as a capacitance, then the velocities of the two cone sections are out of phase with each other as much as 180 degrees. Considering further the electrical analog of the system, it is found that when the resistance of the mid-compliance is increased the phase difference of the velocities of the inner and outer cones is gradually reduced. As the mid-compliance is made more resistive, the relative phase differences approach 90 degrees. This, of course, reduces considerably the cancellation effects which occur when the two cone sections have a phase difference greater than 90 degrees.

In terms of results obtained, when the mid-compliance is made stiffer (high crossover frequency) its stiffness approaches the pulp of the cone. At that time, no definite compliance boundary will exist. When the mid-compliance is made more compliant (lower crossover frequency) the internal damping of the pulp of the cone will be less, thereby increasing the Q of the system at crossover. The mid-compliance must have its mechanical resistance increased to achieve a minimum dip at crossover frequency. Heretofore, the application of material for accomplishing this usually resulted in over-compensation. The physical location of the mid-compliance may be moved along the cone. However, if by doing this, the radiating surface of the inner cone is made too large, the high-frequency response suffers—if too small, insufficient radiation area results.

The proper resistance for the mid-compliance can be simply and effectively achieved by applying a layer of viscous damping liquid to both sides of the cone at the mid-compliance 14. This preparation, when dried, becomes a viscous-plastic layer which acts effectively as a resistance, and does not lose this property with the passage of time. Solutions of plasticized cellulose nitrate having suitable sound-damping qualities are sold under the trade-mark "Viscoloid" by the Radio Corporation of America or as "54007 Cement" by the Du Pont de Nemours Corporation.

To further reduce irregularities in the over-all response characteristic, the magnitude of the mechanical resistance in the edge compliance of the cone at the portion of the edge which is normally attached to the frame of the speaker, is raised to damp the low-frequency branch of the network and to prevent reflections from the edge of the cone. The same viscous material as is employed in the cone corrugation can also be used to accomplish the above.

Regarding Figure 3, the frequency response in the region of crossover just below 1,000 cycles of a 12" speaker is represented by the dotted line 20. There is a "valley"

or hole in the response curve approximately 12 db deep. This was substantially cleared, as shown by the solid-line 22 response curve, after employing this invention.

Loudspeakers which were constructed in accordance with this invention were tested and produced a frequency-response curve as shown in Figure 3. It will be apparent that the response-characteristic of the single-cone speaker is high in the low-frequency end and is substantial at frequencies almost up to 15,000 cycles. The valley at the crossover frequency has been substantially eliminated. Accordingly, as has been described heretofore, in order to produce a single-cone speaker having an extended range of frequency reproduction and which is economical and simple to manufacture, a single-cone speaker has a corrugated region at a distance from the center of the cone which will provide a central cone area having a desired high-frequency response. The corrugation is then coated on both sides with a viscous damping liquid, which adds to the resistance at the corrugated portion with a minimal addition to its mass. Also, at the edges of the cone which are clamped to the supporting ring, material of the same type may be coated upon the corrugations which normally are employed for the purpose of damping.

There has been described and shown hereinabove a novel, simple, useful, and inexpensive arrangement for increasing and improving the loudspeaker performance without substantially adding to its cost.

I claim:

1. In a sound-reproducing device of the type having a conical diaphragm concentrically divided by corrugations into an inner conical section and an outer peripheral section, the improvement in said sound-reproducing device comprising a coating on said corrugations of a resistance-increasing agent.

2. In a sound-reproducing device of the type having a conical diaphragm concentrically divided by corrugations into an inner conical section and an outer peripheral section, the improvement in said sound-reproducing device comprising a layer of a viscous damping liquid on both surfaces of said corrugations.

3. In a sound-reproducing device of the type having a conical diaphragm concentrically divided by corrugations into an inner conical section and an outer peripheral section, the improvement in said sound-reproducing device comprising a viscous plastic layer on both surfaces of said corrugations.

4. In a sound-reproducing device of the type recited in claim 3, wherein said viscous plastic layer is a mixture of plasticized cellulose nitrate having sound-damping qualities.

5. A sound-reproducing device having a conical diaphragm including an inner curved conical section, an outer peripheral section, a section having corrugations joining said inner and outer sections, and a viscous-plastic layer on both surfaces of said corrugation section.

6. A sound-reproducing device having a conical diaphragm including an inner curved conical section, an outer peripheral section, a section having corrugations joining said inner and outer sections, a viscous-plastic layer on both surfaces of said corrugation section, and a viscous-plastic layer at the outer portions of said outer peripheral section.

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