An electro-acoustic transducer such as a loudspeaker is housed in an enclosure having a filling comprising a rigid body of, for example, foamed polyurethane which is capable of transmitting pressure changes caused by operation of the transducer. The body may have an air-impermeable surface to form a sealed enclosure.

7 Claims, 3 Drawing Figures
LOUDSPEAKERS

This application is a division of Ser. No. 788,483, now abandoned.

This invention relates to enclosures for electro-acoustic transducers such as loudspeakers capable of producing from an electric information-carrying signal, sound waves carrying information corresponding to that in the signal.

The invention is particularly applicable to loudspeakers in which sound waves are generated by a rigid diaphragm urged into motion as a whole by an electromagnetic system which is energized by the signal and a part of which is coupled to the diaphragm. The invention is, however, also applicable to alternative forms of loudspeakers, for example loudspeakers of the kind in which the sound waves are generated by an electric field produced by the signal between electrodes.

With the exception of the case where they are freely mounted, loudspeakers have hitherto been mounted within an enclosure or cabinet having walls provided with a suitable decorative external finish.

It is essential, for high quality sound reproduction, that the sound waves radiated by the assembly comprising the combination of a transducer such as a loudspeaker and the enclosure in which it is mounted should bear the closest possible correspondence to the information contained in the electrical signal applied to the transducer. Any deviation between the radiated sound waves and the information in the signal reduces the faithfulness of the reproduction and is known as distortion or coloring.

From inter alia an acoustic point of view, the walls of such an enclosure have hitherto been necessary not only to provide support for the loudspeaker but also to prevent unrestricted pressure changes with the enclosure being transmitted to the surrounding air and vice versa. However, such walls are themselves urged into vibration by the sound waves generated in the loudspeaker and this vibration of the walls consequently distorts the sound radiated by the assembly. The volume of air within the enclosure, by virtue of its properties, also is urged into complex vibration and further distorts the sound radiated by the speaker-enclosure assembly, by virtue of the resonances which are excited by the sound energy.

In order to overcome these difficulties, it has been common practice to construct the walls of the enclosure of heavy panels which resist vibration and sometimes additionally to employ internal bracing together with lining of the panels with a suitable damping material.

In addition and in order to modify the acoustic properties of the space within the enclosure, it has been common practice also to fully or partly fill the enclosure with a light sound absorbent material. This absorbent material assists in absorbing standing wave energy resulting from reflecting of sound waves between the sides of the enclosure and the use of such material reduces the coloration of sound which results from standing waves. The absorbent material generally used is glass fiber and the like which must be suitably supported within the enclosure into which it is introduced.

According to one aspect of the present invention, an enclosure for an electric transducer such as a loudspeaker has a filling comprising a rigid body of having substantially the same shape as the enclosure and including a matrix of passages or intercommunicating cavities which are capable of transmitting through the body, gas pressure changes caused by the transducer.

The body is preferably suitably shaped to receive at least part of the transducer, for example by being provided with a suitably shaped depression.

Conveniently the body is a block of rigid cellular material in which the majority of the cells are intercommunicating, so that the pressure changes produced by the transducer can be transmitted through the body. A suitable cellular material is a foamed plastics material such as polyurethane which is produced by means well known in the art.

Conveniently the body comprising the enclosure is produced by inserting a fluid foaming agent into a mold having internal dimensions substantially that of the enclosure, so that the foamed plastics material fills and sets in the mold. In this case the mold may be arranged simultaneously to provide the body with one or more depressions respectively for receiving one or more transducers. The mould may also be arranged to support, in the correct position, support means by which one or more transducers may be secured to the body, so that these support means become firmly and rigidly incorporated within the body after moulding is completed. The securing means may for example, comprise a baffle to which the transducer is subsequently attached.

Alternatively, the moulding may be made with the transducer already in situ within the mould so that the transducer becomes securely incorporated in and rigidly secured to, the body. In this case, provision must be made for preventing the expanding foaming material from interfering with the transducer, for example, with the diaphragm of a loudspeaker, and subsequently preventing its excursions.

Alternatively the body is produced by suitably bonding together particles of a sound absorbing material so that the matrix is produced by the communicating interstices between the particles. In this case the bonding may also be accomplished in a suitable mould and may be accompanied by some compaction of the particles.

In a preferred embodiment of the invention, the whole of the outer surface of the enclosure with the exception of the orifice through which, in use of the enclosure, sound generated by the transducer is directly transmitted, is arranged to be air-impermeable to produce what is termed a "sealed" enclosure. In such a sealed enclosure, the gas conditions which are brought about by the matrix are isothermal so that the different velocity of sound within the enclosure, as compared with that external to the enclosure (i.e. in the atmosphere), where conditions are adiabatic, is equivalent to increasing the volume of the enclosure.

The compliance of the transducer assembly is thus increased and further improves the low resonant frequency and the Q-characteristics which are provided by the enclosure of the invention.

An air-impermeable outer surface on the body may be produced by suitably moulding the body so that an outer impermeable skin is formed. This skin need not be thick relatively to the dimensions of the body, the rigidity of the body being sufficient to give the necessary rigidity and support to the skin. It will be appreciated
that with this technique, where a depression effective to receive the transducer is moulded integrally with the body an air-impermeable skin formed over the surface of the depression must be separately removed after moulding, to allow pressure changes produced by the transducer to be transmitted into and through the body.

A sealed enclosure may also be produced by covering the body with a suitable material differing from that of the body. Suitably, the body is covered with an impermeable sheet material, such as wood, metal or plastics sheet material, suitably treated if desired to produce an external decorative effect.

Where the rigid body in the enclosure is moulded, the air-impermeable sheet material may itself be arranged to form the mould. By this means the foamed material will, in general, after expanding to fill and set in the mould, become firmly bonded to the sheet material thereby giving it further support and rigidity, and enabling the sheet material of relatively low inherent rigidity to be employed.

In one embodiment of the invention, a sealed enclosure is provided with a suitable opening or resistive window to allow controlled air flow in response to pressure differences between the interior of the enclosure and the atmosphere, and thereby to enable the enclosure respectively to act either as a resonator or to enable its resonance characteristics to be modified.

Such an opening may be incorporated into the skin of the body during moulding or may be suitably incorporated into the sheet covering material when this is used to form the mould itself.

It will be appreciated that where a sealed enclosure is employed, it is essential that the transducer itself forms an airtight seal with the orifice from which sound waves, generated by the transducer are directly radiated. The moulding of the transducer or the supporting baffle into the body is accordingly arranged to ensure that such a seal is produced.

Where the body in the enclosure is merely provided with an air-impermeable skin, the transducer itself may be placed in a suitable position in the mould, the rear of the transducer being covered with a mesh, so that the foamed material will form around the transducer, for example, a loudspeaker unit without interfering with the transducer, but at the same time will mould sufficiently around the supporting means of the transducer (i.e., the frame of a loudspeaker) to hold this rigidly in place. An inhibiting agent on the wire mesh will prevent the foamed material from forming an impermeable skin behind the transducer, i.e., behind the diaphragm of a loudspeaker.

Alternatively, where the body is moulded to include a depression for receiving the transducer, the body may be moulded to include fixing studs, by which the transducer may be held within the body with sufficient rigidity. If during the moulding an air-impermeable skin is formed over the surface of the depression, then this may separately be broken to allow the gas pressure changes produced by the transducer to be transmitted through the body.

In the case where the enclosure is arranged to incorporate more than one transducer, each of which is arranged to reproduce a different frequency range, the lower frequency transducer is mounted in any of the ways herein before described. However, the other

higher frequency transducer or transducers preferably are incorporated into the rigid body after a seal is incorporated to prevent air pressure changes generated by them from having access to the matrix within the body. This seal can be formed by the skin produced on the surface of the corresponding depression when this is moulded integrally with the body. Alternatively, such higher frequency transducers can be directly moulded into the body of the enclosure by allowing the material to foam around them.

The depressions, in the body can, if desired contain an acoustically absorbent material.

Where the enclosure is arranged to receive more than one transducer, each of which is arranged to reproduce sound within a different frequency range, a network effective to divide from the electrical signal driving the transducers, the frequency range components driving the respective transducers can also be incorporated into the body and preferably, is moulded directly into the body of the enclosure.

In one embodiment of the invention open cell expanded material can also be used to absorb the sound radiated from the rear of a transducer.

In an alternative embodiment of the invention the body in the enclosure is in elongated form with an internal cavity which is open at one of the ends of the body to receive the transducer.

In this arrangement, the body is arranged so that substantially the whole of the sound energy radiated from the rear end of the transducer is absorbed in the cavity in order to reduce to a minimum the distortion produced by the transducer-enclosure combination.

As before the body is preferably provided with an air-impermeable outer surface layer to prevent unrestricted transfer of gas between the inside of the enclosure and the surrounding atmosphere.

Preferably the body is moulded and the skin is provided on the outer surface of the cavity during the moulding operation.

Embodiments of the invention will now be particularly described, by way of example, with reference to accompanying drawings, in which:

FIG. 1 is a schematic partly cutaway perspective view of one embodiment of a loudspeaker enclosure according to the invention,

FIG. 2 is a partial sectional view of an alternative embodiment of the enclosure shown in FIG. 1 and;

FIG. 3 is an axial section of a further embodiment of a loudspeaker enclosure according to the invention.

Referring to FIG. 1 of the drawing this shows a loudspeaker cabinet in the form of a rectangular enclosure with an internal filling comprising a rigid body 2 of foamed polyurethane covered by a decorative plastics laminate sheet material 4. The sheet material 4 is contiguous with and preferably bonded to, the body 2 with the exception of the area of an orifice formed by a central depression 6. This depression 6 which is provided in one face of the body 2 is effective to receive a loudspeaker 10 (FIG. 2) which is firmly secured to the enclosure by way of mounting studs 8 embedded in the body 2.

Where the periphery of the loudspeaker frame, (as shown in FIG. 2), makes a gas tight seal with the edge of the orifice formed by the depression 6, the enclosure will be a sealed enclosure of the kind thereinbefore
referred to, if the sheet material of the loudspeaker diaphragm 12 is unbroken and air-impermeable. The enclosure of FIG. 1 may conveniently be produced by assembling the sheet material 4 to the dimensions shown in order to produce the mould. A male mandrel (not shown) having the shape of the depression 6 is arranged releasably to hold the loudspeaker fixing studs 8 and is introduced into the orifice provided in the sheet material 4 at its central region. The mandrel is preferably coated with a release agent to facilitate its subsequent removal from the mould.

Fluid polyurethane together with a foaming agent is then introduced into the mould so as to foam and fill the space within the mould and subsequently to set, bonding to the sheet material 4 of the mould. The conditions under which the polyurethane is foamed are arranged to produce a majority of inter-communicating cells within the foamed material, to enable gas pressure changes generated by the excursions of the loudspeaker diaphragm 12 to be transmitted through the body 2. The formation of an air-impermeable skin on the surface of the depression 6 must be prevented during moulding, as hereinafter described, or, if such a skin is formed, it must subsequently be removed.

In the embodiment of the invention described with reference to FIG. 1 and 2, the gas conditions within the matrix of the body of the enclosure become isothermal to cause a reduction in the velocity of sound compared with the adiabatic conditions existing in the surrounding atmosphere. The change to isothermal conditions has the effect of increasing the effective volume of the enclosure and makes possible the use of enclosures of relatively smaller volumes which retain acoustic characteristics normally capable of being provided by enclosures of relatively larger volume.

After solidification of the body 2 the mould is released from the studs 8 which are left firmly embedded in the body 2, now provided with the depression 6 for receiving the loudspeaker 10. The loudspeaker 10 may be secured to the studs 8 by any suitable means.

Any bonding of the foamed body 2 to the sheet material 4 will, of course, increase the overall strength of the enclosure and enable sheet material 4 of low inherent rigidity to be employed.

In an alternative embodiment of the invention shown in FIG. 2, the depression-forming mandrel is dispensed with, and the loudspeaker 10 itself is inserted in the mould formed by the sheet material 4, so that the periphery of the loudspeaker frame closely abuts the periphery of the orifice 14 in the mould.

A gauze 16 coated with an agent effective to inhibit formation of an air-impermeable skin on foamed polyurethane, is disposed at the rear of the loudspeaker to form a space into which the polyurethane cannot foam. This clear space prevents any interference with the free excursion of the loudspeaker diaphragm 12.

A moulding is completed by inserting fluid polyurethane as before, together with a foaming agent in the mould. The foamed material expands to form a gas-tight seal between the periphery of the loudspeaker frame and the orifice 14 to permit the enclosure to become a sealed enclosure as hereinbefore defined.

In addition and in order to modify the acoustic properties of the space within the enclosure, it has been common practice also to fully or to partly fill the enclosure with a light sound-absorbent material. This absorbent material assists in absorbing the energy produced by the rear of the loudspeaker diaphragm and also in converting wave energy resulting from the internal reflection of sound waves from the sides of the enclosure. This prevents a substantial part of this energy from being transmitted through the openings in the cabinet to the listener. The use of such sound-absorbent material therefore reduces the coloration of sound. A second reason for filling or partly filling an enclosure with sound-absorbent material is to change the gas conditions in the enclosure from adiabatic to isothermal. This causes a reduction in the velocity of sound within the enclosure as compared with that externally of the enclosure, which in turn results in an increase in the compliance of the loudspeaker-enclosure system, equivalent to a substantial increase in the cabinet volume. This enhances the low frequency performance and also lowers the Q of the system. The sound-absorbent material generally used is fiber-glass and the like which must be suitably supported within the enclosure into which it is introduced.

A further embodiment of the invention is shown in FIG. 3, which is particularly applicable to loudspeakers operating in what is usually regarded as the mid-frequency range. In this embodiment the enclosure is elongated and its walls 20 comprise an impermeable skin on the foamed material 2 or added sheets of impermeable material. The foamed material of the body 2 is effective in absorbing all or substantially all the energy. The speaker 10a is supported by support means 21 in the internal cavity 22 in the foamed material, and sealed to the orifice in the skin, as described in greater detail in the introductory part of this specification.

The preferred cellular material for the body 2 has been found to be rigid foamed polyurethane having a density of about 1 pound per cubic foot and having about 90 percent of its internal cells inter-communicating.

It will be appreciated that, while the invention has been described with particular reference to foamed polyurethane it is equally applicable to any material or plastics material in which a matrix of inter-communicating passages or cells are provided to transmit through the body air pressure changes generated by the loudspeaker or alternative form of transducer.

What is claimed is:

1. In combination:
   an electroacoustic transducer,
   an enclosure comprising a skin of plastic material and a filling made of substantially the same plastic material as said skin formed into a rigid cellular structure having a majority of intercommunicating cells and defining a cavity in which said electroacoustic transducer is mounted,
   said skin having an aperture therein in a region in which sound radiated from said transducer into said cavity impinges directly on said filling.

2. The combination of claim 1 wherein said filling of rigid cellular plastics material comprises foamed plastics material.

3. The combination of claim 2 wherein said filling of rigid cellular plastics material comprises foamed polyurethane.
4. The combination of claim 1 wherein said skin covers the entire outer surface of said rigid cellular plastics material with the exception of the region of said aperture.

5. The combination of claim 1 wherein said filling of rigid cellular plastics material has a recess for receiving said electro-acoustic transducer.

6. The combination of claim 5 wherein said electro-acoustic transducer is sealingly connected to said skin at said aperture whereby the space within said enclosure behind said electro-acoustic transducer is substantially sealed.

7. The combination of claim 1 further including means securing said transducer in said enclosure comprising transducer support members embedded in said filling of rigid cellular plastics material.

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