Aug. 24, 1965 B. W. TICHY 3,202,773

ELECTROMAGNETICALLY DAMPED SPEAKER SYSTEM

Filed Jan. 24, 1962

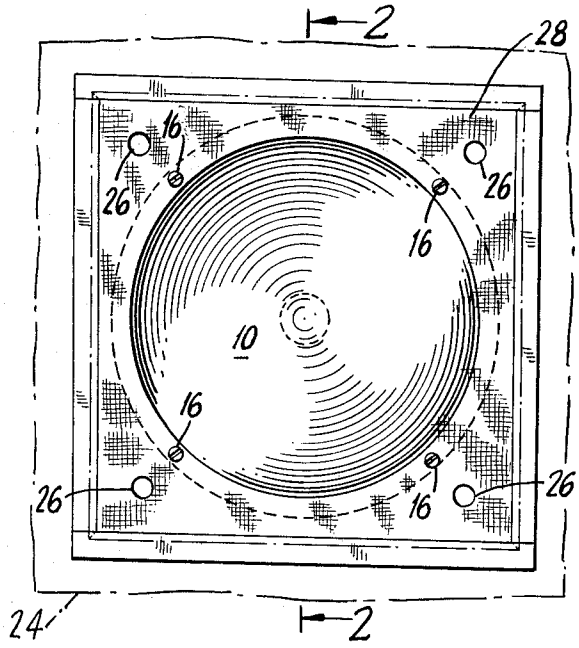


FIG. 1

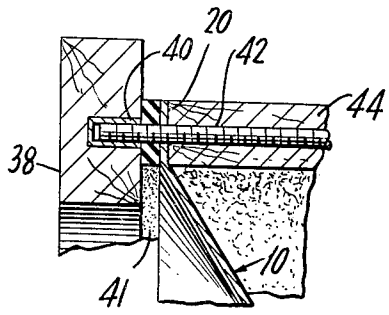


FIG. 4

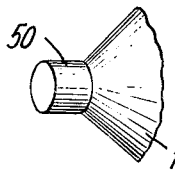


FIG. 5

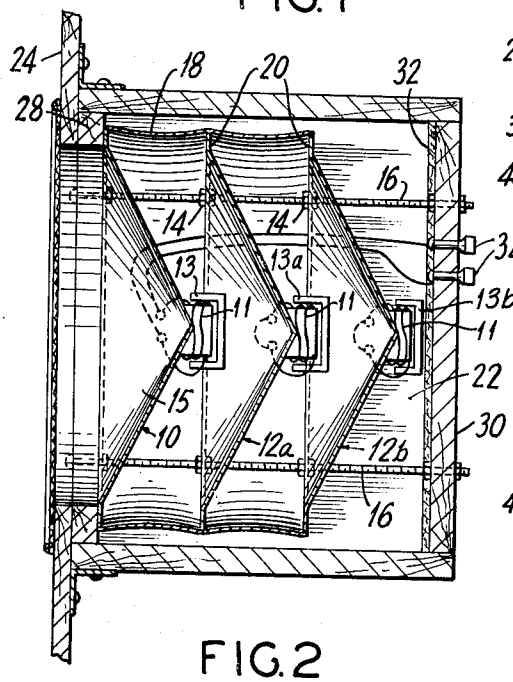


FIG. 2

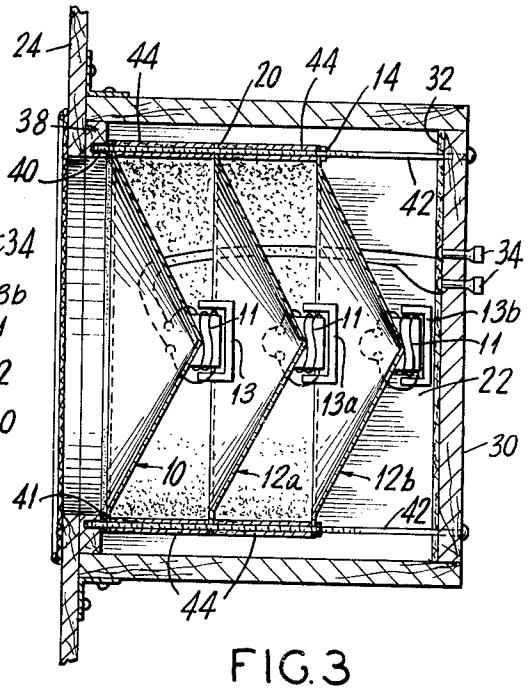


FIG. 3

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3,202,773 ELECTROMAGNETICALLY DAMPED SPEAKER SYSTEM

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This invention relates to improved audio speaker systems and in particular, to speaker systems employed in high fidelity music systems.

In an effort to maintain a smooth frequency response, many complex and costly speaker arrangements have been offered which attempt to (1) eliminate the problem of interference between the sound wave emanating from the front of the speaker system and the sound wave produced by the rear face of the speaker diaphragm and (2) eliminate resonate effects within the speaker and its enclosure. The use of sound absorbent material and other complex sound chambers have, in general, been unsatisfactory because of their uneven frequency response which results in unnatural coloration of the sound.

The advantages in the particular speaker system disclosed hereinafter are first, electrically, the speaker system presents a more or less constant impedance load to the amplifier due to the fact that any resonances within the speaker itself, or its enclosure, are damped out, thereby enforcing a more constant impedance than in normal speakers. Secondly, the speaker has improved acoustical response since the energy that is normally propagated from the rear of the speaker is not reoriented into the room, in varying phase with the desired energy coming from the front side of the speaker causing pattern distortion and beam shift resulting in dead spots within the room, at various frequencies. Thirdly, this speaker can be built into a much smaller size giving it a more esthetic appearance and permitting easier mounting, etc.

These and other features, objects and advantages of the invention will, in part, be pointed out with particularity and will, in part, become obvious from the following more detailed description of the invention, taken in conjunction with the accompanying drawing, which forms an integral part thereof.

In the various figures of the drawing, like reference characters designate like parts.

In the drawing:

FIG. 1 is a front view of one embodiment of the speaker system of this invention.

FIG. 2 is a section taken along line 2—2 of FIG. 1.

FIG. 3 is a cross-section of an alternative embodiment of this invention.

FIG. 4 is an enlarged detail of a corner of FIG 3.

FIG. 5 is a perspective showing of a single turn coil extending from a speaker cone.

One model of the system, shown in FIGS. 1 and 2, consists of three speakers, **10**, **12***a*, and **12***b*, aligned in spaced relationship along a common axis. Their frames are spaced about three inches apart and maintained in that position by nuts **14** clamping them to ¼–20 threaded studs **16**. Four such studs **16** are normally employed.

Speaker **10** is the sound reproducer of the system. Therefore, it must be carefully selected to give the desired performance. Obviously, the quality of this unit will influence the overall performance of the entire system. However, it is not necessary to employ the very

finest obtainable speakers as defects, such as resonances and distortions in less costly speakers, will be eliminated by the principle of this system. The overall performance of an inexpesive speaker will be improved to the point of providing performance superior to expensive speakers mounted in ordinary enclosures. Therefore, a point of diminishing returns will be reached with the selection of more expensive speakers. It is assumed here that cost varies directly with quality. A standard commercial quality full range speaker with a sufficient power rating may be used. A tweeter system may be incorporated, improving the high frequency performance of a less costly speaker, but will result in a slightly larger cabinet. Speaker **10** is provided with a voice coil or armature which is located in the electromagnetic field provided by magnet **13**.

Speakers **12***a* and **12***b* are transducers (speakers with shorted voice coils **13***a* and **13***b*, respectively). These units convert the undesired sound energy into electrical energy and dissipate it in their inherent internal resistance. Speakers are used for this purpose since they are readily available, inexpensive, and ideally suited for the task. Thin, efficient, and inexpensive units are preferred. Thin units permit the use of a finished cabinet of smaller depth. Efficient units are preferred in order to obtain maximum conversion of sound to electrical energy. The advantage of employing inexpensive units is obvious.

A cylindrical waveguide **18** is used to guide the sound energy from the rear surface of the driven speaker **10** into the transducers **12***a* and **12***b*. This waveguide may be constructed by any method resulting in a construction meeting the following requirements.

(a) The wall is non-porous to air and the unit is airtight.

(b) It must be capable of withstanding the internal sound pressures without expanding or contracting.

(c) A pressure-tight seal must be provided between the waveguide and the flanges **20** of the speaker **10** and transducers **12***a* and **12***b*.

One construction method which has been found satisfactory is to cover the edges of the three mounted speakers with a layer of ⅛" cork sheet. Over this several layers of gauze are tightly wound and the gauze impregnated with a liquid polyester resin which is then hardened, resulting in an airtight rigid cylinder **18**. Epoxy resin has also been found suitable for this purpose.

The speakers together with the waveguide assembly are mounted as a unit in a pressure chamber **22**. The pressure chamber affords the necessary air cushion required when the speaker cone is undergoing large excursions at low frequency. The chamber constitutes all the volume external to the waveguide **18** within the cabinet or other housing **24**. As this volume is increased the performance of the system is improved at extreme low frequencies.

A volume of ¾ cubic feet is sufficient when pressure relief ports **26** (FIG. 1) are incorporated in the front panel **28**. A 1¼ cubic foot volume provides excellent low frequency performance without pressure relief ports. However, such ports prevent large pressure differentials in small cabinets during extreme low frequency operation. The number and size of the ports is dictated by the volume of the pressure chamber **22**. Four ¾" diameter ports are adequate with a ¾ cubic foot pressure chamber. A larger volume pressure chamber need not employ as many ports or as much port area. These ports

are placed in the front panel **28**, preferably symmetrically, about the speaker cut-out.

The front panel **28** serves as a mounting board for the speaker assembly and may be part of a cabinet. The cabinet material must be sturdy enough to hold the speaker rigid. A minimum of ¾" plywood, or similar strength material, is suggested.

The rear panel **30** serves as a backboard for the rearward traveling sound waves and also may be an integral part of the cabinet. The panel must be constructed of at least ¾" plywood or equal strength material.

Acoustical absorbing material **32** covering the rear panel absorbs some of the acoustic energy impinging upon the rear panel **30**. The absorber can be any material which has good acoustic properties and is easily attached to the panel. A slight improvement in the system's operation may be obtained if the entire inner surface of the cabinet is lined with the absorber. Heavy felt, fiberglas or flexible plastic foams appear satisfactory for this application.

A pair of terminals **34**, capable of receiving normal interconnecting wiring is required. Solid, permanent connections and wiring must be utilized within the cabinet between the speaker voice coil **11** and terminals. No. 16 stranded plastic covered wire has been successfully employed.

THEORY OF OPERATION

The undesired sound energy emitted from the rear surface of the cone **15** of speaker **10** is introduced into the waveguide **18**. A guided pressure wave is then established which impinges on the cone of the transducer **12***a*.

The transducer is a passive device consisting of a permanent magnet speaker whose voice coil is shorted, resembling a generator loaded by its internal impedance.

It has been found that a tube **50** (shown in FIG. 5) formed of low resistance conductive material, such as copper or aluminum, can take the place of the shorted voice coil, to define a coil of a single turn. Such a configuration has greater efficiency in operation and simplicity in construction. The tube **50** is affixed to the cone **12**. Pressure waves force the transducer cone and armature (voice coil) to oscillate at the driving frequencies. Movement of the armature windings through the speaker magnetic field produces electric power which is dissipated as IR losses in the armature windings. The current flow induced in the armature establishes a back electromotive force, which resists the action of the pressure wave on the cone, effectively damping the transducer.

If a high degree of efficiency is maintained during the transfer of acoustic energy to electrical, it is theoretically possible to attenuate the sound pressure wave by 3 db (½). There will be little or no reflection of the sound wave from the transducer since it presents an acoustic match to the waveguide regardless of the frequency or amplitude of the wave.

Since the transducer cone must move in order to function, the attenuated wave is established on the reverse side of the transducer cone. Continuing down the waveguide the pressure wave is attenuated an additional 3 db, as above, by the second transducer (**12***b*). Again continuing down the waveguide, the wave enters the pressure chamber **22**, reflects from the rear panel **30** and absorber **32** which attenuates the wave one or more db. The resulting reflected wave re-enters the waveguide through the rear transducer **12***b*. In passing through this transducer the wave is attenuated another 3 db. At this time the wave is re-established in the waveguide between the transducers. Passing through the forward transducer, the wave is again attenuated 3 db.

It is theoretically possible to dissipate the undesired rear sound pressure wave a total of 13 db (95%). In practical application 10 db (90%) is reasonable to expect from a two transducer system.

It should be noted that the phase of the wave actuating the transducer from either side has no effect on its function. If the waves are out of phase, at the transducer, they will tend to cancel. If they are in phase, they add. In either case, the amplitude of the transducer cone excursions will vary to accommodate the situation resulting in the same reduction of sound energy. Since the transducers are matched (non-reflecting) to the waveguide and phasing does not affect the system, the spacing between the speaker and transducers is irrelevant, assuming sufficient clearance is provided to accommodate physical movement of the cone. Usually ⅜" to ½" clearance should be maintained.

Critical masses within the system's speaker, transducers, waveguide, cabinet, etc., cannot resonate since any vibrating wave is immediately damped by the action of the transducers. This lack of resonances results in a flat speaker impedance characteristic over the entire audio frequency range.

Referring now to FIGS. 3 and 4, there is shown another embodiment of this invention particularly suited for applications wherein the speaker system is to be installed in a cabinet, room wall, or other supporting means.

In this drawing, there is shown a mounting board **38** provided with threaded inserts **40**. Extending into mounting board **38**, there are provided four studs **42** which are screwed into the threaded inserts **40**. A resilient annular gasket **41** is positioned between the mounting board and speaker **10**.

Speakers **10**, **12***a* and **12***b* are mounted on the studs and are spaced apart by cylinders **44** molded of wood chips secured together by sufficient resin to bond the chips into a monolithic structure. Other suitable materials for the cylinders include common building board of the type formed of sugar cane stalk and paper pulp.

The assembly may now be mounted in a suitable pressure chamber.

In summary, the above described electromagnetically damped speaker system has many advantages, such as:

(*a*) *Acoustic*

The system has a very flat audio frequency response since all resonances within the speaker, transducers, cabinet, etc., are effectively damped by the transducers.

Directional and phase and harmonic distortion effects are minimized since the soundwave is emanating from a single point, the front surface of the speaker.

Transients, ringing, hangover and cone breakup of the speaker are virtually eliminated by the damping effect of the transducers.

(*b*) *Electrical*

The speaker presents a relatively constant or flat impedance characteristic over the entire audio frequency range by virtue of its design.

(*c*) *Physical*

The cabinet volume required for a desired performance is significantly less when utilizing this design than when employing prior designs. High quality performance is obtainable in small shelf-type cabinets.

This new and totally different principle of speaker design in which sound energy is converted into electrical energy and as such, simply dissipated, will find many applications in the field of sound reproduction.

There has been disclosed heretofore the best embodiment of the invention presently contemplated and it is to be understood that various changes and modifications may be made by those skilled in the art without departing from the spirit of the invention.

What is claimed is:

1. An audio speaker system comprising:

an enclosure open at one side;

an acoustical waveguide of generally cylindrical configuration, open at each end, said waveguide being rigidly mounted within said enclosure, one open end

of said waveguide facing the said opening of said enclosure;

a directly radiating louspeaker provided with a rimmed diaphragm, said loudspeaker being rigidly mounted within said waveguide and proximate to the opening of said enclosure, the rim of said diaphragm disposed in abutting relation to said waveguide, and at least one transducer disposed within said waveguide proximate to and rearwardly of said loudspeaker, said transducer comprising a rimmed diaphragm disposed transversely in said waveguide, the rim of said diaphragm in abutting relation to and rigidly mounted within said waveguide, said diaphragm adapted to be vibrated by soundwaves from the rear of said loudspeaker;

an armature coil rigidly secured to said diaphragm and adapted to be moved axially by said vibration of said diaphragm; and

a magnetically polarized member rigidly disposed within said waveguide and electromagnetically proximate to said axial movement of said armature coil; whereby said vibrations of said diaphragm cause said armature to be moved axially to and fro in electromagnetic coupling relation with said polarized member to thereby induce a magnetic field about said coil opposing the magnetic field of said polarized member, to thereby dampen the movement of said coil and said diaphragm secured to said coil.

2. A device as in claim **1** wherein said transducer assembly comprises a permanent magnet loudspeaker having a shorted voice coil.

3. A device as in claim **1** wherein said armature coil comprises a tube formed of conductive material, to define a coil of a single turn.

4. A device as in claim **1** wherein said waveguide comprises a hollow cylindrical member formed of bonded cellulose material, said cylindrical member adapted to abut said rim of said loudspeaker at one opening of said cylinder and to abut said rim of said transducer at the other opening of said cylinder, and means to rigidly secure said diaphragm rim and said transducer rim to said cylinder.

5. A device as in claim **3** wherein said means for securing said cylinder to said diaphragm rim and said transducer rim comprise:

a plurality of spaced openings formed on said rim of said speaker, and similar spaced openings formed on said rim of said transducer;

a plurality of longitudinal bores formed in said cylinder in registry with said openings in said loudspeaker and said transducer in the assembled condition;

a plurality of threaded rods passed through said bores and through said openings in said loudspeaker and said transducer; and

nut means to rigidly connect said loudspeaker and said transducer by means of said threaded rods.

6. An audio speaker system comprising:

an enclosure open at one side;

an acoustical waveguide of generally cylindrical configuration open at each end, said waveguide being rigidly mounted within said enclosure, one open end of said waveguide facing the said opening of said enclosure;

a directly radiating loudspeaker provided with a rimmed diaphragm, said loudspeaker being rigidly mounted within said waveguide and proximate to the opening of said enclosure, the rim of said diaphragm disposed in abutting relation to said waveguide;

a first transducer disposed within said waveguide proximate to and rearwardly of said loudspeaker;

a second transducer disposed within said waveguide proximate and rearwardly of said first transducer, each of said transducers comprising a rimmed diaphragm disposed transversely in said waveguide, the rim of said diaphragm in abutting relation to and rigidly mounted within said waveguide, said first diaphragm adapted to be vibrated by sound waves to the rear of said loudspeaker, said second diaphragm adapted to be vibrated by sound waves from the rear of said first transducer;

a first armature coil rigidly secured to said first diaphragm of said first transducer and adapted to be moved axially by the vibration of said first diaphragm;

a second armature coil rigidly secured to the said second diaphragm of said second transducer and adapted to be moved axially by the vibration of said second diaphragm;

a first magnetically polarized member rigidly disposed within said waveguide and electromagnetically proximate to said axial movement of said first armature coil whereby said vibration of said first diaphragm cause said first armature to be moved axially to and fro in electromagnetic coupling relation with said first polarized member to thereby induce a magnetic field about said first armature coil opposing the magnetic field in said first polarized member, to thereby dampen the movement of said first armature coil and said first diaphragm secured to said coil; and

a second magnetically polarized member rigidly disposed within said waveguide and electromagnetically proximate to the axial movement of said second armature coil, whereby said vibration of said second diaphragm causes said second armature to be moved axially to and fro in electromagnetic coupling relation with said second polarized member to thereby induce a magnetic field about said second armature coil opposing the magnetic field in said second polarized member to thereby dampen the movement of said second armature coil and said second diaphragm secured to said second armature coil, whereby said second diaphragm receives a cumulative damping effect, the resultant of the damping of said first transducer plus the damping effect of said second armature coil in electromagnetic coupling with said second magnetically polarized member.

7. A device as in claim **6** wherein said armature coil comprises a tube formed of conductive material, to define a coil of a single turn.

8. A device as in claim **6** wherein said first and second transducer assemblies comprise permanent magnet loudspeakers each having a shorted voice call.

9. A device as in claim **6** wherein said waveguide comprises a hollow cylindrical member formed of bonded cellulose material, said cylindrical member adapted to abut said rim of said loudspeaker diaphragm at one opening of said cylinder and to abut said respective diaphragms of said rims of said respective first and second transducers within said cylinder, and means to rigidly secure said diaphragm rim of said loudspeaker and said respective first and second transducer diaphragm rims to said cylinder.

10. A device as in claim **9** wherein said means for securing said cylinder to said loudspeaker diaphragm rim and said respective first and second transducer diaphragm rims comprise:

a plurality of spaced openings formed on said rim of said speaker diaphragm, and similar spaced openings formed on said respective diaphragm rims of said first and second transducers;

a plurality of longitudinal bores formed in said cylinder in registry with said openings in said diaphragm rims of said loudspeaker and said diaphragm rims of said first and second transducers in the assembled condition;

a plurality of threaded rods passed through said bores and through said openings in said loudspeaker diaphragm rim and said diaphragm rims of said first and second transducers; and

nut means to rigidly connect said loudspeaker dia-

phragm rim and said diaphragm rims of said respective first and second transducers by means of said threaded rods.

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