March 8, 1960 W. F. KNAUERT 2,927,977

ACOUSTIC SIGNAL TRANSDUCERS

Filed Nov. 17, 1958 2 Sheets-Sheet 1

FIG. 1.

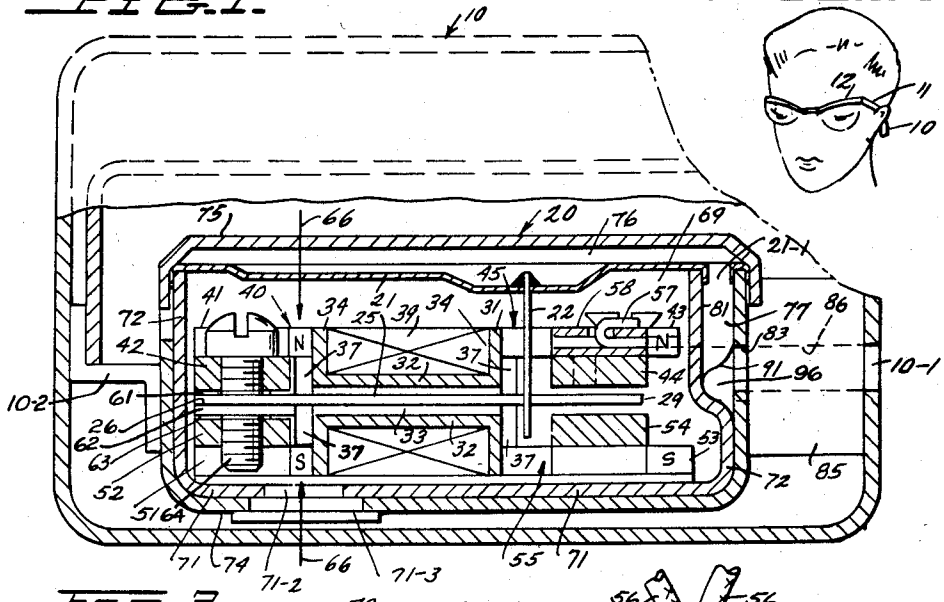


FIG. 1A.

FIG. 3.

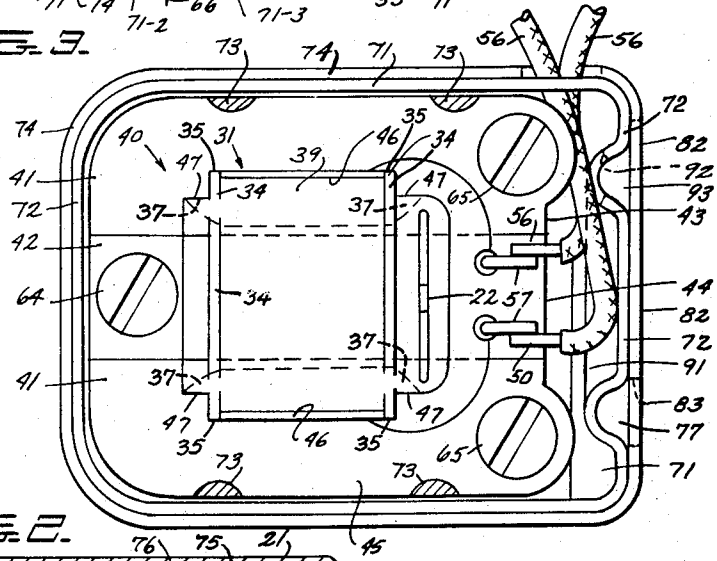
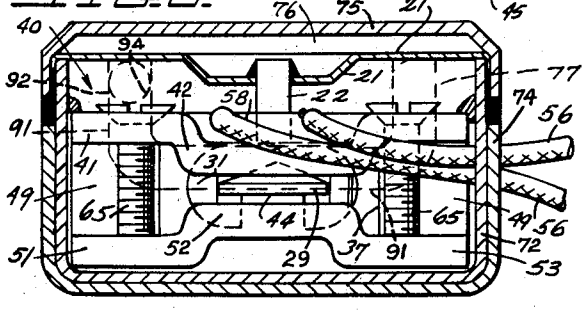


FIG. 2.



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FIG. 5.

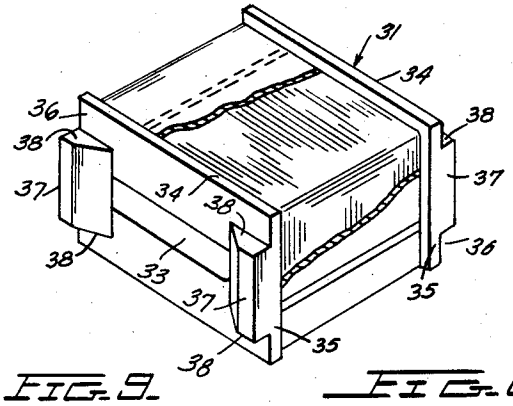


FIG. 5A.

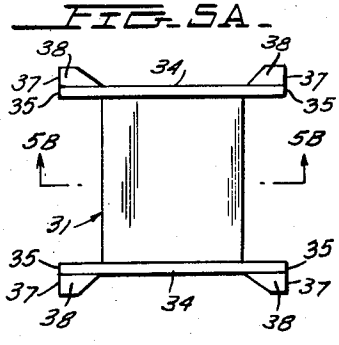


FIG. 9.

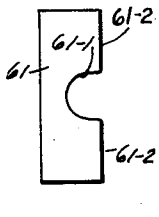


FIG. 6.

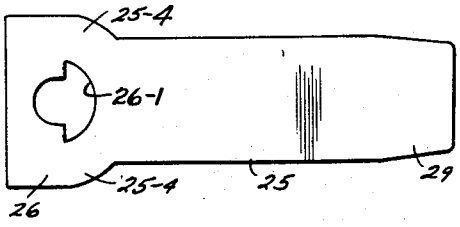


FIG. 5B.

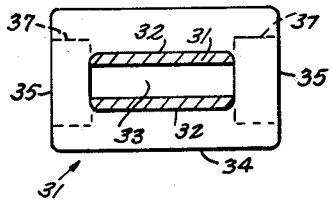


FIG. 7.

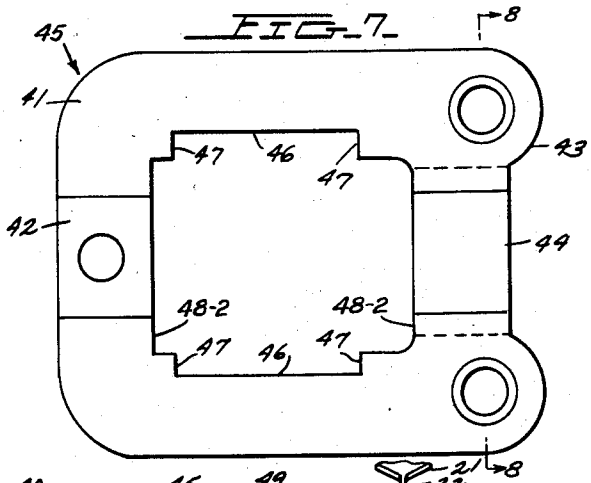


FIG. 8.

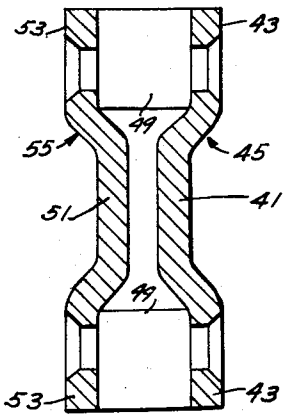
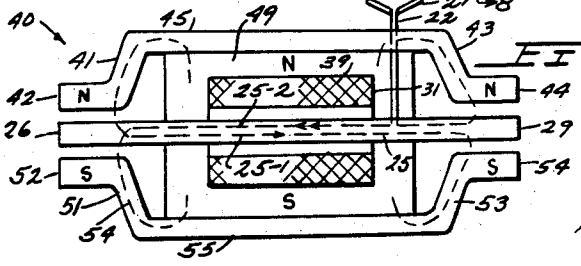


FIG. 4.



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2,927,977

ACOUSTIC SIGNAL TRANSDUCERS

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Application November 17, 1958, Serial No. 774,437

10 Claims. (Cl. 179—115)

This invention relates to acoustic signal transducers of the type described in U.S. Patent 2,432,424, which transduce acoustic signals into electric signals or electric signals into acoustic signals. More particularly, the invention relates to miniature size transducers of this type, the volume dimensions of which should not exceed about 5/16" x 3/8" x 1/2", so as to make it possible to combine two such transducers, one operating as a microphone and the other as a receiver, together with all operating components of a multi-stage transistor-amplifier, into a minute volume fitting into a temple of an eyeglass frame or into a tiny casing fitting behind the outer ear or within the cavity of the outer ear of the user.

In such acoustic signal transducers, an acoustic diaphragm is connected to drive or be driven by a flat ferromagnetic armature or reed which is surrounded by a spool with transducing windings and is arranged to vibrate between one or two pairs of closely-spaced opposite poles of a ferromagnetic core for operation either as a microphone or receiver in transducing vibrations of an acoustically excited diaphragm into corresponding electric signals and vice versa. For efficient operation of such miniature transducers, the tiny flat reed must vibrate within a tiny, flat central spool compartment free from interference by the closely-spaced adjacent compartment walls. Miniature size microphone and receiver transducers of this type suitable for tiny transistor-amplifier hearing aids, present critical operating and space limitations, and they require careful and relatively difficult assembly by specially trained, highly skilled personnel.

Among the objects of the invention are miniature transducers of the foregoing type, embodying features which materially simplify the assembly and assure properly aligned assembly of the tiny transducer components into the composite, efficiently operating transducers, without requiring personnel of unusual skill for their assembly. Among the objects of the invention are also miniature acoustic signal transducers of the foregoing type, which within a given transducer size will provide superior response characteristics.

The foregoing and other objects of the invention will be best understood from the following description of exemplifications theroef, reference being had to the accompanying drawings, showing all parts greatly enlarged, wherein:

Fig. 1 is a cross-sectional view of an acoustic-diaphragm transducer of the invention, shown with some of the adjacent elements of a complete transistor-amplifier hearing aid;

Fig. 1–A is an elevational view of a transistor-amplifier hearing aid as it is worn by the user, with the casing of the hearing aid enclosing two acoustic diaphragm transducers shown in Fig. 1;

Fig. 2 is a transverse cross-sectional view of the transducer of Fig. 1;

Fig. 3 is a top view of the transducer of Fig. 1, with the diaphragm and overlying casing wall removed;

Fig. 4 is a simplified diagrammatic view showing the relationship of the ferromagnetic elements and the windings of the transducer of Figs. 1–3;

Fig. 5 is a perspective view of the spool with the transducer windings of the transducer;

Fig. 6 is a top view of the armature reed of the transducer;

Fig. 5–A is an elevational view of the spool member of the transducer winding;

Fig. 5–B is a cross-sectional view along line 5–B—5–B of Fig. 5–A;

Fig. 7 is a top view of the magnetic core assembly of the transducer;

Fig. 8 is a cross-sectional view along line 8—8 of Fig. 7; and

Fig. 9 is a top view of a spacing shim for the transducer reed.

In Fig. 1 is shown an end view of a complete transistor hearing aid the over-all dimensions of which are small enough to form a rear portion 10 of a temple 11 of an eyeglass frame 12 worn by the user, as seen in Fig. 1–A. The over-all dimensions of the casing 10 of the hearing aid unit are such that its volume may be given a shape so that it fits in its entirety—together with the transistor circuits, battery and volume control—within the concha cavity of the user's ear between the tragus and anti-helix thereof, such as described, for instance, in the pending application of F. A. Hermann, Serial No. 705,841, filed December 30, 1957, and assigned to the assignee of the present application. Within the tiny casing 10 of such complete transistor-amplifier hearing aid are mounted both a microphone-transducer which transduces sound propagated in the surrounding space into corresponding electric signals, and a receiver-transducer which transduces the amplified microphone signals into corresponding sound which is delivered to the ear canal of the user. Both the microphone transducer and the receiver transducer have essentially the same transducer structures, and they will now be described in connection with the acoustic microphone transducer 20 which is shown suspended within the hearing-aid casing 10 in Fig. 1, and also in Figs. 2–4.

The acoustic transducer 20 comprises a vibratory diaphragm 21 which is connected through a drive rod 22 to a vibratory armature or reed 25 of an electromagnetic signal transducer structure having a spool 31 with transducer windings 39 wound thereon, and a cooperating ferromagnetic core structure generally designated 40. The armature reed 25 is of low-retentivity, high-permeability ferromagnetic material, and is shown as being of flat cross-section and extending with its flat surface in a plane perpendicular to the surface of Fig. 1.

The cooperating ferromagnetic core structure 40 comprises one pair of pole arms 41, 51 extending transversely across and spaced from the opposite flat surfaces of the left end portion 26 of the armature reed 25, and another pair of pole arms 43, 53 extending transversely across and spaced from the opposite flat surfaces of the opposite end portion 29 of the armature reed 25. The pole-arm pair 41, 51 has intermediate or central depressed or inwardly offset pole portions 42, 52 of opposite polarity indicated by "N" and "S" signs, with the flat pole surfaces overlying and substantially coextensive with the embraced end surfaces of flat reed end 26 and positioned at a slight spacing on opposite sides thereof so that flat reed end 26 is spaced from the two overlying opposite-polarity pole portions 42, 52 of the ferromagnetic core structure 40. The other pole-arm pair 43, 53 has similar central depressed pole portions 44, 54 of opposite polarity indicated by "N" and "S" signs, with flat pole surfaces overlying and substantially coextensive with the embraced end areas of the other flat reed end 29, and positioned

at a slight air gap spacing on opposite sides thereof so that flat reed end 29 is free to vibrate in the air-gap space between the two overlying opposite-polarity poles 44, 54 of the ferromagnetic core structure 40. The two pairs of pole arms 41, 51 and 43, 53 are shown formed of flat sheet stock of low-retentivity, high-permeability ferromagnetic material, and their respective central poles 42, 52 and 44, 54 are given the desired opposite polarity by permanently magnetized core elements of the magnetic core structure 40. Although each of the two pairs of transverse pole arms 41, 51 and 43, 53 may form a distinct unit, the pole arms 41, 43 form two opposite integral arms of a generally rectangular ferromagnetic pole frame member 45 (Figs. 7 and 8), and the other two pole arms 51 and 53, which are of opposite polarity, form two opposite integral arms of a similarly shaped ferromagnetic pole frame member 55. The two pole frame members 45, 55 form upwardly and downwardly facing opposite frame parts of the magnetic core structure 40, as seen in Figs. 1 and 2.

The desired permanent magnetic polarization and unidirectional field is maintained at the pole pair 42, 52 and the pole pair 44, 54 of the magnetic core, by two elongated permanent magnet members or bars 49 (Figs. 2 and 8) having opposite outer faces held clamped between the overlying inward clamping faces of the two side arms of the opposite pole frame members 45, 55 extending generally parallel to the reed 25, as seen in Figs. 1, 2 and 7, 8, and also in diagrammatic Fig. 4. Each of the two permanent magnet bars 49 are magnetically polarized in a direction perpendicular to the flat surfaces of the overlying pole frame members 45, 55, as indicated by the "N" and "S" signs applied to the core bars 49 in Fig. 1, and in the diagrammatic view of Fig. 4.

The armature reed 25 may be pivotally supported in any known manner at its central region so that when vibrated as a microphone part in opposite directions on its central pivot support, the two opposite reed ends 26, 29 will approach one set of opposite-polarity core poles 42, 54 in one half-cycle of each vibration cycle, and will approach the other set of opposite-polarity core poles 44, 52 in the opposite half-cycle of each vibration cycle. As the two opposite reed ends 26, 29 so approach in opposite vibration half-cycles, opposite-polarity core poles 42, 54 and 44, 52, respectively, the permanently magnetized core 40 will induce in reed 25 oppositely-directed magnetic fluxes, respectively, indicated by single-head arrow 25—1 and double-head arrow 25—2 (Figs. 1, 4) and thereby generate corresponding oscillating electric signal currents in the surrounding transducer windings 39. When operating as a receiver, opposite half-cycles of oscillating current traversing the transducer windings 39 will induce in the reed 25 oppositely directed magnetic polarizing fluxes indicated by the two opposite arrows 25—1, 25—2. As a result, the two alternately polarized reed ends 26, 29 will vibrate between the respective two sets of opposite-polarity core poles 42, 52 and 44, 54, in accordance with their alternating polarization.

In the acoustic transducer shown, one reed end namely reed end 26, is held clamped and fixed by central clamping screw 64 at a magnetic center position between the overlying opposite-polarity poles 42, 52 of the permanently magnetized core, so as to pivotally support the reed 25 for vibration with free reed end 29 in the air gap between opposite-polarity core poles 44, 54 (Figs. 1 and 2). When operating as a microphone, the acoustic diaphragm drive rod 22 vibrates the reed 25 in spool compartment 32, and the free reed end 29 will alternately approach the opposite-polarity core poles 44, 54 and similarly induce oppositely directed magnetic fluxes indicated by opposite arrows 25—1 and 25—2 in successive half-cycles of each complete vibration cycle and thereby generate corresponding oscillating electric signal currents in the surrounding transducer windings. When operating as a receiver, with the clamped reed end 26 held fixed in the magnetic center between the overlying opposite-polarity core poles 42, 52, oscillating currents traversing the transducer windings 39 will induce in the armature reed 25, oppositely directed magnetic polarizing fluxes indicated by the opposite arrows 25—1, 25—2, thereby causing the free reed end 29 to vibrate in the air gap between its associated opposite-polarity core poles 44, 54 in accordance with the sequence of opposite polarizations imparted to the free reed end 29 during each opposite half-cycle of each complete reed vibration cycle.

In the transducer of Fig. 1, the opposite surfaces of the clamped, fixed reed end 26 are held spaced from the two opposite-polarity central pole portions 42, 52 of the core structure 40 by spacers or shims 61, 62, 63 so as to maintain the clamped pivot reed end 26 in the magnetic spacing center between the overlying opposite-polarity core poles 42, 52. When the transducer windings 39 of such transducer are not traversed by any direct current of the transistor-amplifier circuit, the magnetic spacing center coincides with the physical spacing center, and the clamped reed end 26 is held in the physical spacing center between the opposite-polarity core poles 42, 52 by non-magnetic spacer shims of non-magnetic metal, for instance, of the same thickness. When the transducer windings 39 of such transducer amplifier hearing aid are traversed not only by alternating signal currents, but also by a direct-current component of the amplifier circuits, such direct-current component imparts permanent direct-current polarization to clamped reed end 26, thereby shifting the magnetic spacing center to a point other than the physical spacing center between the overlying opposite-polarity core poles 42, 52. In order to maintain the clamped reed end 26 clamped in the true magnetic spacing center position between its overlying opposite-polarity core poles 42, 52, the clamped reed end 26 is shown held spaced from core pole 52 by a non-magnetic spacer shim 62 and a magnetic spacer shim 63, and the opposite side of the clamped reed end 26 is held spaced from the opposite-polarity core pole 42 by a non-magnetic spacer shim 61 of non-magnetic material the thickness of which is chosen to assure that the clamped reed end 26, which is additionally polarized by direct current through the transducer coil 39, is held clamped and retained in a true magnetic spacing center between the opposite-polarity core poles 42, 52.

As indicated in Fig. 1, clamping screw 64 has a head overlying the outer surface of the depressed central core pole portion 42 of core arm 41, and it has a threaded rod or shank which passes through corresponding aligned openings of core pole 42, reed end 26 and spacing shims 61, 62, 63, and the threaded opening in similarly depressed, central core pole portion 52 provides for proper, positive mounting and clamping engagement of the clamped reed end 26 at the proper magnetic center position between the core poles 42, 52. The other screws 65 passing through holes in opposite end portions of the other pairs of pole arms 43 and 53 of the two core frame members 45, 46, respectively, complete the clamping connections between the two pole frames 45, 55 across the two elongated permanent magnet bars 49 and join them into a relatively rigid unitary, self-supporting magnetic core structure 40.

The elongated spool member or spool 31 of the transducer windings 39 (Figs. 1–3 and detail Figs. 5 to 5–B) has a flat cross-section corresponding to the cross-section of the reed 25 which it surrounds. The spool 31 has two flat spool walls 32 enclosing between them a flat central spool compartment 33 within which the major part of the reed 25 is positioned for vibratory motion in the spool compartment 33 in a direction transverse or perpendicular to the major surface of the reed and the spool walls 32. The spool 31 has two end walls 34 of a height corresponding to the height of the surrounding core structure 40, and side edges 35 which have fitting engagement with inward side edges 46 of the two pole frame members

45, 55. Referring to Figs. 1–3 and detail Figs. 7, 8, the two generally rectangular core frame members 45, 55 are identical in shape and in every other respect, and along its inward edge each core frame member 45, 55 has inward side-arm edges 46, four corners with corner edges 47, and two cross-arm edges 48—1, 48—2, which surround the frame space within which the spool 31 with its transducer windings are positioned. The distance between the opposite inward side-arm edges 46 of each pole frame member 45, 55 corresponds to the distance between the side edges 35 of the spool end walls 34, so as to receive with an aligning fit the lateral edges 35 of the spool end walls 34 and positively fix the transverse operating central position of the spool 31 between the side arms of the pole frame members 45, 55. The distance between the facing frame corner edges 47 which extend perpendicularly to the side frame edges 46, corresponds to the longitudinal distance between the outer surfaces 36 of the spool end walls 34 so as to receive with an aligning fit and positively locate the end surfaces 36 of the spool end walls 34 and positively locate the longitudinal operative position of the spool 31.

In miniature acoustic signal transducers of the present invention, where space limits are critical, the distance between the spool compartment walls 32 (Fig. 5–B) which define the operative compartment height across which the armature reed 25 vibrates, must be kept to a minimum. Thus, in a miniature transducer operating with a magnetic armature reed having a thickness of .010", it is desirable to keep the height of the spool compartment 33 or the distance between its flat walls 32 to a minimum at which their inwardly facing surfaces will remain free from the slightest interference with the freely vibrating portions of reed 25 held between them. As an example, in the specific transducer shown, it is desirable to keep the distance between the facing spool walls 32 at about .026"±.001". The minute dimension tolerance of .001" in the height dimension of such spool is needed for enabling production of such spools on a practical basis, as by molding with a resin, without prohibitive shrinkage losses.

In assembling the components of such miniature transducer, critical problems are encountered in the proper positioning of the spool 31 in relation to the core 40, for assuring that the spool compartment walls 32 are at the proper critical distance from the opposite surfaces of the vibratory reed 25. Even with skilled operators, excessive production shrinkage is caused by failures in the required accurate positioning of the spool 31 with respect to the magnetic core 40, that would eliminate interference with the free reed vibrations in the assembled transducer, and avoid prohibitive shrinkage losses.

In accordance with the present invention, the critical difficulties encountered in the accurate positioning of the spool compartment walls 32 relatively to the major surfaces of the vibratory reed 25 when assembling such miniature transducers, are substantially overcome by providing the spool end walls 34 at a plurality of peripherally spaced regions thereof with outwardly extending aligning projections or members of a height corresponding exactly to the operative spacing of the two opposite pole frame members 45, 55, and arranged for aligning engagement with peripherally displaced portions of the assembled core frame members 45, 55. Since the spacing of the two pole frame members 45, 55 defines the spacing of their two sets of opposite-polarity pole pairs 42, 52 and 44, 54 and the magnetically centered operative position of the reed 25, such peripherally displaced aligning projections of the spool 31 makes it possible to assure that in the assembly of the transducer components, the two spool compartment walls 32 are automatically positioned in the required critical spacing relation relatively to the vibratory reed 25 extending therethrough.

Referring to Figs. 1–3, and detail Figs. 5–5–B, each spool end wall 34 is provided along its outward end wall surface 36 with two spaced outwardly projecting spool aligning shoulders or projections 37 extending parallel to the direction of the vibratory motion of the reed 25. Each of the four spool aligning projections 37 has a pair of accurately positioned transverse spool aligning surfaces 38 which define the height at which the assembled core pole frames 45, 55 are engaged by them so as to assure that they are placed in the accurate operative position wherein the central spool compartment walls 32 remain free from interfering engagement with the vibratory reed 25 passing therethrough. The spacing of each pair of spool aligning surfaces 38 is identical with the spacing of the facing upper and lower surfaces of the permanent magnet core bars 49 (as seen in Figs. 1 and 3) which are held clamped between the two core frame members 45, 55. The four aligning projections 37 of the spool 31 are located at four peripherally displaced outward portions of the spool structure 31, thereby assuring that the four aligning shoulders 37 will engage four peripherally displaced cooperating aligning surfaces at the four corners of each of the two outer core pole frames 45, 55, and enable accurate aligned positioning and assembly of the core elements 45, 55, 49, the spool 31 and the reed 25 into the composite, operative transducer unit 40 shown. By providing the tiny spool 31 with the four peripherally displaced aligning shoulders 37 along the outward surfaces of the spool end walls 34, the assembly and accurate positioning of the spool with the other elements of the composite transducer structure is thus greatly simplified. By way of example, such assembly may be performed as follows:

In a suitable jig, there is first positioned the lower core pole frame 55. After placing on the transverse core pole 52 the proper lower spacing shim or shims, such as spacing shims 62, 63, the reed 25 with the spool 31 and the transducer winding 39 previously positioned over the reed, are dropped into the jig which aligns them in their proper positions with the spool end walls 34 fitting between the two inward side edges 46 and the four corner edges 47 of the lower core frame member 55. This brings the four downward spool aligning surfaces 38 of the spool 31 (as seen in Figs. 1, 2, 5) in aligning contact engagement with four peripherally spaced aligning corners 47 of the lower pole frame 55. Thereupon the upper shim, such as shim 61, is placed over the to-be clamped reed end 26 and the two permanent magnet cores 49 are placed along the side arms of the lower pole frame member 55 within the assembly jig. Thereafter, the upper pole frame member 45 is placed in the jig wherein it is automatically aligned over the component assembly, in which position the inwardly facing surfaces of the four inner corners 47 of the upper frame 45 automatically come into aligning engagement with the peripherally displaced upwardly facing spool aligning surfaces 38 of the four spool aligning projections 37, thereby automatically assuring that the spool 31 with its closely spaced compartment walls 32 will be properly aligned with respect to the two core pole frame members 45, 55 and therethrough with respect to the vibratory transducer reed 25. The assembly is completed by screwing in position the three clamping screws 64, 65 which join the assembly into the operative transducer unit.

The outwardly extending aligning spool projections 37 do not increase the over-all dimensions of the transducer assembly because the spool-aligning projections 37 merely occupy space available at the four inner corner regions of the generally rectangular core assembly 40 of the transducer. The aligning spool projections 37 also make it possible to provide the spool body 31 around which the transducer windings are wound, with the required rigidity while reducing to a minimum the lateral space occupied by the walls of the spool compartment 33, as seen in Figs. 1–5 and 5–B. The reduction of the lateral space occupied by the walls of the spool compartment 33 of the winding spool 31 is secured by eliminating the

side walls of the spool compartment and utilizing as winding support only the two flat spool compartment walls 32 bordering the upper and lower sides of the minute spool compartment 33, as seen in Figs. 1–5 and 5–B. The required additional rigidity that would be supplied by compartment side walls, is provided by the four aligning projections 37 which serve as four reinforcing members extending transversely to the two spool compartment side walls 32 and give them the rigidity required for providing the proper support for the transducer windings, 39 and assure that the two spool compartment walls 32 are not deformed under strain and are maintained at the correct spacing of the spool compartment 33 free of interfering engagement with vibrating portions of the armature reed 25.

In mainiature transducers of the foregoing type, it is desirable to utilize highly permeable ferromagnetic material, for instance the material known as "Hymu 80," for the resilient, vibratory reed 25. The limitations on the minimum required cross-section and on the length of the vibratory reed 25, make it difficult to obtain a reed of such highly permeable magnetic material which will operate with the compliance required for optimum transducer sensitivity. In accordance with the invention, the vibratory ferromagnetic reed is given the desired greater compliance within the required minimum length and thickness dimensions, by arranging the clamping connection of the clamped reed end 26 in such manner as to permit free vibration of a part of the clamped reed end 26 which would normally be held clamped and restrained against vibration. The novel arrangement of the clamped reed end 26 which increases the free vibrating length of the reed, while assuring that the clamped reed end is properly maintained in its clamped operative position, will now be described (Figs. 1, 2, 6 and 9).

In the accepted prior-art practice, the spacing shims 61, 62, 63 with which the reed was held clamped between the facing pole portions 42, 52 of the two pole frames 45, 55, normally extended over the entire area of the reed end 26, which is embraced by the two pole portions 42, 52, of core frames 45, 55. In accordance with the invention of Harry A. Pearson, assigned to the assignee of the present application, the dimensions of the spacing shims, and particularly of the non-magnetic shims 61, 62 overlying the clamped reed end 26, are limited along the longitudinal direction of the reed 25 only up to at most three-quarters of the reed area embraced by the core poles 42, 52. In the arrangement shown, the two spacer shims 61, 62 have the shape shown in Fig. 9. Each shim, such as shim 61, has two arms extending from its outer edge along both sides of the fastening member or clamping screw or rod 64 to the inward edge of the screw opening 61—2 through which the clamping screw 64 passes. The so-formed shims 61, 62 of the clamped reed end 26 confine the clamping engagement to the outward edge region of the clamped reed end and two rear portions of the adjoining reed mounting portion embracing the clamping screw 64 which are in clamping engagement with the inner edge 61—2 of the adjacent overlyng spacing shims 61, 62. In addition, the part of the clamped reed end 26 with the reed opening 26—1 (Fig. 6) through which the screw 64 extends, is enlarged in the adjoining inward reed region extending beyond the overlying inner spacer shim edges 61—2, thereby providing the free inward reed portions adjoining the clamped reed end 26 with two flexible resilient reed junction arms 25—4 having a raidal dimension shorter than the radial dimension of the adjoining reed portions which are held clamped between the shims 61, 62. This makes it possible to give the reed 25 the desired greater compliance and secure operation thereof with the desired resonant mode at which the acoustic transducer will operate with desired overall response.

Circuit connections from the coil winding 39 to cooperating exterior surfaces may be provided in any conventional way. When used as a part of a compact hearing-aid, the connections to the windings 39 are provided by two flexible wire conductor leads 56 which are covered by an insulating coating layer and pass through an opening in a rim side wall of transducer casing 71, with the opening being sealed as by cement so as to retain therein the conductors 56 and keep the lead opening sealed. The internal ends of the two insulated conductor leads 56 are stripped of their insulation and are electrically affixed, as by solder, to two spaced metallic transducer terminals 57, to which the transducer windings 39 are connected. The transducer terminals 57 are mounted on an underlying terminal support which is mounted on the transducer unit 40. The insulating support for the transducer terminals 57 may be formed of overlapping layers of insulating sheet material, for instance resin-impregnated cloth, holding between them one leg of two tiny U-shaped terminals 57, leaving one terminal leg 57 exposed for connection to the stripped conductor lead ends 56.

Miniature acoustic transducers of the type described herein, usually also have a casing or cup 71 of suitable metal, for instance, brass or aluminum, within which the transducer assembly is mounted. The transducer structure is suitably affixed to the casing 71, for instance, as by placing four drops 73 of cement along spaced peripheral regions of the upwardly facing core frame member 45 where it adjoins the casing side walls 72 (Fig. 3). The casing 71 has side walls or a rim 72 with a rim edge to which the edge of diaphragm 21 is secured, as by cement. The casing 71 may be of magnetic shield material, where it is desired to magnetically shield the electromagnetic elements of the transducer against magnetic interlinkage with disturbing magnetic fields of another similar transducer, for instance, for suppressing magnetic feedback interlinkage between the electromagnetic elements of a microphone transducer and receiver transducer forming parts of a transistor hearing aid. The casing 71 may be made of a non-magnetic metal, and where a shield enclosure is desired, an outer magnetic shield casing or cup 74 is placed in contact with and over the interior housing cup 71. A cover wall 75 of metal, overlying the exterior side of the vibratory diaphragm 21, has a rim which is joined, as by cement, to the casing 72. Acoustic excitation of the diaphragm 21 or delivery of generated sound, may be obtained by providing the casing cover 75 with one or more acoustic openings.

After the internal transducer unit 40 is assembled in the casing 71 and before the diaphragm 21 is affixed thereto and to the casing, the operative position of the vibratory reed 25 is checked to assure that it is in the magnetic center beween he adjacent poles 42, 52 of the core structure. Although proper choice of the magnetic shim in relation to the magnitude of the direct-current traversing the coil windings 39 will secure proper magnetic centering of the mounting end 26 of the armature reed, additional minute adjustment of the reed position is desirable to assure optimum operation of the transducer. Such minute adjustment of the reed 25 may be effected by applying to the upper or the lower side of the reed 25, as seen in Fig. 1, the tip of a bending pin or rod for giving it a minute permanent bend in one or the other direction to bring the reed 25 to its optimum operating position. The optimum operating position may be checked by connecting the transducer windings to an instrument, for instance an oscilloscope, and observing the response of the transducer unit 40 over a critical frequency range thereof. In the transducer shown, such setting tool may be applied to the portion of the reed 25 which is exposed in the transducer unit 40 between the inward edge of the core-pole pair 42, 52 and the adjacent spool end walls 34, as seen to the left in Figs. 1 and 3, the tool being applied in the direction of one of the arrows 66. In order to make it possible for such setting tool to be applied to the reed in the direction of arrows 66 while assembled in casing 71, this casing and also the

shielding casing 74, if used, are provided with an opening 71—2, thereby exposing at the opening 71—2 the downward facing side of reed 25 to the tool for giving it the final adjustment setting. After the setting of the reed is completed, the opening 71—2 may be closed as by applying thereto, as with cement, a cover plate 71—3.

The acoustic transducer 20, which may be a microphone, is shown suspended in the interior of the hearing-aid casing 10 so as to suppress transmission of vibrations between the transducer 20 and the outer casing 10 and the other similarly suspended acoustic transducer, such as the receiver mounted in the hearing-aid casing 10. Such vibration-suppressing suspension may be provided by generally Z-shaped suspension members 10—2 of vibration-damping sheet material, such as elastomer material, having opposite end tongue portions secured to the outer surface portions of the transducer casing 71 and the hearing-aid casing 10, respectively, in which it is carried.

The acoustic responses of a transducer of the type described above, are controlled by the acoustic characteristics of the interior transducer compartment 69 bounded by the inner side of diaphragm 21 and casing 71, and of the outer diaphragm compartment 76 bounded by the outer side of diaphragm 21 and the outer casing cover 75. In the transducer shown, the acoustic connection from the outer diaphragm compartment 76 to the exterior space (in the case of a microphone) or to the ear canal (in the case of a receiver), is provided by a sound channel or passage 77 extending along the casing rim wall 72 of the casing 71. In accordance with the invention, the side rim wall 72 of casing 71 is formed with an inwardly recessed channel-shaped wall portion 81 extending from the level of the diaphragm 21 to an inward wall level, and a cover wall 82 is affixed, as by cement or solder, to the recessed channel-shaped wall portion 81 of casing rim 72 to form the desired sound channel 77 between the outer diaphragm compartment 76 and the exterior space. A cover wall opening 83 connects the sound channel 77 to the exterior space. The vibratory diaphragm 21 overlying the upper end of the sound channel 77 (as seen in Fig. 1) has an opening 21—1 through which the channel passage 77 is connected to the diaphragm front compartment 76, thereby completing an acoustic connection from the exterior space to the outer diaphragm compartment space 76. In the case of a hearing aid, the channel opening 83 of the sound channel 77 is suitably connected either to the exterior space when operating as a microphone for exciting the diaphragm by exterior sound, or to the ear canal of the user for delivering or propagating the sound generated in the front diaphragm compartment 76 to the ear canal of the user. In Fig. 1, the transducer is shown operating as a microphone which is excited by sound propagated from the exterior space through sound channel 77.

The sound channel opening 83 of the sound passage 77 is connected to a casing opening 10—1 of the hearing-aid casing through a coupling channel 85 (Fig. 1) for the transmission of sound propagated in the surrounding space through casing opening 10—1, sound passage 86 of coupling channel 85, sound channel opening 83, and through sound channel 77, into the outer diaphragm compartment 76 for exciting the diaphragm 21 and cause it to generate corresponding signals in the transducer windings 39. The coupling channel 85 may be made of elastomer material, and has one end surface sealingly engaging the surface of the casing 10 surrounding casing opening 10—1. The opposite end surface of coupling channel 85 sealingly engages the facing opening 83 of sound-passage 77 of casing rim 72.

The acoustic passage 73 formed by the recessed casing wall portion 81 through which the outer transducer diaphragm compartment 76 is connected to the exterior space, is dimensioned so that it provides an acoustic mass impedance which lowers the resonant frequency of the transducer and thereby enhances the response of the receiver over the lower frequency range. Thus, in the specific form of transducer shown, the acoustic passage connection 77 from the outer diaphragm compartment 76 to the exterior space is dimensioned to provide an acoustic mass impedance which lowers the resonant frequency of the transducer system from about 2000 c.p.s. (cycles per second) to 1400 c.p.s., or in general, to a resonant frequency in the range between 1300 c.p.s. and 1500 c.p.s. Such acoustic passage connection to the exterior space may be readily designed, as by restricting its cross-section over a specified length thereof, for raising its acoustic resistance and thereby damp the peaked transducer response at its resonant frequency.

By forming the acoustic passage connection from the outer diaphragm compartment to the exterior space with a recessed casing wall channel of the transducer casing rim, the sound connection to the surrounding space is provided along a side wall or rim of the transducer casing. Such acoustic connection along the relatively short side wall of the transducer casing eliminates the problems encountered in miniature all-in-one hearing aids when making an acoustic connection to the diaphragm compartment openings of an acoustic transducer through an opening in a casing such as casing wall 75 overlying the diaphragm 21.

In accordance with a phase of the invention, such inwardly recessed channel-shaped wall portion of the transducer casing, such as transducer casing 71, is utilized in conjunction with an outer cover portion such as cover wall 82 to provide a sound passage of predetermined acoustic characteristics through which one of the transducer compartments is connected either to the exterior space or to another transducer compartment and thereby modify or control the acoustic response of the transducer over a predetermined frequency range. In addition, such acoustic channel passage or restricted cross-section may be used, for instance, in the manner described in Knauert Patent 2,820,107, for raising the frequency response of a microphone between 200 and 600 c.p.s. In the transducer, shown, the inner transducer compartment 69 has connected thereto a restricted sound passage of predetermined impedance which forms with the space of the interior transducer compartment an acoustic system.

There will now be described one manner in which an acoustic passage channel formed by an inwardly-recessed, channel-shaped wall portion of transducer casing 71, is utilized for similarly raising the frequency response of a microphone in the low-frequency range, for instance between 400 and 600 c.p.s., or in general, between 200 and 600 c.p.s.

In the transducer shown, the recessed portion of rim side wall 72 of the transducer which forms with casing cover wall 82 the recessed sound channel 77, has further recessed channel wall portions 91 and 92 which form with casing cover wall 82 an additional sound passage 93 which contacts sound channel 77 to the interior transducer compartment 69. The recessed wall portion 92 of the additional acoustic channel or passage 93 has an acoustic opening 94 below the level of the diaphragm 21, through which the space of additional sound passage 96 is acoustically connected to the inner transducer compartment 69. The acoustic impedance of the additional channel passage 93 and its opening connecttion 94 to the inner transducer compartment 69, is designed to have a predetermined impedance which will form in conjunction with the acoustic space of the inner transducer compartment 69 an acoustic system which resonates, for instance, at 400 or 500 c.p.s. (cycles per second), for thereby raising the frequency response of the microphone in this frequency range, in a manner similar to that explained in the referred-to Knauert patent. In a similar way, other wall portions of the transducer casing 71 may be provided with recessed channels for forming acoustic passages connected to an acoustic compartment of the transducer for modifying or

controlling the response of the transducer in a selected part of its frequency range.

The cover wall **82** which forms with the recessed channel-shaped portions of casing rim wall **72**, the sound channels **77** and **93**, described above, may be of a dimension just sufficient to slightly overlap the width of the passage, the cover wall portion **82** being secured to the underlying wall portion of the casing rim wall **72**, as by cement or solder. In the arrangement shown, a single cover wall member **82** is secured to the recessed channel-shaped wall portions **81**, **92**, of the casing side wall, for forming therewith the two sound passages **77** and **93**. Where the microphone casing **71** is provided with a magnetic shield, cover wall **82** may be formed of ferromagnetic high-permeability material and may form part of the magnetic shiled **74** seated over the inner casing wall **81** and forming a magnetic shield enclosure around it.

By way of example, there are given below, construction data of a practical embodiment of the invention in the form of a miniature microphone transducer of a hearing aid:

Reed.—HYMU 80 magnetic material; .010″ thick; .300″ long; .100″ wide, with mounting end .135″ wide. Diameter of reed opening .021″ to .047″; width of two reed arms beyond reed opening .037″ to .050″ depending on desired response.

Cut-off spacer shim for reed.—Brass; thickness either 0.002″; 0.003″; 0.0035″; 0.004″, depending on desired response. Distance from opening center to rear edge, .040″, and to shorter front edge .010″.

Permanent magnet cores.—Alnico 2; .330″ long; .070″ in height; .067″ width.

Pole arm frames.—Alloy of 50% N, 50% Fe; .025″ thickness; .080″ pole arm width; .055″ side arm width; .215″ spacing of inner side arm edges; .218″ spacing of inner pole arm edges.

Spool.—Nylon; .150″ total length; .009″ thickness; .115″ height; .188″ width of reed compartment; .009″ thickness of compartment side walls; .026″ height and .118″ width of reed compartment; .009″ thickness of compartment side walls.

Spool-aligning projections.—.070″ height transverse to reed; .016″ projection length and end area width.

Main casing.—.008″ wall thickness; .170″ inside height; .436″ by .336″ inside area; .021″ channel-recess depth, and .042″ channel recess width.

Aluminum foil diaphragm.—.0005″ foil thickness of receiver; .0007″ thickness of microphone.

The claims in the present application are directed to a miniature-size acoustic transducer device wherein the sound outlet from the diaphragm compartment is formed by a channel recess along the short side wall of the transducer casing instead of along the wide casing wall overlying the diaphragm. Other features of the invention disclosed herein constitute the subject-matter of the co-pending applications, Serial No. 774,438, filed on November 17, 1958, by W. F. Knauert, and Serial No. 774,439, filed November 17, 1958, by Harry A. Pearson, and assigned to the assignee of the present application.

It will be apparent to those skilled in the art that the novel principles of the invention disclosed herein in connection with specific exemplifications thereof will suggest various other modifications and applications of the same. It is accordingly desired that in construing the breadth of the appended claims, they shall not be limited to the specific exemplifications of the invention described above.

I claim:

1. In an electromagnetic acoustic transducer device for transducing electric signals into acoustic signals or vice versa, a ferromagnetic armature arranged to vibrate transversely to a major dimension thereof, a cooperating ferromagnetic core structure extending adjacent said armature and forming therewith at least one ferromagnetic core loop carrying a magnetic flux which fluctuates in accordance with the armature vibrations, transducer windings interlinked with the core loop and responsive to the flux fluctuations thereof for transducing vibratory motion of the armature into corresponding electric signals passing through the windings and vice versa, a vibratory diaphragm having an intermediate portion connected to said armature for transmitting vibrations therebetween, an inner casing section having a rim wall surrounding an inner casing compartment, the peripheral region of said diaphragm being joined to said rim wall for enclosing said armature said core structure and said windings in said inner compartment, an outer casing section overlying the outer side of said diaphragm and forming with it a front compartment, said rim wall having an inwardly recessed channel-shaped wall portion extending from the level of said diaphragm to an inward level of said rim wall spaced from said diaphragm, a cover wall overlying and affixed to said channel-shaped wall portion and forming therewith a sound channel extending from said diaphragm to said inward level, said cover wall having in the region of said inward level, a cover opening acoustically connecting said channel to the exterior space, said diaphragm having a diaphragm opening through which said front compartment is acoustically connected to said sound channel and therethrough to the exterior space for propagation of sound between said front compartment and the exterior space.

2. In a transducer device as claimed in claim 1, said rim wall having a further recessed channel-shaped rim wall portion extending from the region of said cover opening to a further rim wall portion peripherally displaced from the cover-opening region, a further cover-wall portion overlying and affixed to said further channel-shaped rim wall portion and forming therewith a further sound channel extending from the region of said cover opening to said further rim wall portion, said further rim wall portion having a rim opening acoustically joining said further sound channel and said interior compartment into an acoustic system which resonates within a selected frequency range between 200 and 600 cycles per second for raising the response of said transducer device over a region of said selected frequency range.

3. In a transducer device as claimed in claim 2, said cover walls being formed of ferromagnetic high-permeability material and being part of a shield enclosure enclosing at least said inner casing section for suppressing magnetic interlinkage between the ferromagnetic core elements and windings of the transducer device with external magnetic flux.

4. A transducer device as claimed in claim 1, said cover walls being formed of ferromagnetic high-permeability material and being part of a shield enclosure enclosing at least said inner casing section for suppressing magnetic interlinkage between the ferromagnetic core elements and windings of the transducer device with external magnetic flux.

5. In an electromagnetic acoustic transducer device, an elongated flat ferromagnetic reed armature arranged to vibrate transversely to its length between two opposite end positions and having two armature ends, a hollow spool member having an elongated interior space in which the major length of said armature is held for vibration therein in a direction transverse to its length, transducing windings surrounding and held by said spool member, a ferromagnetic core structure comprising two elongated core bodies extending parallel along opposite sides and confining between them said spool member and one pair of ferromagnetic pole-arms extending transversely to and on opposite sides of each of the two flat armature ends between said two elongated core members and forming therewith two substantially closed ferromagnetic core return paths of opposite polarity in the opposite end positions of said armature and thereby causing vibratory motion of said armature to generate corresponding electric oscillations in said windings and vice

versa, a vibratory diaphragm having an intermediate portion connected to said armature for transmitting vibrations therebetween, an inner casing section having a rim wall surrounding an inner casing compartment, the peripheral region of said diaphragm being joined to said rim wall for enclosing said armature said core structure and said windings in said inner compartment, an outer casing section overlying the outer side of said diaphragm and forming with it a front compartment, said rim wall having an inwardly recessed channel-shaped wall portion extending from the level of said diaphragm to an inward level spaced from said diaphragm, a cover wall overlying and affixed to said channel-shaped wall portion and forming therewith a sound chanel extending from said diaphragm to said inward level, said cover wall having in the region of said inward level a cover opening acoustically connecting said channel to the exterior space, said diaphragm having a diaphragm opening through which said front compartment is acoustically connected to said sound channel and therethrough to the exterior space for propagation of sound between said front compartment and the exterior space.

6. In a transducer device as claimed in claim 5, said rim wall having a further recessed channel-shaped rim wall portion extending from the region of said cover opening to a further rim wall portion peripherally displaced from the cover-opening region, a further cover wall portion overlying and affixed to said further channel-shaped rim wall portion and forming therewith a further sound channel extending from the region of said cover opening to said further rim wall portion, said further rim wall portion having a rim opening acoustically joining said further sound channel and said interior compartment into an acoustic system which resonates within a selected frequency range between 200 and 600 cycles per second for raising the response of said transducer device over a region of said selected frequency range.

7. In a transducer device as claimed in claim 6, said cover walls being formed of ferromagnetic high-permeability material and being part of a shield enclosure enclosing at least said inner casing section for suppressing magnetic interlinkage between the ferromagnetic core elements and windings of the transducer device with external magnetic flux.

8. In a transducer device as claimed in claim 5, said cover walls being formed of ferromagnetic high-permeability material and being part of a shield enclosure enclosing at least said inner casing section for suppressing magnetic interlinkage between the ferromagnetic core elements and windings of the transducer device with external magnetic flux.

9. In an electromagnetic acoustic transducer device for transducing electric signals into acoustic signals or vice versa, a ferromagnetic armature arranged to vibrate transversely to a major dimension thereof, a cooperating ferromagnetic core structure extending adjacent said armature and forming therewith at least one ferromagnetic core loop carrying a magnetic flux which fluctuates in accordance with the armature vibrations, transducer windings interlinked with the core loop and responsive to the flux fluctuations thereof for transducing vibratory motion of the armature into corresponding electric signals passing through the windings and vice versa, a vibratory diaphragm having an intermediate portion connected to said armature for transmitting vibrations therebetween, an inner casing section having a rim wall surrounding an inner casing compartment, the peripheral region of said diaphragm being joined to said rim wall for enclosing said armature, said core structure and said windings in said inner compartment, an outer casing section overlying the outer side of said diaphragm and forming with it a front compartment, a casing wall of said inner casing section having an inwardly recessed channel-shaped wall portion of restricted transverse dimensions, a cover wall overlying and affixed to said channel-shaped wall portion and forming therewith a sound channel, the length of said sound channel being at least about five times the average transverse dimension of said channel, a certain small wall portion of a wall bounding said channel having one channel opening acoustically coupling the space of said channel to the space of one of said compartments.

10. In a transducer device as claimed in claim 9, a further wall portion of a wall bounding said channel which is at a substantial distance from said one channel opening having a further opening through which an acoustic space exterior to said one compartment is acoustically coupled by way of said channel to said one compartment.

No references cited.