United States Patent

[11] 3,617,653

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Joseph A. Sawyer, both of Camden, Maine

[21] Appl. No. 7,370
[22] Filed Feb. 2, 1970
[45] Patented Nov. 2, 1971

[73] Assignee Tibbetts Industries, Inc.
Camden, N.J.

Continuation of application Ser. No. 638,878, May 16, 1967, now abandoned.

[54] **MAGNETIC REED TYPE ACOUSTIC TRANSDUCER WITH IMPROVED ARMATURE**

18 Claims, 36 Drawing Figs.

[52] U.S. Cl. ..... 179/114 A
[51] Int. Cl. H04r 11/00
[50] Field of Search ..... 179/114 R, 115 R, 117, 119 R; 335/231

[56] References Cited

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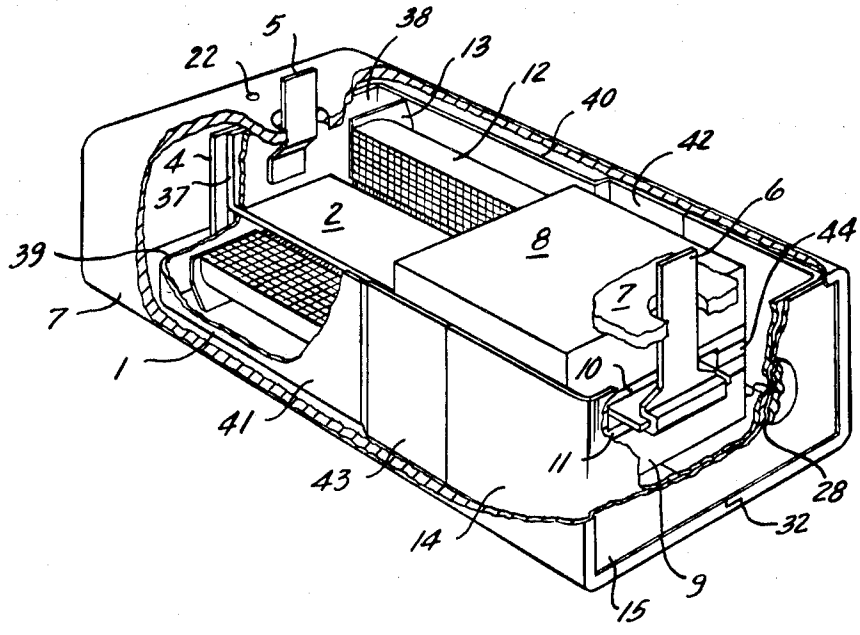
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Primary Examiner—Kathleen H. Claffy
Assistant Examiner—Thomas L. Kundert
Attorney—Kenway, Jenney & Hildreth

ABSTRACT: A miniaturized electromechanical transducer has a casing of high magnetic permeability material, magnets within the casing providing polarizing flux across a working gap, an electrical signal coil, and an armature of particular configuration. The armature has a substantially straight leg portion compliant in flexure and extending from the working gap through the coil to a crosspiece portion connected to another portion of the armature attached to the casing, whereby the position of the armature leg in the working gap may be adjusted by twisting inelastically the crosspiece portion.



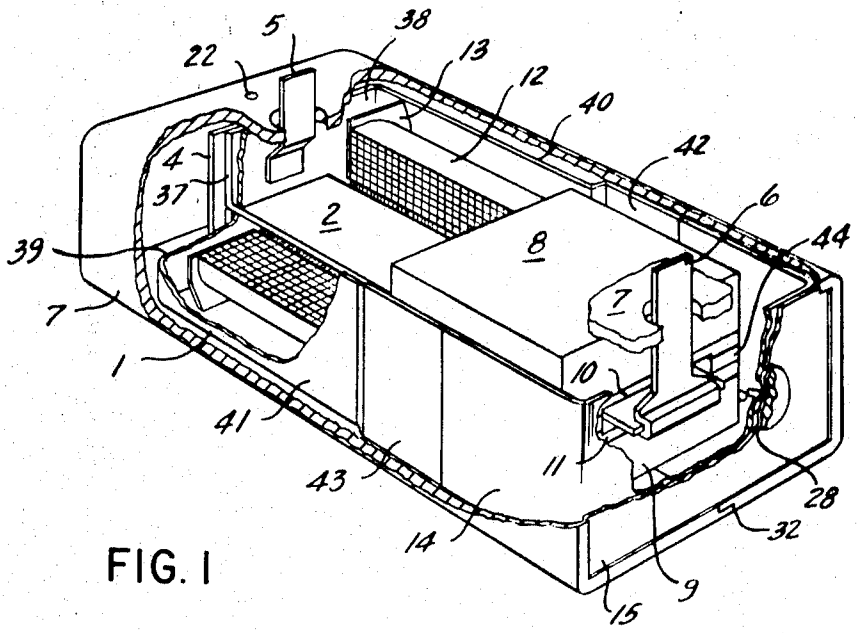

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FIG. 1

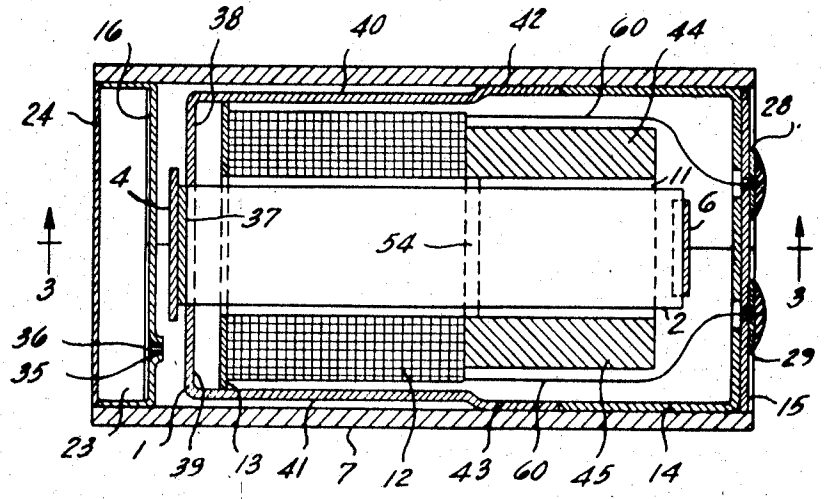

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FIG. 2

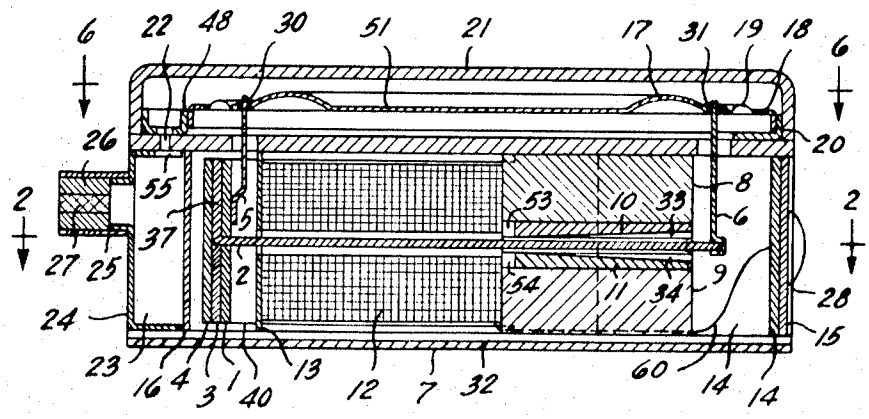


FIG. 3

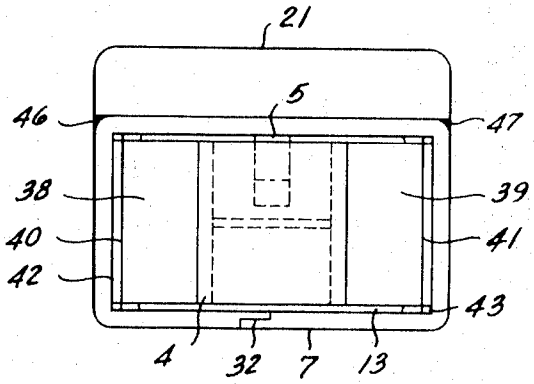


FIG. 4

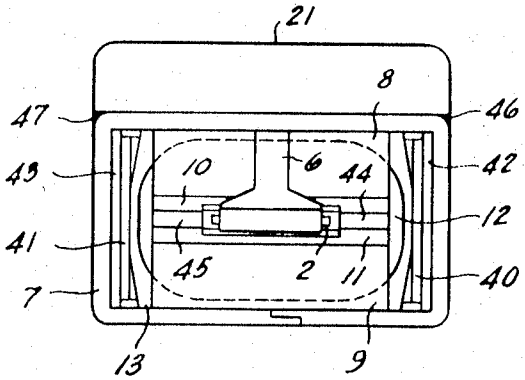


FIG. 5

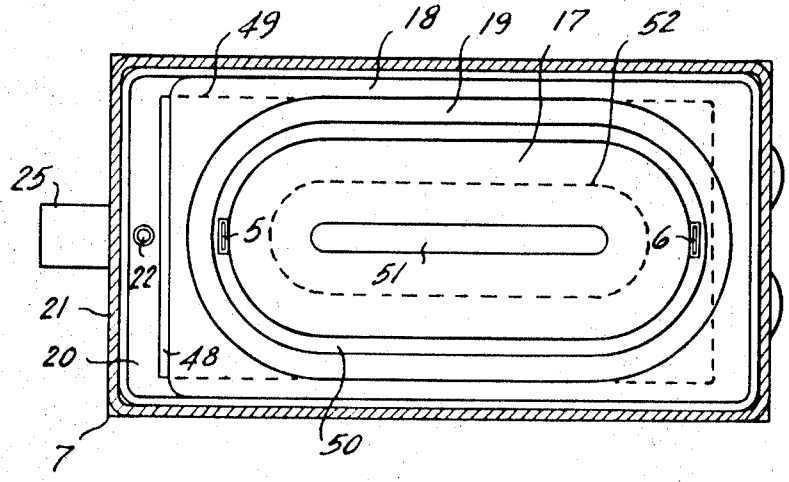


FIG. 6

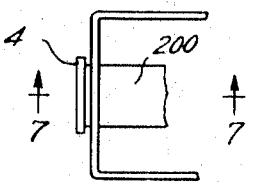


FIG. 8

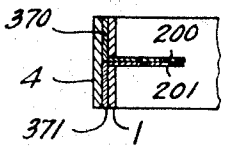
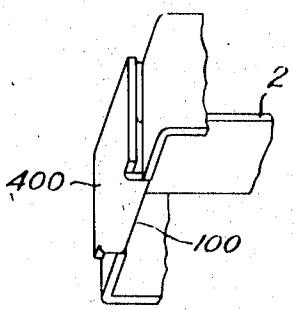


FIG. 7

FIG. 11



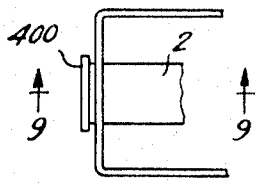


FIG. 10

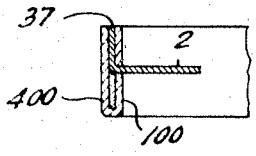
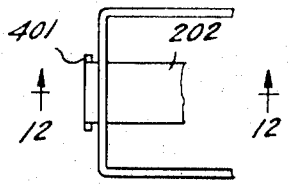


FIG. 9

FIG. 13



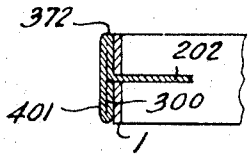


FIG. 12

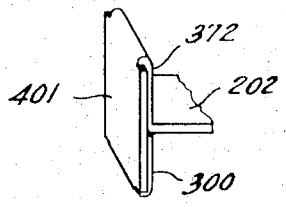


FIG. 14

FIG. 16

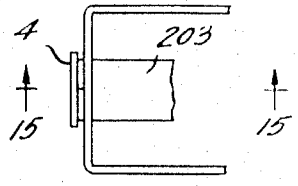
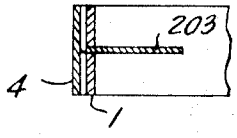


FIG. 15



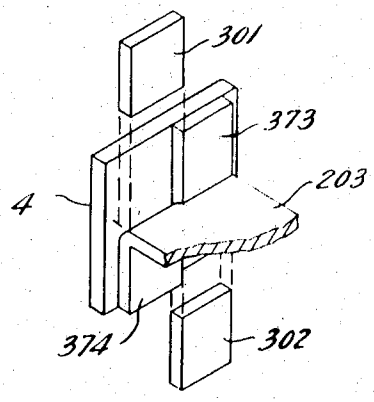


FIG. 17

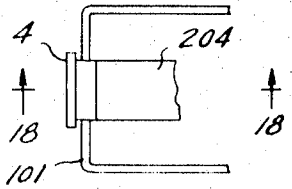


FIG. 19

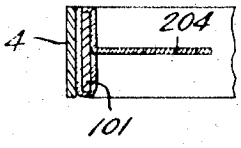


FIG. 18

FIG. 21

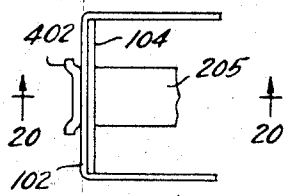
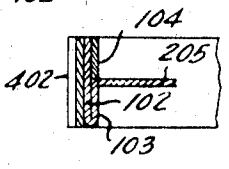


FIG. 20



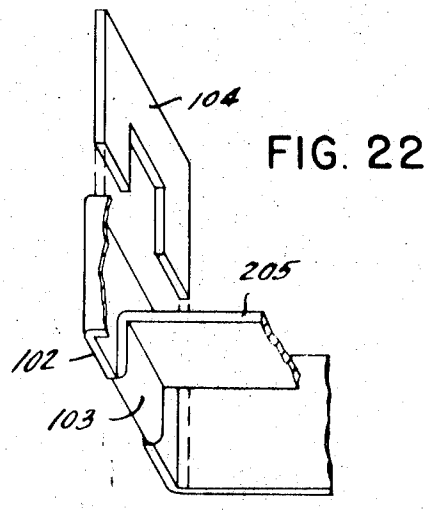


FIG. 22

FIG. 24

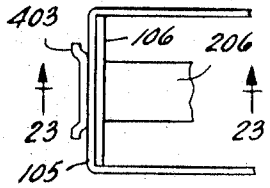


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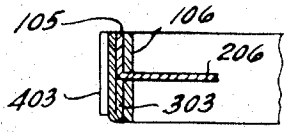


FIG. 25

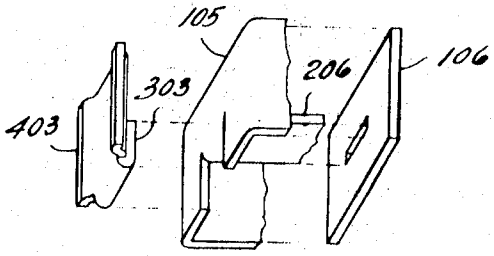


FIG. 27

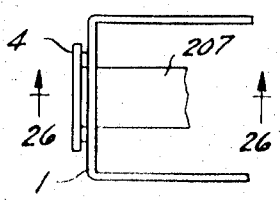


FIG. 26

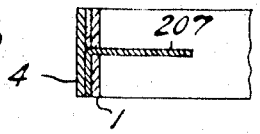
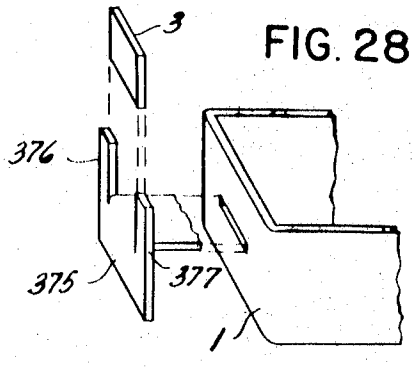


FIG. 28



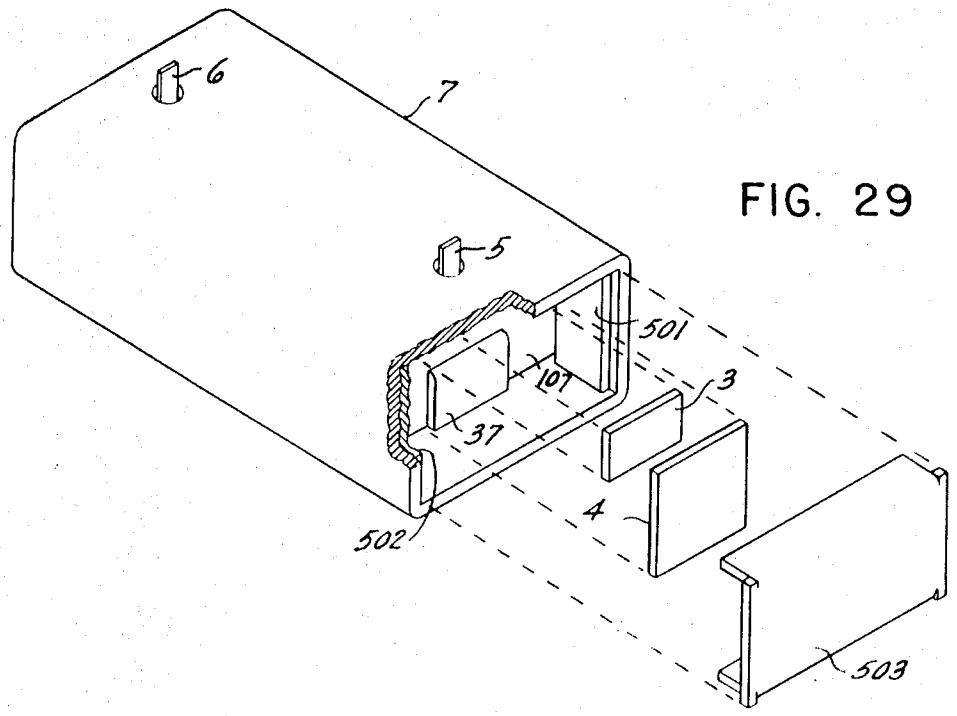


FIG. 29

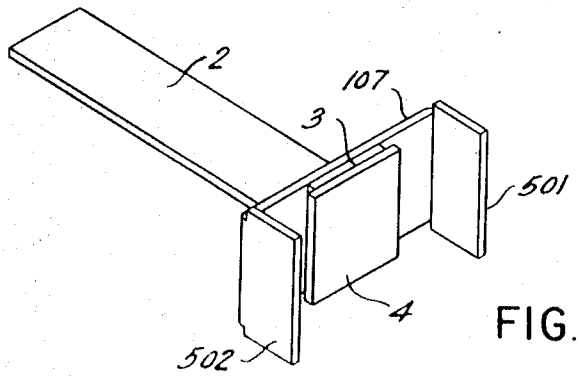


FIG. 30

FIG. 32

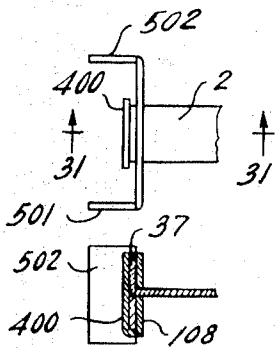


FIG. 31

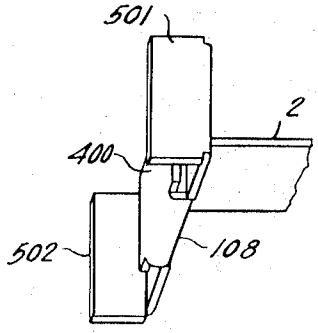


FIG. 33

FIG. 35

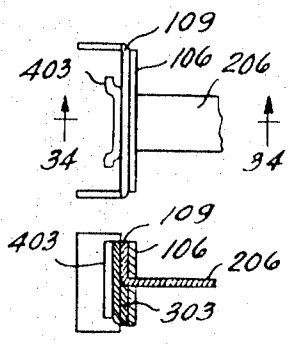


FIG. 34

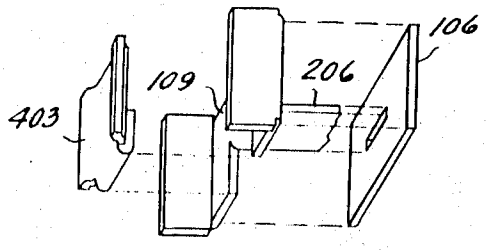


FIG. 36

MAGNETIC REED TYPE ACOUSTIC TRANSDUCER WITH IMPROVED ARMATURE

This application is a continuation of Ser. No. 638,878 filed May 16, 1967, and now abandoned.

BACKGROUND OF THE INVENTION

Transducers of this invention are particularly useful in hearing aids. The transducers, which are bilateral in operation, may be used as microphones to convert acoustic energy to an electrical signal or as receivers to convert electrical energy to acoustic energy.

The present trend in this segment of the electroacoustic transducer field is toward smaller units. In part, this trend has resulted from the development of components and methods for making electronic amplifiers of very small size. Thus it is desired that the transducers used with such amplifiers also be miniaturized, for example so that an entire hearing aid may be small enough to fit well within the pinna of the ear of the user and to extend into a substantial portion of the external auditory meatus.

As the size of the transducer is reduced the problems associated with transducer manufacture increase substantially, particularly in the structure of the armature. A portion of the armature must be free to vibrate in a working gap traversed by polarizing magnetic flux. When manufactured the structure must be such that the armature can be readily "balanced," i.e., adjusted to a position in the working gap such that under conditions of use the armature will carry negligible static flux. If the transducer is not well balanced, the sensitivity and frequency response of a microphone are degraded and the nonlinear distortion of a receiver, particularly the even order distortion, is greatly increased.

Further, the armature, once adjusted to the desired quiescent position must retain this position despite severe mechanical shock to the transducer. Thus the armature and its means of attachment must strongly resist permanent translation or rotation within the completed transducer. Finally, the armature must be of a construction which can be readily assembled, even though the component size is quite small.

To summarize, the armature for electromechanical transducers of the general class described above must be such that it can be readily assembled with other components to form a complete transducer in a very small size, can be relatively easily adjusted in production to a location in the working gap where the static flux conveyed along the armature can be neglected, and will maintain its adjusted position despite the severe external mechanical shock to which such transducers—and in particular hearing aid transducers—are subjected in use.

The prior art has partially solved these problems in various ways. For example, in a parallel magnetic circuit configuration of the type disclosed in U.S. Pat. No. 2,994,016 of Raymond W. Tibbetts et al., the straight armature of that invention can be adjusted mechanically to an approximate position of balance by inserting a tool through an aperture (FIGS. 1 and 6) in each pole plate near the fixed end of the armature and bending the armature up or down toward either pole plate, a fine magnetic adjustment being made thereafter by bending tabs 19 or 20 (FIG. 7) toward either pole plate as more fully disclosed in the copending application of George C. Tibbetts, Ser. No. 680,753 filed Aug. 28, 1957. In a series magnetic circuit configuration of the type disclosed in the copending application of George C. Tibbetts, Ser. No. 168,183 filed Jan. 23, 1962 and now U.S. Pat. No. 3,515,818, the folded armature of that invention can be adjusted mechanically to an approximate position of balance by bending the armature to change its location in the working gap between the pole pieces, and then if necessary performing a fine magnetic adjustment by means of an adjustable piece of magnetic material as disclosed in U.S. Pat. No. 3,185,779 of Joseph A. Sawyer or by means of an adjustable piece of permanent magnetic material as disclosed in U.S. Pat. No. 3,230,426 of Joseph A. Sawyer et al.

SUMMARY OF THE INVENTION

We have devised an improved armature for use in magnetic electromechanical transducers. While the invention will be described in connection with electroacoustic transducers used in hearing aids, it is to be emphasized that the armature of the invention is not of such limited application and may be equally useful in electromechanical transducers for other applications.

Accordingly we provide an electromechanical transducer having a casing, magnets within the casing which provide polarizing flux across a working gap, an electrical signal coil, and an armature having at least two portions which contribute to the working compliance at one point thereof, namely a vibratable portion compliant in flexure and extending from the working gap through the coil to another vibratable portion of the armature compliant in torsion, said portion of the armature compliant in torsion connected to another portion of the armature attached to the casing, whereby the position of the armature in the working gap may be adjusted by twisting inelastically the portion of the armature which is compliant in torsion, the plastic deformation being substantially confined to that portion.

In this invention the portion of the armature compliant in torsion may play an essential role in the shielding of the unit against response to or production of stray magnetic fields.

Also in this invention in one embodiment thereof the portion of the armature attached to the casing extends from the portion compliant in torsion back to a region adjacent and exterior to the working gap and is attached to the casing in that region, thus providing greater stability of the quiescent position of the portion of the armature in the working gap.

In addition, the transducer of the invention may comprise a casing of high permeability magnetic material which encircles the armature, coil, and magnets, and interconnects the magnets, the armature being attached to the casing by structural means such as spot welding and brazing.

The configuration and mode of adjustment of the armature are such that the resistance of the armature to damage by mechanical shock is maximized. Furthermore, in this invention the armature may be composite to allow the various portions of the armature to perform their respective functions in an optimum manner. The transducer of the type described is well adapted to fabrication in very small sizes and furthermore to fabrication in elongate shapes of very small cross section.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view, with parts partially broken away to show construction of the electromechanical transducer portion of a particular embodiment of the invention;

FIG. 2 is a plan view, partially in section of an electroacoustic transducer shown as a particular embodiment of the invention, taken on the line 2—2 of FIG. 3;

FIG. 3 is a side elevation in section of an electroacoustic transducer taken on the line 3—3 of FIG. 2;

FIG. 4 is an end elevation of the left end of the electroacoustic transducer as shown in FIGS. 2 and 3 with the acoustic closure and the bulkhead removed;

FIG. 5 is an end elevation of the right end of the electroacoustic transducer (as shown in FIGS. 2 and 3) with the terminal board and the underlying closure removed;

FIG. 6 is a horizontal section, taken on the line 6—6 of FIG. 3, which shows a plan view of the diaphragm of this embodiment.

The assembly of the armature, which may comprise an armature leg and an armature yoke, may take various forms in addition to that illustrated in FIGS. 1–6. The following drawings illustrate alternative configurations of the armature

in the rear region where the armature leg joins the armature yoke. Thus:

FIG. 7 is a vertical section showing the rear region of a modified form of the armature wherein the armature leg is composite, taken along the line 7—7 of the plan view of FIG. 8;

FIG. 9 is a vertical section of a portion of another embodiment of the rear region of the armature taken along the line 9—9 of the plan view of FIG. 10, this embodiment showing an adjustment pad integral with the armature yoke;

FIG. 11 is a bottom perspective view of the embodiment of FIGS. 9 and 10;

FIG. 12 is a vertical section of still another embodiment of the rear portion of the armature where the armature leg attaches to the armature yoke, this section being taken long the line 12—12 of the plan view of FIG. 13;

FIG. 14 is a rear perspective view of a portion of the rear region of the armature illustrated in FIGS. 12 and 13;

FIG. 15 is a vertical section of another embodiment of the rear region of the armature taken along the line 15—15 of the plan view of FIG. 16;

FIG. 17 is a perspective view of the embodiment of FIGS. 15 and 16 with parts removed for clarity;

FIG. 18 is a vertical section of another embodiment of the rear portion of the armature where the armature leg joins the armature yoke, taken along line 18—18 of the plan view of FIG. 19;

FIG. 20 is a vertical section of a different form of the same region of the armature taken along line 20—20 of the plan view of FIG. 21;

FIG. 22 is a bottom exploded perspective view of a portion of the rear region of the armature illustrated in FIGS. 20 and 21;

FIG. 23 is a vertical section of another embodiment of the rear region of the armature taken along the line 23—23 of the plan view of FIG. 24;

FIG. 25 is a bottom exploded perspective view thereof;

FIG. 26 is a vertical section of a further embodiment of the rear region of the armature where the armature leg joins the armature yoke, taken along the line 26—26 of the plan view of FIG. 27;

FIG. 28 is an exploded perspective view of a portion of the assembly illustrated in FIGS. 26 and 27.

An even more compact transducer may be obtained by fabricating the armature yoke and the casing of the same material or of materials having closely similar thermal expansion characteristics, so that it is permissible to have the armature yoke bridge directly across within the casing. Thus:

FIG. 29 is a perspective view of such a preferred embodiment, with parts shown exploded away for clarity; and

FIG. 30 is a perspective detail view of the armature of FIG. 29. As with the previous embodiment, the embodiment of FIGS. 29 and 30 may have variations of the configuration of the armature leg and armature yoke, and thus:

FIG. 31 is a vertical section of the rear region of the armature taken along line 31—31 of the plan view of FIG. 32;

FIG. 33 is a bottom perspective view of the modification of FIGS. 31 and 32;

FIG. 34 is a vertical section of another embodiment of the rear region of the armature taken along line 34—34 of the plan view of FIG. 35; and

FIG. 36 is a bottom exploded perspective view of the modifications shown in FIGS. 34 and 35.

GENERAL DESCRIPTION

Briefly and in general terms, for example as shown in FIG. 1, the improved electromechanical transducer of the invention includes a casing of magnetic material 7 which in this embodiment is essentially a sleeve of substantially rectangular cross section. A pair of magnets 8 and 9 are secured to opposite interior faces of the sleeve 7 near one end thereof; each magnet is provided with a pole piece, the magnet 8 with the pole piece 10 and the magnet 9 with the pole piece 11. A working gap is formed between the pole pieces. A coil 12 is positioned in the sleeve endwise adjacent to the magnets. An armature leg 2 extends through the aperture of the coil and through the working gap between the pole pieces 10 and 11. The armature leg 2 is connected at one end (the left end as seen in FIG. 1) to a generally U-shaped armature yoke 1. The arms 40 and 41 of the armature yoke include the portions identified as 42 and 43. The arms are joined by an integral crosspiece having portions identified as 38 and 39. The end of the armature leg 2 remote from the attachment to the armature yoke is vibratable in the working gap defined by the pole pieces 10 and 11. It will be observed that the armature yoke has its greatest cross-sectional dimension in a direction normal to the plane of the armature leg 2. As will be explained in detail below, this structure permits the armature to remain stably fixed under the effects of severe mechanical shock and wide temperature changes, and yet permits ready adjustment of the quiescent position of the armature in the working gap. The basic structure permits a variety of armature constructions and may readily be assembled even in very small sizes.

SPECIFIC DESCRIPTION OF THE PREFERRED EMBODIMENTS

More specifically, the particular embodiment of the invention shown in FIGS. 1–6 includes a generally U-shaped armature yoke 1 having an aperture, central in the crosspiece comprising portions 38 and 39, through which passes an armature leg 2 having a portion 37 formed at a right angle thereto and fastened to the armature yoke. A filler piece 3 (FIG. 3) of the same material and thickness as that of the armature leg permits an adjusting pad 4, whose function will be hereinafter described, to be properly fastened to the armature assembly. The arms 40 and 41 of the armature yoke have terminal portions 42 and 43 which are slightly widened and spaced slightly farther apart than the remaining portions of arms 40 and 41. The outer faces of the terminal portions are attached to the sleeve 7. The slight widening and slightly greater spacing provide clearance in all directions between the armature yoke and the sleeve except where attached. The sleeve 7 of high permeability magnetic material may be formed from flat strip and if so it has a longitudinal lap joint or seam 32 (FIGS. 1, 3, 4 and 5).

A magnet assembly to provide polarizing magnetic flux includes the magnets 8 and 9, the pole pieces 10 and 11, and nonmagnetic shims 44 and 45. The magnet assembly fits in the sleeve 7 in the direction shown as vertical in FIG. 5 and is bonded thereto by adhesive. The pole pieces 10 and 11 are coined so as to define tapered gaps 33 and 34 (FIG. 3) between the armature leg and the facing portions of the pole pieces.

An electrical signal coil 12, which surrounds a portion of the armature leg 2, is bonded at one end to the magnet assembly; the pole pieces may be provided with notches 53 and 54 to act as stops or catch pockets to prevent the flow of the bonding adhesive onto the coined surfaces of the pole pieces. At the other end the coil has a flange 13 which completes the support of the coil, the top and bottom of the flange being bonded by adhesive to the sleeve 7, and portions of the sides of the flange being a slip fit between the arms 40 and 41 as shown in FIG. 2. As shown in FIG. 5, the remaining portions of the sides of the flange 13 are relieved to insure that adhesive will not flow by capillarity between the flange and the arms 40 and 41.

A flexural pivot 5 attached to the armature yoke and a connecting pin 6 attached to the otherwise free end of the armature leg extend through apertures in the sleeve 7. The sleeve is closed at one end (the right end of the transducer illustrated in FIGS. 1, 2 and 3) by a generally U-shaped closure 14 which preferably is fabrication from high permeability magnetic material to provide magnetic shielding in conjunction with sleeve 7. The U-shaped closure, which is a slip fit in the sleeve

7 and is further located by abutment against the portions 42 and 43, is covered on its outer face by a terminal board 15; both are secured in place by adhesive. The terminal board may conveniently be fabricated from a copper-epoxy-glass cloth laminate, chemically etched to provide copper terminals 28 and 29. Internal lead wires 60 (FIGS. 2 and 3) from the coil 12 extend through apertures in the closure 14, in the terminal board, and in the terminals, and are secured and electrically connected to the latter by soft solder. Vernier magnetic adjusting means may be incorporated, for example such as disclosed in U.S. Pat. No. 3,185,779 of Joseph A. Sawyer or U.S. Pat. No. 3,230,426 of Joseph A. Sawyer et al.

As described, the armature assembly is free of attachment to the sleeve except at the portions 42 and 43 adjacent the working gap comprising the gaps 33 and 34. Accordingly, the state of adjustment of the armature leg in the working gap is not greatly affected by incidental rotation of the joints between portions 42 and 43 and the sleeve about an axis normal to the planes of the joints, or by equivalent motions such as may result from slight damage to the sleeve 7 occurring subsequent to the final adjustment of the device. Preferably the joints are spot welded to provide initial location of the armature assembly and to insure close fits and low magnetic reluctances between the portions 42 and 43 and the sleeve. The entire assembly thus formed is then brazed in a hydrogen furnace, as described hereinafter, to produce an essentially one-piece structure from the viewpoint of mechanical strength and creep resistance. A point that must be considered is that, if distinct, the alloys being joined will in general having different thermal expansion coefficients. The consequent bimetallic effects preferably are minimized by making the portions 42 and 43 relatively short. However, motions due to the bimetallic effect are in the plane of the armature leg 2, and thus the armature is effectively unmoved in the working gap by such motions. Furthermore, in this embodiment of the invention the armature yoke does not bridge directly across within the sleeve, so that slight but not necessarily insignificant thermally induced differences in width (in the sense shown in FIG. 2) between the armature yoke and the sleeve are readily accommodated by flexure of the free portions of the arms 40 and 41.

With reference to FIGS. 2 and 3, it is event that the arms 40 and 41 are substantially rigid with respect to translation in a direction normal to the plane of FIG. 2 or with respect to rotation about any axis normal to the plane of FIG. 3, since the arms are of substantial width in the direction shown as vertical in FIG. 3. The portions 38 and 39 of the crosspiece of the armature yoke, connected to the arms 40 and 41, are likewise substantially rigid with respect to translation in a direction normal to the plane of FIG. 2. However the armature crosspiece is compliant, indeed maximally so, with respect to rotation about the axis normal to the plane of FIG. 3 which passes through the center of the cross section of the armature yoke shown in FIG. 3. That is, the portions 38 and 39 are compliant in torsion so as to contribute to the working compliance of the armature assembly as measured at the pin 6. Because the arms 40 and 41 are essentially rigid in the sense described, the portion of the armature leg 2 in the working gap may readily be adjusted by engaging the projecting edges of the adjusting pad 4 with closable jaws of an adjusting arm mounted in a fixture holding the sleeve, and by this or similar means twisting inelastically the portions 38 and 39 about an axis passing substantially through the center of the cross section of the crosspiece as described above. In so doing the armature leg 2 is not significantly deformed at any point and thus is not disturbed metallurgically. In consequence the resistance of the armature leg 2 to damage by mechanical shock is not impaired by the foregoing mode of adjustment of the armature assembly. While the same is not true of the portions 38 and 39 of the crosspiece, the cross sectional dimensions of the armature yoke may be chosen so that the resistance to mechanical shock of the plastically deformed portions 38 and 39 approximates that of the armature leg 2.

In order that the armature assembly have the utmost stability and strength, it is preferred that the armature yoke 1, the armature leg 2 and its portion 37, the filler piece 3 and the adjusting pad 4 be brazed one to another subsequent to spot welding operations made to locate the parts and to insure a joint of low magnetic reluctance between the portion 37 and the armature yoke. Preferably the amount of brazing material is adjusted to provide a significant fillet of the braze onto the armature leg 2 beyond the aperture in the armature yoke. The result is an essentially one-piece structure. If the pad 4 must have sufficient strength in very thin sections to enable adjustment of the armature assembly, it may be fabricated from a high strength material such as a precipitation hardenable martensitic steel. Since in general there may be three distinct materials joined in this region, there is such case a net "-bimetallic" effect which nonetheless does not greatly affect the position of the armature 2 in the working gap if the symmetry of the armature assembly is preserved by fabricating the filler piece 3 from the same material as that of the armature leg. However, it is preferred that in this region the net "-bimetallic" effect be made substantially nil by providing an additional symmetry in the armature assembly. This may be approximated by fabricating the adjusting pad 4 from the same material and in the same thickness as those of the armature yoke 1.

As shown in FIGS. 1–5 the sleeve 7 has the lengthwise seam 32, but nonetheless the sleeve is one piece and therefore is a highly effective portion of the magnetic shielding of the transducer. Furthermore, by making the inner edge of the seam 32 substantially central on either magnet 8 or magnet 9, the seam carries negligible flux with the result that effectively none of the high permeability paths provided by the sleeve between the magnets (which include the paths in the sleeve between the portions 42 and 43 and the magnets) is interrupted by the seam 32. Moreover, the sleeve is relatively long and throughout its extent is effective in carrying the polarizing flux provided by the magnets. Accordingly the wall of the sleeve may be made relatively thin for a specified maximum flux density in the sleeve, and a considerable saving of space results. In the figures the seam 32 is shown adjacent the magnet 9 so that the apertures carrying the flexural pivot 5 and the pin 6 may be more easily blanked. Although a seam may be provided to allow the fabrication of the sleeve from strip, alternatively it may be fabricated from seamless round tubing by a forming operation or may be cut from tubing drawn to the desired shape of the sleeve cross section. These and other configurations and advantages of the sleeve casing are disclosed more fully in copending application Ser. No. 638,892 of George C. Tibbetts et al., filed of even date herewith and now abandoned. Although the particular embodiment illustrated in FIGS. 1–6 employs a sleeve of the type disclosed in said copending application of George C. Tibbetts et al., the present invention is not limited to the employment of such means. For example, a two-piece casing adapted from the prior art may be utilized, wherein preferably the portions 42 and 43 each extend between facing walls of the two pieces when assembled one within the other to form the casing.

Preferably the present invention employs the tapered gap means disclosed in U.S. Pat. No. 3,172,022 of George C. Tibbetts. As previously noted, one object of the present invention is to provide transducers in elongate shapes of very small cross section, In many such applications the gaps 33 and 34 are relatively long, in which case the tapered gap means provides very much improved stability and linearity of operation.

As shown in FIGS. 1–3 and 5, the magnet assembly which includes magnets 8 and 9, magnetic pole pieces 10 and 11, and nonmagnetic shims 44 and 45 is similar to that shown in U.S. Pat. No. 3,172,022 and thus needs no further elaboration, although the present invention is not limited to magnet assemblies of that general type. Preferably the pole pieces 10 and 11 and shims 44 and 45 comprise a subassembly which may be spot welded and brazed. The magnets 8 and 9 are magnetized in a common direction normal to the plane of FIG. 2 with the

result that the polarizing magnetic fields in the gaps 33 and 34 have essentially the same direction.

A typical assembly of the foregoing embodiment may be made as follows. The armature leg 2 is inserted through the aperture in the armature yoke 1, and the portion 37 and the properly located filler piece 3 are spot welded to the armature yoke. The adjusting pad 4 is located over the portion 37 and and filler piece 3, and is spot welded thereto. Brazing material in the form of cut lengths of wire is sprung between the armature yoke and the projecting edges of the adjusting pad 4. The partially completed armature assembly is inserted in the sleeve 7 and after being located is spot welded to the sleeve at the portions 42 and 43. By light spot welding, segments of brazing wire are tacked in place adjacent the junctions between the sleeve and the abutting edges of the portions 42 and 43. The flexural pivot 5 is positioned through the corresponding aperture in the sleeve and is spot welded to the armature yoke. The assembly is now brazed in a hydrogen atmosphere furnace, the hydrogen acting as flux during the brazing operation. The magnet assembly, comprising magnets 8 and 9 bonded by adhesive to the subassembly of pole pieces 10 and 11 and shims 44 and 45, is bonded by adhesive to the coil 12. The resulting coil-magnet assembly is pushed into the sleeve 7 and over the armature leg 2, and after being located, the appropriate portions of flange 13 and magnets 8 and 9 are bonded to the sleeve by adhesive. The upper extremity of the pin 6 is fitted up through the corresponding aperture in the sleeve and the base of the pin is positioned on the armature leg 2 and bonded thereto by adhesive. The U-shaped closure 14 is slipped into the sleeve after the internal lead wires from the coil 12 are threaded through the apertures in the closure. Adhesive is applied at the periphery between the closure 14 and the sleeve 7 so as to flow by capillary action thoroughly between the sleeve and the arms of the closure and to serve as a source of adhesive for bonding the terminal board 15 to the closure and the sleeve. After threading the lead wires through its apertures, the terminal board with its terminals 28 and 29 is inserted in place, the adhesive is cured, and the lead wires are soldered to the terminals. The structure of the electromechanical transducing assembly is now substantially complete. Accordingly the magnets may be magnetized, and the armature adjusted by means of pad 4 while concurrently demagnetizing the magnets to the desired operating point. After such adjustment of the armature and magnets, the transducer is operative so that mechanical energy may be transferred via the connecting pin 6 and electrical energy via the terminals 28 and 29, the flow of the two forms of energy being interdependent by transduction. The detailed operation of the electromechanical transducer will be evident to the artisan, but it should be noted that the present invention is concerned with transducers employing a magnetically balanced armature such that substantially the armature carries only signal flux under the intended operating conditions, and furthermore which employs a series magnetic circuit such that signal flux through the armature divides between the magnets and is conveyed by the magnets.

The remainder of the electroacoustic transducer shown in FIGS. 2–6 as a particular embodiment of the invention comprises a frame 20 having an upturned peripheral rim, an aperture indicated by the broken line 49 in FIG. 6, and a formed boundary 48 adjacent the aperture. Preferably the frame 20 is located and partially attached to the sleeve 7 by spot welding; in that case the spot welding operation may be performed prior to the insertion of the armature assembly in the sleeve. An aperture is provided in the frame to coincide approximately with the aperture 22. Preferably a diaphragm of the type disclosed in U.S. Pat. No. 3,166,148 of George C. Tibbetts is employed, and comprises a diaphragm portion 17, a diaphragm means surround 19, and a self-frame 18 having a peripheral rim which fits within the frame 20 in the sense shown in FIGS. 3 and 6. The self-frame 18 and frame 20 are bonded and sealed together by adhesive. The diaphragm portion 17 has flats 50 and 51, the former being provided with apertures through which the flexural pivot 5 and connecting pin 6 extend slightly. Adhesive masses 30 and 31 connect the flexural pivot 5 and pin 6 to the diaphragm portion as shown in FIG. 3 but omitted in FIG. 6 for the sake of clarity. Between the flats 50 and 51 the diaphragm portion 17 is formed so as to increase greatly the flexural stiffness of the diaphragm portion between the flexural pivot 5 and pin 6. For example the form may correspond to a continuous trough generated by a portion of a sphere the projection of whose center follows the contour indicated by the broken line 52 in FIG. 6. In part the foregoing structure is a particular embodiment of the diaphragm and translating member means disclosed in the copending application of Joseph A. Sawyer et al. Ser. No. 638,926, filed of even date herewith, which may be consulted for a full description of the advantages and mode of operation of a pivoted diaphragm connected to the extremity of an armature or similar translating means. The diaphragm is protected and a confined space above the diaphragm is provided by a cover 21 which is located by the rim of the frame 20. After adhesive is applied about the junction of the rim of the frame 20 with the sleeve 7, the cover is fitted in place, and the adhesive bonds the cover to the frame and to the sleeve and serves also to seal the frame to the sleeve. Adhesive filler masses 46 and 47 (FIGS. 4 and 5) may be provided by the cover bonding adhesive or may be applied in a subsequent operation. The frame 20 and cover 21 may be fabricated from magnetic material to provide somewhat increased magnetic shielding against stray flux traversing the apertures containing the flexural pivot 5 and connecting pin 6.

The bulkhead 16 which acoustically closes the sleeve near the end remote from the terminal board is generally U-shaped as shown in FIG. 2 and has a pierced hole which carries an adhesive mass 35 having a fine aperture 36 therethrough. The aperture serves to equalize the static pressure on each side of the diaphragm. After the bulkhead is located within the sleeve 7 the arms of the bulkhead may be spot welded to the sleeve. An acoustic end closure 24 which is also generally U-shaped as shown in FIG. 3, has a short tubular drawn portion which may carry an acoustic connector 25 and a sleeve 26 having an aperture 27 which defines an acoustic inertance and which may in addition contain a porous acoustic impedance means. The closure 24, which is narrowed beyond its face so that its arms may fit widthwise between the arms of the bulkhead, is provided with a notch 55 which leaves the aperture 22 unobstructed when the closure is fitted in place. The assembly may now be completed by applying sufficient adhesive to the accessible junctions of the bulkhead 16 with the sleeve 7 and thereafter slipping the closure 24 into the sleeve until the inward face of the closure abuts the end of the arms of the bulkhead. The previously applied adhesive spreads by capillary action throughout the face and edge joints of this portion of the assembly, and when cured seals the bulkhead and the closure to the sleeve and securely bonds the closure in place.

As in the copending application of George C. Tibbetts, Ser. No. 168,183 filed Jan. 23, 1962 and now Pat. No. 3,515,818, the armature of the present invention may play an essential role in the shielding of the inner components of the transducer, particularly the coil, the free end of the armature, and the magnets. The crosspiece of the armature yoke 1 substantially closes the sleeve 7 near one end thereof to prevent external stray magnetic flux from penetrating the assembly to induce a spurious e.m.f. in the coil 12, as well as to prevent internal flux caused by current in the coil 12 from escaping the assembly to form an external stray magnetic field. Flux collected by the crosspiece of the armature yoke 1 is returned to the sleeve 7 by low reluctance paths terminating at the attachments of the portions 42 and 43. Thus the bulkhead 16 and the closure 24 may be fabricated from nonmagnetic material.

Additional acoustic compliances and inertances, interconnected advantageously, may be desirable or necessary in the quantitative design of such a miniature transducer. Thus an acoustic compliance corresponding to the space 23 is provided between the bulkhead 16 and the closure 24, and an

acoustic inertance connecting the space 23 and the space above the diaphragm is provided by the aperture 22. Since this structure is accomplished within the sleeve 7, it may be continued further, as disclosed in copending application Ser. No. 638,892 and now abandoned of George C. Tibbetts et al., referred to previously. The particular embodiment shown in FIGS. 2–6 may be employed either as a receiver or as a microphone. However, rather than the end connector 25 shown, acoustic connection may be made to any of the available sides of the space 23, or alternatively may be made to the space above the diaphragm. In the latter case the bulkhead 16 and closure 24 may be replaced by a single acoustic closure and the aperture 22 may be modified to be similar to aperture 36 for venting purposes.

Although the particular embodiment illustrated in FIGS. 1–6 employs the diaphragm and translating member means disclosed in copending application Ser. No. 638,926 of Joseph A. Sawyer et al., referred to previously, the present invention is not limited to the employment of such means. For example, notches corresponding to notches 53 and 54 may be provided in the magnets 8 and 9, and connecting pin attached to the armature leg 2 between the coil 12 and the pole pieces 10 and 11 may extend within the notches on one side of the armature leg through an aperture in the sleeve 7 to connect to a conventional nonpivoted diaphragm.

A particular composite armature is illustrated in FIGS. 1–4. A composite armature may be desirable, for example to provide different thicknesses of the armature yoke 1 and armature leg 2, to provide different materials for these members, to provide ease of fabrication of the armature, or to provide a number of these features in combination. It is desirable that the armature leg 2 be fabricated from a material having high saturation induction and high yield strength, but it may happen that one or the other of these requirements narrows the choice to materials that can be formed only when hot or under other special circumstances. Thus a different magnetic material would be required for the armature yoke 1 in order that the portions 38 and 39 be sufficiently ductile in torsion to provide the armature adjustment described above. The particular structure illustrated in FIGS. 1–4 provides an armature leg of simple configuration and an aperture in the armature yoke which not only provides self-location of these two members during assembly but also makes possible an assembly of particularly high strength when brazed.

However, the armature need not be composite in the sense shown in FIGS. 1–4. For example the assembly of the armature leg to the armature yoke may differ, the armature yoke or the armature leg or both may be composite, a portion of the armature yoke may be integral with a portion of the armature leg and so forth. Furthermore the armature need not be composite but may be substantially integral.

Some of these variations are illustrated in FIGS. 7–28. To simplify the description, the same reference characters (1, 2, 3 etc.) are used if the element is the same as shown in FIGS. 1–6, and different reference characters beginning with the same number (1 becomes 100 or 101, etc.) are used if the element is of different structure. In FIGS. 7 and 8 the armature leg is composite, having members 200 and 201 which have formed portions 370 and 371 respectively. In FIGS. 9–11 an adjusting pad 400 is integral with the armature yoke 100, the adjusting pad contributing to a joint to the portion 37 of the armature leg 2 which is of lower reluctance and of higher flux carrying capability. In FIGS. 12–14 an armature leg 202, its formed portion 372, an adjusting pad 401 and a filler piece 300 are formed from one piece. In FIGS. 15–17 an armature leg 203 has portions 373 and 374 formed in opposite directions, whereby the joint between the armature leg and the armature yoke 1 may have higher flux carrying capability; corresponding filler pieces 301 and 302 are placed between the adjusting pad 4 and the armature yoke. In FIGS. 18 and 19 an armature leg 204 is wrapped entirely around the armature yoke 101 to provide a joint of minimal reluctance. In FIGS. 20–22 the reluctance of a joint is avoided by making the armature substantially integral, an armature leg 205, its portion 103 and an armature yoke 102 being formed from one piece. A member 104 may be fitted about the portion 103 and may be laminated (as by brazing) to the cross arm of the armature yoke 102 with the result that that portion of the armature yoke effectively becomes composite. An adjusting pad 402 is formed to provide projecting edges. Similarly, in FIGS. 23–25 an armature leg 206 is integral with an armature yoke 105. A rectangular washer 106 may be laminated to the armature yoke, becoming effectively a portion thereof. An adjusting pad 403 has an integral filler piece 303 which fits within the notch in the armature yoke 105. In FIGS. 26–28 a formed portion 375 of an armature leg 207 is widened to provide prongs 376 and 377, the prongs and the widened portion 375 providing a joint to the armature yoke 1 of reduced reluctance an increased flux carrying capability.

Further variations will be evident to the artisan. It should be recognized that joints need not be made by brazing since spot or other welding may suffice, and newer techniques such as detonative welding may be desirable, particularly when joints of very low magnetic reluctance must be obtained. The same variety of structure applies to the configuration of the portions 42 and 43 and their attachments to the sleeve.

If the armature yoke and the casing have closely similar thermal expansion characteristics, or are made of the same material, the construction of the transducer can be simplified, examples of which are shown in FIGS. 29–36 in which the armature yoke bridges directly across within the casing. The omission of the free portions of the arms 40–41 extending to the region of the working gap will then have little or no effect on the temperature coefficients of the various characteristics of the transducer, but the unit will be of reduced stability if there is rotation (by creep or other mechanism) of the joints between the armature yoke and the casing or if there are equivalent motions such as caused by mechanical distortion of the casing. However, if such motions are sufficiently small to be negligible, such a construction permits a more compact transducer, or permits the use of a larger coil, or both, and the manufacturing process is simplified somewhat.

A particular embodiment is indicated in FIG. 29, with parts exploded away, and in the detail of FIG. 30. Again to simplify the description, if the element is the same as shown in FIGS. 1–6 it has been labeled with the same reference character, and if the element is of different structure it is given a different reference character. Thus the embodiment of the invention shown in FIGS. 29 and 30 comprises a generally U-shaped armature yoke 107 having a central aperture in its crosspiece through which passes an armature leg 2 having a portion 37 formed at a right angle thereto and fastened to the armature yoke. A filler piece 3 of the same material and thickness as that of the armature leg is also fastened to the armature yoke adjacent portion 37, and an adjusting pad 4 is fastened to the filler piece 3 and portion 37. Arms 501 and 502 of the armature yoke extend in the same direction as armature leg 2 but in the reverse sense, and are attached to the inside wall of the sleeve 7. The sleeve and the armature yoke have closely similar thermal expansion characteristics or are made of the same material, as noted above. The arms 501 and 502 extend farther upward and downward, in the direction shown as vertical in FIGS. 29 and 30, than the crosspiece of armature yoke 107, to provide corresponding vertical clearances between the crosspiece and the sleeve. The outer ends of arms 501 and 502 are spaced inwardly of the end of sleeve 7. A flexural pivot 5 and a connecting pin 6 attached to the otherwise free end of the armature leg 2 extend through apertures in the sleeve 7. A generally U-shaped closure 503 closes the end of the sleeve, with its upper and lower arms located between the arms 501 and 502 at the upper and lower inside walls of the sleeve and with portions of the inner face of the closure abutting the outer ends of the arms 501 and 502. The remaining elements of the device may be of the form disclosed in FIGS. 1 to 5.

The armature assembly, including the armature leg 2 and armature yoke 107 as well as portion 37, filler piece 3, and ad-

justing pad 4, clears the sleeve except at the arms 501 and 502. Thus, as with the previous embodiments, the position of the armature leg 2 in the working gap between the magnets may be adjusted by engaging the projecting edges of the pad 4 with an adjusting tool and then twisting inelastically the crosspiece of the armature yoke to move the free end of the armature leg 2 toward either magnet. Likewise, the crosspiece of the armature yoke 107 is compliant in torsion and contributes to the working compliance of the armature assembly.

The various elements may be assembled and attached by spot welding, brazing, adhesive or the like as previously disclosed with reference to FIGS. 1–5. The arms 501 and 502 extend from the crosspiece of the armature yoke on the side opposite from armature leg 2, so that the coil may occupy the full width of the sleeve. There is no loss of space caused by such reversed arms, since the space is required between yoke 107 and closure 503 for elements 3, 4, and 37, and provides the acoustic compliance discussed above. The armature yoke 107 substantially closes the sleeve near one end, and since it is of magnetic material, may provide an essential portion of the magnetic shielding of the transducer. Thus closure 503 may be of nonmagnetic material. The crosspiece of armature yoke 107 may also function as an acoustic bulkhead; accordingly the clearance spaces between the sleeve and the upper and lower edges of the crosspiece may be filled with a very soft sealant.

As with the embodiment of FIGS. 1–5, the armature of the embodiment of FIGS. 29 and 30 may take other forms. FIGS. 31 to 33 show a variation similar to that shown in FIGS. 9–11, and FIGS. 34 to 36 show a variation like that of FIGS. 23–25. In FIGS.31–33 an adjusting pad 400 is integral with the armature yoke 108, the adjusting pad contributing to a joint to the portion 37 of the armature leg 2 which is of lower reluctance and of higher flux carrying capability. In FIGS. 34–36 an armature leg 206 is integral with an armature yoke 109. A rectangular washer 106 may be laminated to the armature yoke, becoming effectively a portion thereof. An adjusting pad 403 has an integral filler piece 303 which fits within the notch in the armature yoke 109.

Many other configurations, choice of materials and the like will be obvious to the artisan. However, the invention is to be limited only by the scope of the following claims.

We claim:

1. A magnetic transducer comprising an armature; a pair of magnets having a working gap therebetween; a high magnetic permeability casing member interconnecting said pair of magnets; said armature having a substantially planar first portion compliant in flexure and extending into the working gap, said first portion extending substantially perpendicularly from an intermediate substantially planar portion compliant in torsion, said intermediate portion being within said casing member and spaced therefrom along parallels to the plane of said first portion, and further portions at each end of the intermediate portion and extending substantially perpendicularly from said intermediate portion in respective planes substantially at right angles to the plane of said first portion; each of said further portions having joints of high mechanical rigidity and low magnetic reluctance with said casing member; said first, intermediate and further portions each being of high magnetic permeability material, the intermediate portion being limited substantially to magnetic signal flux paths which are not also polarizing flux paths, and the first portion being limited substantially to said signal flux paths except within the working gap; said intermediate portion having sufficient ductility to enable permanent adjustment of the position of said first portion in said gap by torsional inelastic deformation of the intermediate portion.

2. A magnetic transducer as in claim 1 further comprising an electrical signal coil through which extends said first portion of said armature.

3. A magnetic transducer as in claim 2 wherein each of said joints is near the end of each further portion and remote from said intermediate portion.

4. A magnetic transducer as in claim 2 wherein said joints are adjacent the ends of said intermediate portion, whereby said intermediate portion essentially bridges directly across within said casing member.

5. A transducer as in claim 2 wherein an L-shaped piece comprises said first portion, with the leg of the L extending through said intermediate portion and the foot of the L facing and attached to said intermediate portion.

6. A transducer as in claim 5 further comprising a filler piece attached to said intermediate portion complementary to said foot of said L-shaped piece, and an adjusting pad located on said foot and said filler piece, the position of said first portion in said gap being adjustable by way of said adjusting pad when engaged by a tool suitable to exert sufficient torque on said intermediate portion.

7. A transducer as in claim 2 wherein a T-shaped piece comprises said first portion, with the leg of the T extending from said intermediate portion and the head of the T extending contiguous with and attached to said intermediate portion.

8. A transducer as in claim 7 wherein said leg extends through the intermediate portion and said head is on the face of the intermediate portion opposite that from which the leg extends.

9. A magnetic transducer as in claim 1 further comprising an adjusting pad adjacent the face of the intermediate portion opposite that from which said first portion extends, the position of said first portion in said gap being adjustable by inelastic twisting of said intermediate portion by way of said adjusting pad.

10. A magnetic transducer comprising an electrical signal coil, means for establishing a magnetic field across a working gap comprising a pair of magnets and a high magnetic permeability casing member associated with said magnets, and an armature comprising a generally U-shaped armature yoke and an armature leg, said armature yoke comprising a pair of arms and a connecting crosspiece, said armature leg having a substantially planar portion which extends from said working gap through said coil to the crosspiece of said armature yoke, wherein said crosspiece lies in a plane perpendicular to the plane of said portion, and the arms of said armature yoke each lie in a plane perpendicular to the plane of the crosspiece as well as perpendicular to the plane of said portion, and extend parallel to the plane of said portion, said crosspiece and armature leg being supported within and spaced from said casing member by said arms.

11. A magnetic transducer as in claim 10 wherein each of said arms is connected by a low reluctance joint with said casing member.

12. A magnetic transducer comprising a pair of magnets having a working gap therebetween and providing magnetic polarizing flux thereto; an electrical signal coil; an armature extending from said gap through said coil and comprising a vibratable first portion lying substantially in a first plane, compliant in flexure and extending transversely from a vibratable intermediate portion compliant in torsion, said intermediate portion lying substantially in a second plane perpendicular to said first plane and extending to a juncture with a further portion of said armature in a direction along the intersection of said first and second planes; and a high magnetic permeability casing member forming a partial enclosure for said magnets, coil and first portion and conducting at least a portion of said polarizing flux, said further portion extending to a connection with said casing member; said armature intermediate portion being spaced from but substantially partitioning said casing member and completing a portion of said enclosure, and being supported by said casing member to render said intermediate portion substantially rigid with respect to translation normal to the plane of said first portion; and means for intercepting stray magnetic signal flux of any origin which otherwise would traverse the interior of the casing member where partitioned, said means comprising said armature intermediate portion.

13. An electromechanical transducer comprising, in combination,

means forming a housing for said transducer,

an armature yoke, said yoke being formed of material having a substantially rectangular cross section and being of generally U-shaped configuration comprising a pair of arms and a connecting crosspiece, each bend between the arms and the crosspiece of said U-shaped armature yoke being about an axis parallel to the longer dimension of said cross section,

means securing said armature yoke to said housing at a face of each of said arms,

an armature leg of substantially rectangular cross section,

means securing one end of said armature leg to the crosspiece of said armature yoke, said armature leg extending from said crosspiece in the general direction of the arms of said armature yoke, and said armature leg being positioned on said crosspiece such that the wider dimension of the cross section of said armature leg is along the direction of extent of said crosspiece of said armature yoke,

permanent magnets within said housing for providing polarizing flux across a working gap, a portion of said armature leg extending into said working gap,

an electrical coil about a portion of said armature leg, and

means connected to said armature leg for mechanical displacement therewith.

14. An electromechanical transducer as in claim 13 wherein said means connected to said armature leg comprises acoustic diaphragm means.

15. A magnetic transducer comprising an electrical signal coil, means for establishing magnetic polarizing flux in a working gap comprising a pair of magnets and a high magnetic permeability casing member associated with said magnets, a high magnetic permeability armature extending through said coil and having a vibratable elongate substantially planar first portion compliant in flexure and extending into said gap, said armature having two further portions extending to connections with said casing member in two regions adjacent the working gap on opposite sides thereof, said connections having low reluctance to magnetic signal flux, said armature having a vibratable intermediate portion within and spaced from said casing member, connected with said first portion and extending between and having opposite ends joined with said further portions to render said intermediate portion substantially rigid with respect to translation normal to the plane of said first portion, said intermediate portion being compliant in torsion about an axis transverse to the direction of extent of said first portion cooperatively with the flexural compliance thereof.

16. A magnetic transducer comprising an electrical signal coil, means for establishing magnetic polarizing flux in a working gap comprising a pair of magnets and a high magnetic permeability casing member associated with said magnets, a high magnetic permeability armature extending through said coil and having a vibratable elongate substantially planar first portion compliant in flexure and extending into said gap, said armature having a vibratable intermediate portion within and spaced from said casing member, said first portion extending from and being connected with said intermediate portion in a region between opposite ends thereof, said armature having two further portions joined to said opposite ends of said intermediate portion and extending directly to connections with the casing member at the vicinity of their junctures with the intermediate portion, the connections to said casing member having low reluctance to magnetic signal flux, said intermediate portion being substantially rigid with respect to translation normal to the plane of said first portion and being compliant in torsion about an axis transverse to the direction of extent of said first portion cooperatively with the flexural compliance thereof.

17. A magnetic transducer comprising an electrical signal coil, a high magnetic permeability armature extending through said coil and having a vibratable first portion compliant in flexure, said first portion lying substantially in a first plane and extending into a working gap, and means for establishing magnetic polarizing flux in said gap comprising a pair of magnets and a high magnetic permeability member conducting at least a portion of said polarizing flux; said armature having a vibratable intermediate portion connected with said first portion, said intermediate portion lying substantially in a second plane perpendicular to said first plane and extending to a juncture with a further portion of said armature in a direction along the intersection of said first and second planes; said further portion extending to a connection with said member, said connection having low reluctance to magnetic signal flux, said further portion rendering said intermediate portion substantially rigid with respect to translation normal to the plane of said first portion, said intermediate portion being compliant in torsion about an axis along said direction of extent cooperatively with the flexural compliance of said first portion.

18. A transducer as in claim 17 wherein said intermediate portion is sufficiently ductile to enable permanent adjustment of the position of said first portion in said gap by torsional inelastic deformation of the intermediate portion.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,617,653 Dated November 2, 1971

Inventor(s) George C. Tibbetts and Joseph A. Sawyer

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading the address of the assignee should be Camden, Maine instead of Camden, New Jersey.

In the Abstract, second sentence, after "crosspiece portion" (first occurrence) insert --of the armature compliant in torsion, said crosspiece portion--.

Column 3, line 10, cancel "adjustment" and substitute --adjusting--; line 15, cancel "long" and substitute --along--; line 65, cancel "modifications" and substitute --modification--. Column 4, line 73, cancel "fabrication" and substitute --fabricated--. Column 5, line 43, cancel "event" and substitute --evident--; lines 59-60, cancel "portion" and substitute --position--. Column 6, line 64, cancel "," and substitute --.--

Signed and sealed this 2nd day of May 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents