

United States Patent

Bryant

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[54] **ELECTROACOUSTIC TRANSDUCER
WITH MAGNETIC TRANSDUCING
ELEMENT CLAMPING**[72] Inventor: **Herbert William Bryant,**
Middletown, N.J.[73] Assignee: **Bell Telephone Laboratories, Incorporated,** Murray Hill, Berkeley Heights, N.J.[22] Filed: **Dec. 15, 1971**[21] Appl. No.: **208,307**[52] U.S. Cl. **310/9.1, 179/110 A, 310/8.2; 8.5**[51] Int. Cl. **H04r 17/00**[58] Field of Search **310/8.2, 8.5, 9.1-9.4;**
179/110 A[56] **References Cited****UNITED STATES PATENTS**

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Primary Examiner—J. D. Miller*Assistant Examiner*—Mark O. Budd*Attorney*—R. J. Guenther et al.[57] **ABSTRACT**

An electromechanical transducing element is bonded to a magnetic plate, and the composite structure is clamped within a transducer housing by means of one or more magnets attached thereto or embedded therein. The magnets serve to semirigidly clamp the plate to the housing, obviating the need for cement or other rigid clamping means, thereby reducing undesirable high or non-uniform stresses in the plate and allowing radial expansion and contraction of the plate due to thermal variations without damage to the transducer or alteration of its performance.

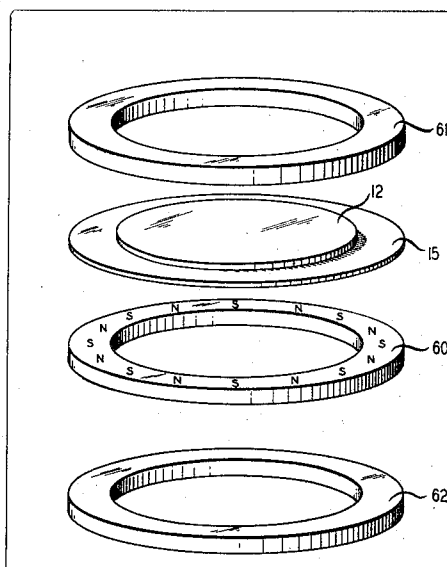
12 Claims, 4 Drawing Figures

FIG. 1

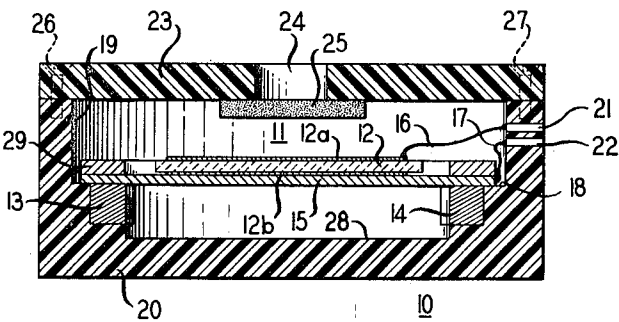
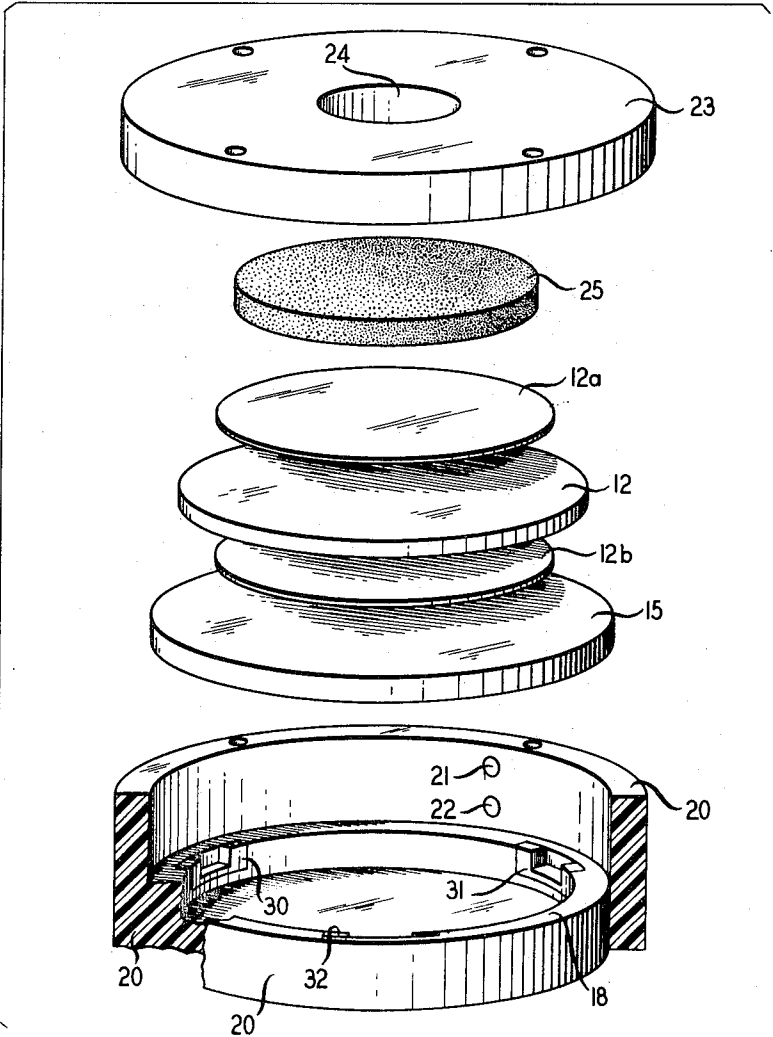


FIG. 2



SHEET 2 OF 2
FIG. 3

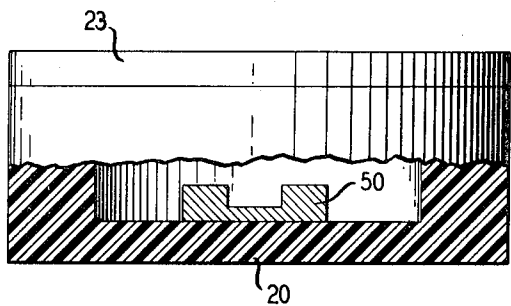
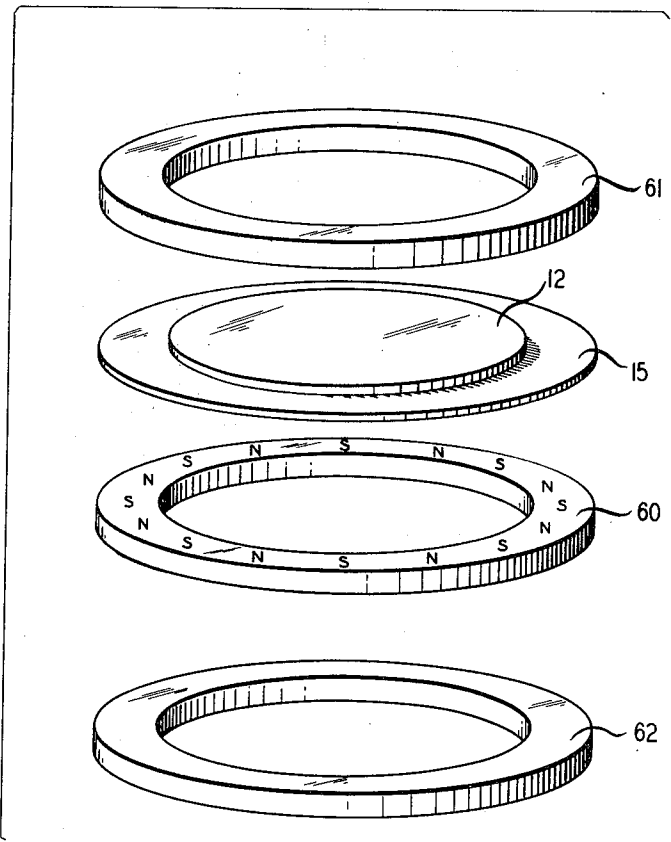


FIG. 4



ELECTROACOUSTIC TRANSDUCER WITH MAGNETIC TRANSDUCING ELEMENT CLAMPING

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to electroacoustic transducers utilized to convert sound energy into electrical energy and vice versa, and, more particularly, to such transducers having improved means for clamping the transducing element to the transducer housing.

2. Description of the Prior Art

While the carbon microphone has faithfully served the electronics industry for many years, recent advances in technology call for a higher degree of stability and a generally smaller size than is afforded by the carbon instrument. This is especially true in the telephone art, where new compactness and efficiency in components and circuitry, as well as more streamlined customer equipment, necessitate a corresponding improvement in transducer design. An attractive substitute for the carbon microphone is the piezoelectric ceramic transducer, by virtue of its reduced volume requirements and its low manufacturing cost. Besides its use as a microphone, such a transducer may also be employed as a receiver or speaker.

In order to make effective use of the piezoelectric ceramic transducer, or most other electromechanical transducing devices, however, a number of design problems must be overcome, outstanding among which is the provision of a suitable means for clamping the transducing element to the transducer housing. Conventional clamping arrangements have typically included a pair of hard annular surfaces for rigidly clamping a metal-ceramic transducing element, or a pair of gaskets, at least one of which is rubber, for supporting opposite faces of a double-disc ceramic transducing element. In the latter instance, the gaskets, typically "O" rings, are compressed against the flat faces of the ceramics near their periphery, so that a pressure seal is provided, and the element held in the desired position. Unfortunately, the use of such clamping means has several disadvantages. First, and most importantly, the stiffness of the vibratory system is closely tied to the amount of compression applied to the rings. As a result, small changes in manufacturing tolerances, assembly techniques, or in rubber composition, produce varying amounts of compression, which, in turn, may often adversely affect the transducer frequency response characteristics, or, at least cause unwanted variations in such characteristics between individual transducers of the same lot. Second, the use of such gaskets leads to the possibility of element damage due particularly to uneven compression, either in manufacture or assembly, or to fracture of the element if an overly unyielding system is dropped or subject to impact. Additionally, the use of a rubber material in the element supporting structure can introduce an undesirable and virtually uncontrollable time dependent variation in the transducer frequency response characteristics, by virtue of changes that occur in the physical properties of the rubber as it ages. Alternatively, the use of rigid clamping in a metal-ceramic transducer to avoid the problems associated with rubber gaskets is accompanied by similar undesirable variations in per-

formance as well as increased danger of damage due to physical abuse, unevenness in the seating surface, and temperature changes.

To avoid the problems inherent in the use of rubber washers and rigid clamping, other prior art arrangements, particularly those in which the transducing element is bonded to a thin metallic diaphragm, have used cement, epoxy, or other adhesive material to maintain the composite diaphragm-element structure in its desired position within the transducer housing. However, in such instruments, the cementing process may result in undesirably high or nonuniform stresses in the diaphragm, thereby adversely affecting the transducer frequency response characteristic. Additionally, the cement adds an extra degree of complexity to the transducer manufacturing operation, and does not allow radial expansion and contraction of the plate due to ambient temperature changes without damage to the transducer.

Accordingly, it is the broad object of the present invention to provide an electroacoustic transducer, preferably of the piezoelectric ceramic type, having an improved means for clamping the transducing element of either the double-disc or the metal-ceramic type to the transducer housing.

An additional object of the invention is to provide a clamping means for an electromechanical transducing element wherein the stiffness of the vibratory system is relatively uniform, and independent of age induced variations, so that a stable transducer frequency response characteristic may be achieved.

Further objects of the invention include the provision of such a clamping means that does not require the use of cement, and that permits temperature induced radial movement of the transducing element without transducer damage.

SUMMARY OF THE INVENTION

Each of the foregoing and additional objects are achieved in accordance with the principles of the invention by the provision in an electroacoustic transducer of magnetic means for clamping the transducing element to a transducer housing. More particularly, an electromechanical transducing element, such as a piezoelectric ceramic, is bonded to a magnetic plate or diaphragm, and the plate nested on an inwardly facing generally annular lip provided in the transducer housing. In like manner, a double-disc transducer may be magnetically clamped if it is first attached to a thin angular ring of magnetic material having the same outside diameter as the ceramic discs. One or more magnets attached to the housing below the plate, or embedded in the housing lip, serve to semi-rigidly clamp the composite diaphragm-element structure to the housing, thereby maintaining it in desired position. By suitably dimensioning the lip boundaries slightly larger than the outer edges of the plate, small amounts of radial expansion and compression due to ambient temperature variation are enabled, while gross radial movement of the composite structure is inhibited. Accordingly, transducer damage due to temperature variation is avoided. Additionally, the advantageous provision of clamping means that do not require the use of rubber gaskets or other rigid clamping means enables the attainment of a desired degree of clamping stiffness

which is not time dependent, but which is controlled only by the number and positions of the magnets employed and their attractive forces. Since cement is not required, the high and non-uniform stresses caused thereby are eliminated.

BRIEF DESCRIPTION OF THE DRAWING

The aforementioned and other features and advantages of the instant invention will become more readily apparent to persons skilled in the art by reference to the following detailed description, when read in light of the accompanying drawing, in which:

FIG. 1 is a central cross-sectional view of an electroacoustic transducer constructed in accordance with the principles of the invention;

FIG. 2 is an exploded view, in perspective, of one arrangement of the magnetic clamping means of the transducer of FIG. 1;

FIG. 3 is a view, similar to FIG. 1, of another embodiment of the invention, and

FIG. 4 is an exploded view, in perspective, of yet another magnetic clamping arrangement in accordance with the invention.

DETAILED DESCRIPTION

Referring now to FIG. 1, there is shown in central cross-sectional view an electroacoustic transducer constructed in accordance with the principles of the invention. The transducer comprises a housing, designated generally at 10, defining an internal chamber 11, and a planar electromechanical transducing element 12 supported by a magnetic diaphragm 15 within the chamber. Means for clamping the composite element-diaphragm structure 12, 15 to housing 10 include magnets 13 and 14, to be more fully described hereinafter.

Transducing element 12 may be of the piezoelectric ceramic type, and comprise a disc or slab of a poled ferroelectric ceramic material such as barium titanate, lead zirconate-lead titanate, or sodium potassium niobate. The disc may be fabricated in various ways, one of which is fully described in application, Ser. No. 190,209, filed Oct. 18, 1971, by T. C. Austin and myself, entitled "Electroacoustic Transducer Having Improved Transducing Element Supporting Means" and assigned to the same assignee. After fabrication, electrodes are affixed to both faces of the ceramic disc, such as electrodes 12a and 12b, shown greatly enlarged in FIG. 1 for the purpose of illustration. The electrodes may be formed from thin sheets of metal foil cemented to the ceramic faces, or by depositing a thin metallic layer directly onto the ceramic. Thin metal foil leads 16 and 17 are attached to electrodes 12a and 12b, respectively, for enabling connection to transducing element 12.

Transducing element 12 is next affixed to a magnetic plate or diaphragm, such as diaphragm 15, which serves to support element 12. Diaphragm 15 may be fabricated from a thin slab of magnetic material i.e., a material that is attracted by a magnet, such as nickel-steel, having a surface area at least coextensive with the area of element 12. While in certain cases, the outer peripheries of element 12 and diaphragm 15 may be congruent, it may be advantageous in other instances, to be explained hereinafter, to employ different shapes for the aforesaid components, and/or nonsymmetri-

cally locate element 12 with respect to diaphragm 15. Fastening of element 12 to diaphragm 15 may be accomplished by applying a layer of cement, epoxy, or other suitable adhesive therebetween, and by applying pressure thereto. If desired, lead 17 may be attached to diaphragm 15 instead of electrode 12b; in this event, the cement used must be electrically conductive, or alternatively, a very thin layer of nonconducting cement may be employed, provided metal-to-metal contact between electrode 12b and diaphragm 15 is assured when these components are pressed together. To prevent rupture or damage to the element-diaphragm bond due to temperature changes, the coefficient of thermal expansion of the magnetic material is preferably selected to be comparable to the thermal coefficient of element 12.

The assembled element-diaphragm structure (12, 15) is seated on an inwardly extending lip 18 provided around the inner sidewall 19 of a cup-shaped body member 20, preferably plastic, which forms the major part of housing 10. Lip 18 serves to support diaphragm 15 within chamber 11, and to maintain it in spaced relation from the inner bottom wall 28 of member 20. The inner side walls 19 of member 20 above lip 18 are arranged to be slightly larger than the outer extremities of diaphragm 15, so that the latter may expand due to ambient temperature variations without causing damage to the transducer. Embedded in lip 18, in accordance with the invention, are one or more magnets, such as magnets 13 and 14 shown in FIG. 1. Magnets 13 and 14 may be fabricated from Alnico V, with poles typically 0.050 by 0.100 inch, with a height of 0.040 inch, connected by a suitable bar section. Each of the poles of magnets 13 and 14 may advantageously be arranged to be flush with the upper face of lip 18, and, where two or more magnets are utilized, they may be spaced substantially equally around the periphery of lip 18. The attractive force between magnets 13 and 14 and diaphragm 15, typically on the order of 10 grams, serves to semi-rigidly clamp the composite element-diaphragm structure to member 20. Thus, while piston-like motion of the composite-element diaphragm structure in a direction perpendicular to the faces of element 12 and diaphragm 15 is inhibited by magnetic clamping, movement in the radial direction is enabled by the relatively small force required to overcome friction between diaphragm 15 and lip 18.

Assembly of the transducer of FIG. 1 is completed by next fastening leads 16 and 17 to terminal rivets 21 and 22, respectively, which extend through the sidewall 19 of member 20. A frontal plate 23 having an aperture or port 24 drilled therethrough is then positioned atop the open end of member 20, and suitably fastened thereto by retaining screws, such as screws 26 and 27. A slab of acoustic resistance material 25 may be placed across port 24 prior to positioning plate 23, the port and resistance material serving as an acoustic low pass filter and a damping means, respectively, according to well-known acoustic design theory. If desired, a ring 29 of magnetic material having an outer diameter substantially equal to that of diaphragm 15 may be placed atop diaphragm 15, as shown in FIG. 1. This ring serves to decrease the reluctance of the magnetic flux paths and greatly increase the holding force of magnetic attraction.

Operationally, the transducer of FIG. 1, when used as a microphone with a piezoelectric ceramic transducing element, transforms acoustic energy to electrical energy by converging the cupping or spherical bending action induced in element 12 by the incoming sound waves to a voltage generated across electrodes 12a and 12b by piezoelectric action. This voltage may be connected to a desired load by its attachment to the external portions of terminal rivets 21 and 22. The frequency response characteristic of this conversion is largely a function of the mechanical properties of the diaphragm 15 supporting the transducing element 12, the effective mass of the vibratile system, and the nature of the clamping between diaphragm 15 and housing 10. The first is controlled during transducer design, by taking proper account of the dimensions of diaphragm 15, and the physical properties of the material selected (Young's modulus, for e.g.). The last, in accordance with the invention, is determined by the number, positions, and attractive forces associated with the magnetic means positioned within the housing.

One arrangement of the magnetic means contained within housing 10 that has been found particularly suitable for a transducer intended for use in telephone applications is depicted in FIG. 2. As shown therein, three magnets 30, 31 and 32 are spaced substantially equally around the periphery of lip 18, which, in this embodiment, is generally circular. Understandably, the use of only three clamping points, as compared to more than three, reduces the available magnetic clamping force. This can be rectified by the use of a reluctance reducing ring similar to ring 29 of FIG. 1, and/or by fabricating magnets 30, 31, and 32 from a "super" magnetic material such as Co_5Sm , which is appreciably more powerful than magnets constructed from Alnico V. The use of three point clamping serves to reduce the undesirable resonant peak in the transducer frequency response characteristic by upsetting the natural resonance of the element-diaphragm structure. Further peak reduction may be accomplished, if desired, by mounting a transducing element 12 having a first geometrical shape on a diaphragm 15 having a second, different shape. For example, the first shape may be round and the second square, or vice versa, or rectangular shapes may be utilized. Additionally, as mentioned previously, nonsymmetrical location of element 12 with respect to diaphragm 15 may be employed. In each instance, the natural resonance of the vibratory system is upset, and the resonant peak exhibited in the transducer frequency response characteristic is accordingly reduced.

Irrespective of the particular magnet configuration utilized and shape of the components selected, it should be apparent that the provision, in accordance with the invention, of magnetic means within chamber 11 of housing 10 to clamp diaphragm 15 to the housing meets the desired objectives of a clamping system whose stiffness is independent of time, since the variation in magnetic attraction of permanent magnets is minimal over time spans corresponding to transducer life-expectancy. Additionally, the need for rubber in the clamping system is obviated, thereby eliminating varying degrees of clamping compression and stiffness in favor of a system wherein the desired degree of clamping is easily obtained by proper design of magnet

strength and location. As a result of the elimination of cement or other adhesives from the clamping system, high or nonuniform stresses associated with glueing are similarly eliminated, and transducer fabrication is simplified. In addition, as mentioned previously, damage to the transducer due to thermal expansion of diaphragm 15 is minimized by allowing a small amount of radial clearance between the periphery of diaphragm 15 and inner side walls 19, and by properly selecting the thermal coefficients of element 12 and diaphragm 15.

Referring now to FIG. 3, there is shown an alternate configuration of the transducer of FIG. 1. In this embodiment, a single magnet 50 is seated on the bottom inner wall 28 of member 20, and arranged to exert an attractive force on diaphragm 15. The magnet is arranged to have sufficient strength to clamp the composite element-diaphragm structure in its desired position on lip 18. A small degree of clearance is maintained between the upper portions of magnet 50 and the lower face of diaphragm 15, so that vibration thereof is not impeded.

Still another magnetic clamping arrangement in accordance with the invention is depicted in FIG. 4. In this embodiment, transducing element 12 and diaphragm 15 are clamped to a transducer housing by an annular magnetic ring 60 fabricated from a material such as Alnico IX having a high coercive force. Such materials may be locally magnetized, thereby creating a plurality of alternate north and south poles around the periphery of the ring. To enhance the attractive force, a first ring 61 of magnetic materials such as iron or steel may be placed atop diaphragm 15 in alignment with magnetic ring 60, and/or a second similar ring 62 may be located beneath ring 60. Rings 61 and 62 serve to decrease the reluctance of the magnetic flux paths created by magnetic ring 60, and thus increase the magnetic attraction thereof.

Many modifications and adaptations of this invention will readily become apparent to persons skilled in the art. For this reason, it is intended that the invention be limited only by the appended claims. For example, it should be apparent that the heretofore described electroacoustic transducer may function equally well as a receiver for converting electrical energy into sound energy, or as a microphone. Additionally, the means employed for clamping transducing element 12 to housing 10 may, on occasion, be useful in an instrument wherein said element is of an electromechanical type other than a piezoelectric ceramic. Still further, while the magnet means utilized in accordance with the invention are advantageously permanent magnets of any well-known variety, the use of electromagnets may sometimes be worthwhile.

What is claimed is:

1. An electroacoustic transducer comprising an electromechanical transducing element, a housing defining an internal chamber for containing said element, a diaphragm of magnetic material for supporting said element, and at least one magnet for clamping said diaphragm to said housing within said chamber.

2. The invention defined in claim 1 wherein said housing includes an inwardly extending lip for supporting said diaphragm and wherein said magnet is imbedded within said lip.

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3. The invention defined in claim 2 wherein said lip is generally circular and wherein three magnets are spaced substantially equally around said lip.

4. The invention defined in claim 3 wherein said transducing element is rectangular.

5. The invention defined in claim 4 wherein said transducing element comprises a poled ferroelectric ceramic material.

6. The invention defined in claim 5 wherein said ceramic material is selected from the group consisting of barium titanate, lead zirconate-lead titanate, and sodium potassium niobate.

7. The invention defined in claim 1 wherein said housing includes a cup-shaped member having sidewalls, a bottom wall, and an inwardly extending lip around said sidewall for supporting said diaphragm in spaced relation from said bottom, and said magnet is fastened to said bottom wall and arranged to exert an attractive force on said diaphragm.

8. An electroacoustic transducer comprising an electromechanical transducing element, a housing defining an internal chamber for containing said element,

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a magnetic diaphragm for supporting said element, an inwardly extending lip within said chamber of said housing for supporting said diaphragm, and magnetic means for clamping said diaphragm to said lip.

9. The invention defined in claim 8 wherein said magnetic means includes at least one magnet imbedded within said lip.

10. The invention defined in claim 8 wherein said lip is generally circular, and said magnetic means includes three magnets spaced substantially equally around the periphery of said lip.

11. The invention defined in claim 10 wherein said transducer further includes a magnetic ring atop said diaphragm for increasing the diaphragm clamping force.

12. The invention defined in claim 8 wherein said housing includes an inner bottom wall, and said magnetic means is fastened to said bottom wall and arranged to exert an attractive force on said diaphragm.

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