Nov. 1, 1966 W. F. EVANS 3,283,086

VERSATILE EXTENSIVE AREA SOUND REPRODUCER OR AUDIO TRANSDUCER

Filed June 17, 1963 2 Sheets-Sheet 1

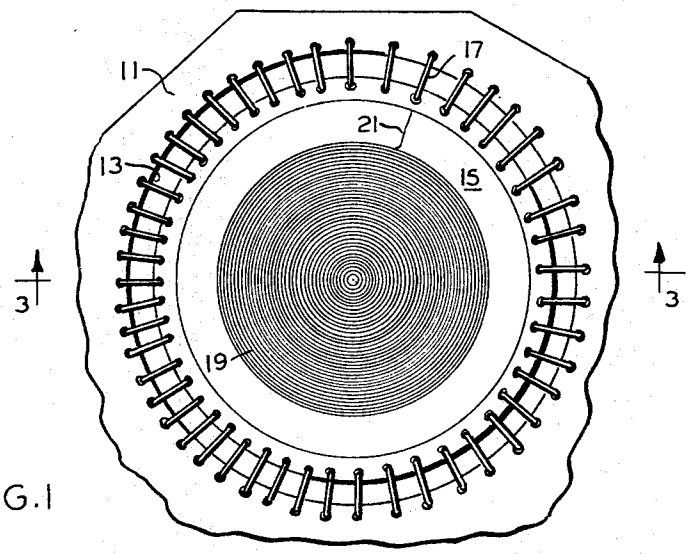


FIG.1

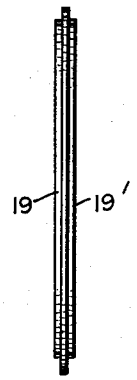


FIG.2

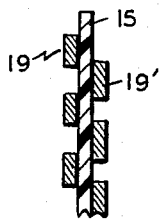


FIG.2A

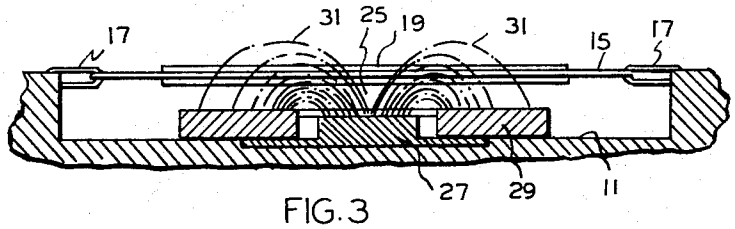


FIG.3

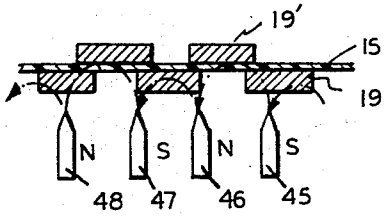


FIG.4

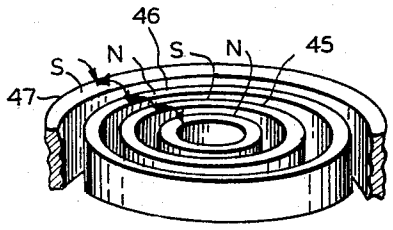


FIG.5

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VERSATILE EXTENSIVE AREA SOUND REPRODUCER OR AUDIO TRANSDUCER

Filed June 17, 1963 2 Sheets-Sheet 2

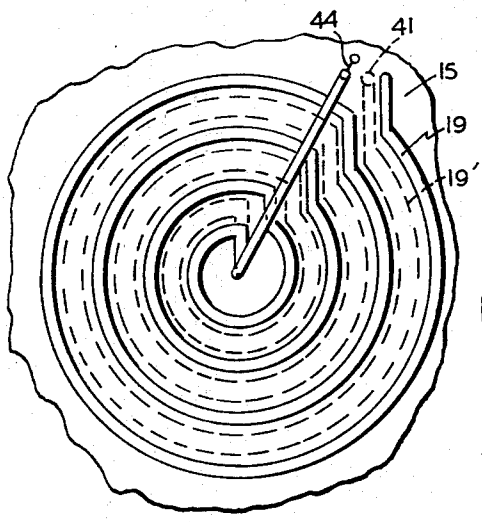


FIG. 6

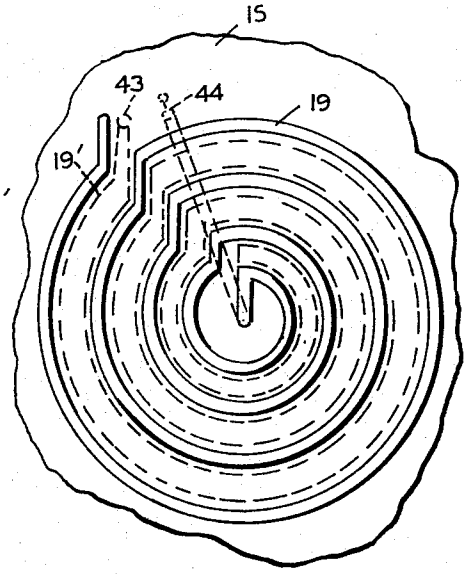


FIG. 7

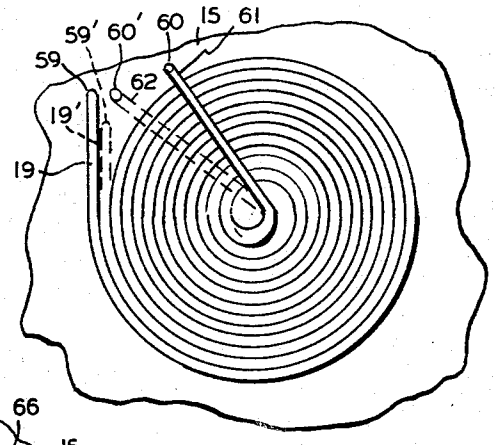


FIG. 8

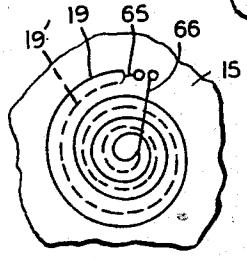


FIG. 8A

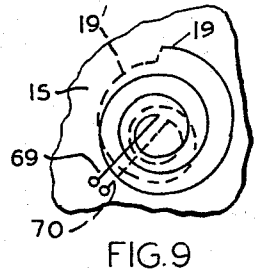


FIG. 9

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United States Patent Office 3,283,086 Patented Nov. 1, 1966

3,283,086

VERSATILE EXTENSIVE AREA SOUND REPRODUCER OR AUDIO TRANSDUCER

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Filed June 17, 1963, Ser. No. 288,282
10 Claims. (Cl. 179—115.5)

The present invention relates to the transducer field in general and more particularly to the provision of novel speaker or microphone embodiments susceptible to incorporation into entertainment type instruments such as home TV, high fidelity or stereo systems, and the like. Also, other commercial and military use is contemplated.

The transducer of the subject invention is of the type capable of producing audio sound output in response to applied audio signals or the inversion thereof; namely, providing an output audio frequency voltage or current in response to actuation by sound wave energy. It will be described in detail in connection with the speaker use; it being borne in mind that the principles are applicable to the microphone use.

Over the years speakers have become increasingly more complex devices for the reason that compensation with respect to highs and lows and other characteristics have been added, along with frequency extenders and various other improvements which has resulted in a modern day relatively complex device. This applies equally to the electro-dynamic loud-speaker employing the cone shaped diaphragm driven by a voice coil, disposed in a constant magnetic field, as well as the well known electro-dynamic loud-speaker of the type having a periphery clamped diaphragm with annular ribs or ridges and employing conductors situated in magnetic fields for power drive movement.

An important object of the present invention is the provision of an extremely simple and readily fabricatable speaker or microphone, exhibiting even improved characteristics over those commonly found in commercial devices, as will be particularly pointed out. The simplicity of the structure is occasioned, not only by fewer components, but by the simplest of components.

For example, the diaphragm rather than being of the cone or annular ribbed type is flat. The driving energy is effective generally perpendicularly throughout the area of the diaphragm rather than concentrated at the apex of a cone or within a ribbed channel about a small portion thereof, as in presently utilized diaphragms.

The voice coil or its counterpart is preferably deployed on the diaphragm, as a printed circuit of various configurations to be described, which may be disposed on one or both sides thereof in the form of a continuous conductor, as series aiding coils or as parallel coils.

The magnetic field for the voice coil may be produced by the simplest of permanent magnets in one embodiment, or by a novelly arranged cooperating magnetic system in another embodiment.

In either event, the thinnest of speakers may be produced from the smallest to large sizes heretofore practically unavailable. They are particularly suited for use as single or multiple cabinet wall faces for entertainment reproducing devices or as detachable picture-like speakers suitable to stereophonic orientations and modern decor up to and including room wall sizes.

The invention finds utility in commercial and military detecting networks, as for example as an audio transducer for automatically detecting mines or the like upon the approach of vessels or as one of a plurality of deployed detectors for plotting courses of enemy vessels or vehicles. The elements of the invention may readily be epoxied and the entire device rendered corrosion resistant. Also

the detector may be submerged to great depths without pressure influence because of the flat diaphragm construction and because a pressure resisting external housing is unnecessary, the operative force connection being simply magnetic fields for use underwater or in the atmosphere.

More particularly, the diaphragm may comprise a suitable fabric, preferably in circular configuration, having silkscreened thereon (or otherwise following printed circuitry technique deployed thereon) a continuous conductor voice coil in discrete geometrical configuration form. In one embodiment this circuit takes the form of concentric circles where as in another embodiment a spiral deployment is utilized. Other geometrical patterns may follow the principles herein set forth. In any event, the magnetic field is arranged to encompass the voice coil configuration in a flux pattern approaching the greatest uniformity available in a practical device.

The diaphragm is preferably peripherally suspended in a manner leaving it free to float, such that mechanical resistance is minimized. Since the entire diaphragm moves as essentially a single unit, whether a large or small diaphragm is employed, uniformity of mass will be distributed over the entire diaphragmatic surface rather than being concentrated at the center or in the form of widely spaced rings extending to the periphery. Naturally, the inverse is true also when the diaphragm is employed as a microphone pick-up for remote sounds.

The voice coil may be comprised of a continuous conductor in either embodiment. It is, of course, desirable that the single source or concentric source magnetic field or fields influence the entire length of the conductor in an additive manner such that the elemental currents developed will flow in the same direction.

The single conductor may comprise a double spiral configuration, which is wound in like direction on both surfaces of the diaphragm, when viewed directly (not through a surface). For example, if the conductor is laid down in a counter-clockwise spiral on a first surface of the diaphragm, it may penetrate the diphragm at the outer edge and form a spiral on the reverse side, also wound in a counterclockwise direction when viewed directly. It will be realized that such spirals are not interleaved but, in fact, are oppositely wound. However, when a single source magnetic field is deployed adjacent to either surface, additive currents are developed along the increments of the spirals such that they may be considered as being series aiding voice coils with external terminals being provided by the ends of the single conductor disposed at the inner areas of the spirals.

Alternatively, when one spiral is wound in a counterclockwise direction and the other in a clockwise direction, each as viewed directly, then the conductor may penetrate the diaphragm near the center and an external lead is brought out from this center point to comprise one terminal, the other terminal being connected to the free ends of the spirals such that the two spiral configurations are connected in parallel for increased current production. It will be understood that the outer ends of the conductor may also penetrate the diaphragm and be connected to an external lead. Alternatively the spirals may be laid down separately and the ends brought out separately to provide two coils, connectible in series of parallel additive relation. The arrangement also, of course, assumes a single uniform magnetic source in juxtaposition with one of the diaphgram surfaces and permits the spirals to be interleaved.

In the concentric circular deployment, both series and parallel arrangements are contemplated, each with respect to a single magnetic source and also with respect

to a multiple magnetic source of a concentric magnet type.

Considering first the single source magnetic field, the continuous conductor may be laid down in like directions on both sides of the diaphragm, when viewed directly, to provide a series aiding configuration. For example, the conductor may have a first terminal near the outer edge of the diaphgram and form concentric circles decreasing in diameter, in a counter-clockwise direction, toward the center of the diaphragm where the conductor may penetrate to form interleaved concentric circles on the opposite side of the diaphragm, also winding in a counterclockwise direction, when the diaphgram is turned over and viewed directly. This configuration terminates in a second external terminal disposed outwardly of the concentric circles.

When the multiple magnetic source is employed, a like deployment of the conductor admits of paralleling of the two concentric configurations to provide increased current output. In other words, in the situation where the conductor extends from an external terminal in a counterclockwise diminishing configuration to penetrate the diaphragm at its center and then form a counterclockwise expanding interleaved configuration to terminate in an external terminal, the two external terminals are connected together to form one ouput terminal with the other output terminal being joined to the middle point of the conductor (the point of penetration between the configurations).

The other alternatives contemplate the use of oppositely wound concentric circles conveniently connected in parallel for use with a single source and oppositely wound concentric circles conveniently connected in series at the outer edge for use with a multiple or concentric magnetic field source.

The interleaving feature of the embodiments described enables the voice coil to approximate a thin pliable metal disc insofar as the magnetic field is concerned, thereby offering a maximum number of conductive paths distributed throughout the extensive area within the magnetic field influence. As a matter of fact, preferably the interleaved concentric circles and spirals actually overlap somewhat such that the diaphragm presents no uncovered areas throughout the configurations.

These particular deployments enable the optimum use of practical magnetic sources to provide a practical commerical device. For example, the spiral deployment outlined is readily operative in a uniform magnetic field which distributes the effective magnetic forces across the diaphragm in a uniform manner. As a matter of fact, when a single two pole concentric magnetic field approach is utilized consisting of, for example, a central core of one polarity and an annular ring of another polarity, the spiral type voice coil receives substantially uniform exposure. In the case of such magnetic sources where it is found that, as a practical matter, a greater flux concentration occurs near the center of the magnet, it has been found desirable to graduate the spiral deployed on each side of the diaphragm to permit some spacing (uncovered diaphragm) in the central area where the flux is concentrated with increasing coverage in the decreasing regions thereby compensating to yield uniform diaphragm actuation.

The concentric circular diaphragm is particularly suitable to use with a multi-pole concentric circle magnet, adjacent magnetic structures being oppositely polarized. For example, a core in the form of a north pole is surrounded by an annular maget polarized south, in turn surrounded by a magnetic north, etc. In this manner, each incremental region of the diaphragm is exposed to the flux (due to adjacent annular poles) and the diaphragm is substantially uniformly actuable.

With the foregoing in mind, it is among the objects of this invention to provide a novel and effective audio transducer.

It is is a further object to provide such a transducer susceptible to extensive dimensions for greater sensitivity in the detection function and greater moving power for the sound dissemination function.

A still further object is the provision of such an audio transducer capable of being epoxied and subjected to adverse conditions of the elements without concern as to corrosion or pressure differential problems.

It is yet another object of the invention to employ uniquely cooperative components which are readily manufacturable or commercially available.

The invention will now be described in connection with its application to certain perferred embodiments explained in detail in conjuction with the appended drawing wherein:

FIG. 1 is a view in elevation of a typical transducer, operable in accordance with the principles of the present invention.

FIG. 2 is a view in end elevation of the structure of FIG. 1.

FIG. 2A is a view of a portion of the structure of FIG. 1 or FIG. 2, greatly enlarged and in section to show how the continuous conductor is laid down in interleaved fashion relative to opposite sides of the diaphragm.

FIG. 3 is a view in section of the apparatus of FIG. 1.

FIG. 4 is a further detailed view of a structure of a different embodiment.

FIG. 5 is a view in perspective of a suitable magnetic source for use with certain embodiments of the invention.

FIGS. 6 and 7 show respectively elevational views of a concentric circular deployment of a continuous conductor starting on one side of the diaphragm and extending along the reverse side thereof.

FIG. 8 is an elevational view of a spiral type deployment.

FIG. 8A is a schematic illustration of an alternative type spiral configuration, and

FIG. 9 is a schematic illustration of graduated oppositely wound spiral configurations.

Referring now to FIG. 1 there is shown generally a hoop or supporting structure **11** having a central opening **13** for accommodating a thin diaphragm **15**. The diaphragm is maintained in a taut condition by flexible resilient supporting strands **17**, laced or grommeted between the periphery of the disc **15** and the supporting structure **11**. A voice coil or continuous conductor **19** is shown partly deployed on the visible surface of the diaphragm **15**, the visible end of the conductor **21** being brought out near the upper periphery of the diaphragm with the remainder (not shown in FIG. 1) of the conductor penetrating the diaphragm **15** in the center thereof to develop a further configuration **19'** (FIG. 2) on the reverse side of the diaphragm **15**. Various modifications of the configuration will be described in detail hereinafter.

FIG. 2A is a view of a portion of the structure of FIG. 2, greatly enlarged to show how the continuous conductor **19–19'** is laid down in interleaved fashion relative to opposite sides of the diaphragm **15**. It will be noted that the width of the conductor **19–19'** exceeds the width of the spacing between adjacent turns thereby providing an effectively, and completely metalized disc.

FIG. 3 is a view of the structure of FIG. 1 with a magnetic source **25** in association therewith. The diaphragm **15** is shown tautly stretched by supporting strands **17** such that the magnetic source **25**, consisting of a central core **27** and annular pole piece **29**, is disposed in fixed relation thereto being retained by, for example, a portion of the supporting structure **11**. If it is considered that the core **27** is a north pole and the annular ring **29** the south pole, then magnetic flux is caused to flow out of the north pole, through the diaphragm, and back into the south pole. Obviously, the magnetic source **25** may be of the permanent magnet or electric coil type and in either event is primarily used to provide a substantially uniform flux field, as shown by the lines **31**

effective on the area of the conductor configurations **19–19′**.

Typical materials may include gold for the conductor **19–19′**, which may be laid down by printed circuit techniques. The diaphragm **15** may comprise a suitable synthetic membrane of 0.015 inch in thickness. By way of example, the outside diameter of a typical embodiment would measure 12–24 inches or longer for the diaphragm with the conductor deployment occupying some 8–16 inches or more of the central portion. In such a model the thickness of the conductor may be of the order of 0.002 inch with a typical conductor width being 1/16 inch, more or less.

The disc or diaphragm **15** may be of synthetic membrane and the disc and conductor deployments may be cemented to a thin 1/8 inch wooden skin for certain applications. Also a thin flat skin of speaker cone paper may be attached to the entire surface of the membrane along either side of the double deployed circuit by adhesive to provide damping effects. The resilient material **17** may be bunge cord threaded through grommets to render the membrane free floating. For other applications, the membrane may be attached to supporting structure in the form of a hoop which also provides high damping.

The conductor **19–19′** may be deployed in various configurations, such as those depicted in FIGS. 6 through 9, now to be described.

Considering first the concentric circle configuration of FIGS. 6 and 7, it will be noted that when the diaphragm **15** is viewed from one surface, as in FIG. 6, the conductor **19** traces out concentric circles in a clockwise direction toward its center from external terminal **41** of the diaphragm. The conductor is shown penetrating the diaphragm center to come out on the backside of diaphragm **15** as conductor **19′** extending outwardly in increasing diameter circles to provide terminal **43**. Viewed from its surface, the direction of winding is opposite to that of FIG. 6, being counterclockwise from outside to inside. The interleave of the conductor circles on opposite surfaces is apparent from a comparison of FIGS. 6 and 7, as is also the effective overlap.

In operation, the diaphragm **15** is deployed in proximity with a magnetic source of, for example, the concentric pole type of FIG. 5. This deployment is shown in exaggerated partial view in FIG. 4, wherein it may be seen that the concentric magnetic poles **45**, **46**, **47** and **48** occupy positions relative to the conductor **19–19′** to establish flux paths through the conductor to develop current in an additive direction, the flux lines encircling the conductor portions on the opposite halves of diaphragm **15** from opposite directions. Thus, it may be appreciated that the concentric poles of the magnetic source are quite thin, but the structure is practical of manufacture.

Use of a multiple-concentric magnetic source with the oppositely wound concentric circular deployments results in the production of currents in opposite directions in the conductors **19–19′**. They may be paralleled by joining terminals **41** and **43** as one outside terminal, with lead **44** (to the center point of either conductor **19** or **19′**) serving as the other output terminal. They may be connected in series conveniently by letting conductor **19–19′** be continuous at the outer edge to penetrate diaphragm **15** at the location of terminals **41** and **43**, with the output terminals then both being brought out from the center of the respective surfaces, as by conductors such as **44**. In this event the single conductor **19–19′** has its free ends at the respective centers and the external connections may be made to either side or may both be on a single side of one of **19** or **19′** penetrates the central area.

The concentric circular type deployment of the conductor **19–19′** is also cooperative with the magnetic source **25** of the single variety (single north and south poles) wherein each conductor element is exposed to the substantially uniform field. For the oppositely wound conductors **19–19′**, the use of a single source produces currents in opposite directions along adjacent layers and accordingly it is desirable to connect the individual conductors **19–19′** in parallel. This is readily achieved by permitting penetration at both the outer and inner positions. Then connections are made to both points of penetration for paralleled coils. Alternatively, an outer end of one of conductors **19** or **19′** may be joined to an inner end of the other to provide a series arrangement of the two coils.

The conductors **19**, **19′** may overlap, as in FIG. 2A, or may be spaced sufficiently to leave uncovered gaps, as in FIGS. 6 and 7, on the diaphragm surfaces.

The single source **25** is also preferably the type employed with the spiral configurations of FIGS. 8, 8A and 9. In FIGS. 8 and 8A, the conductor **19** is deployed on one side of the surface **15** as a spiral and the conductor portion **19′** is interleaved therewith on the other surface of the diaphragm **15**. While the conductor **19–19′** may be continuous as in FIG. 8A, where it penetrates the diaphragm **15** near the conductor midpoint and also near the outer edge of the spirals, it will be appreciated that the spirals may be each separate, as in FIG. 8, such that connection of corresponding ends **59–59′** and **60–60′** (of inner connections **61** and **62**) may parallel the spiral circuits or connection of say inner end **60′** to outer end **59** provides an additive series arrangement.

For practical reasons, the spiral type voice coil is interposed in a uniform type magnetic field, it being impractical to manufacture a spiral type magnet. The spirals of FIGS. 8 and 8A are interlaced because the spirals on opposite sides of the diaphragm **15** are wound in different directions, when viewed directly.

In FIG. 8A, the conductors **19–19′** are shown penetrating the diaphragm at both inner and outer locations to comprise a closed loop of two coils. The external terminal connections **65** and **66** then provide paralleling of the coils.

A graduated spiral configuration including like wound spirals is depicted in FIG. 9. The spirals are concentrated near the center as shown by the conductor **19–19′** and adjacent turns are spaced further apart toward the periphery. This structure is suitable for cooperation with a typical magnetic source of the type shown in FIG. 3 at **25** wherein there is some flux concentration near the central core. The graduated deployment of the conductor tends to maintain the magnetic forces uniformly distributed across the diaphragm **15**. Also, the arrangement of FIG. 9 depicts spirals wound in like directions such that no interlacing is presented. However, the coils are adapted to additive series use by letting conductor **19–19′** be continuous by penetrating diaphragm **15** near the outer periphery with the inner ends being connected to external terminal connections **61** and **70**.

While the invention has been described in connection with its application to certain preferred embodiments, it will nevertheless be appreciated that other modifications will be apparent to those skilled in the art from a reading of the description hereof and such modifications within the principles of the invention are intended to comprise a part hereof, and thus the scope is to be limited only by the appended claims.

What is claimed is:

1. An extensive area transducer comprising, in combination, a flat diaphragm; means for resiliently supporting the diaphragm in a taut state; a continuous conductor coil deployed on both sides in spreading configuration from the central area of the diaphragm toward its edges; and means disposed adjacent one side of the diaphragm for producing magnetic flux lines linking substantially all increments of the conductor to generate current build-up therein upon relative movement between the flux lines and conductor coil.

2. The transducer of claim **1**, wherein the means for producing the magnetic flux lines comprises a single magnet consisting of an annular pole and a central hub pole.

3. The transducer of claim **1**, wherein the means for

producing the magnetic flux lines consists of a plurality of concentric magnets with adjacent magnetic poles being oppositely polarized.

4. An extensive area transducer comprising, in combination, a frame; a flat diaphragm; resilient means for supporting the diaphragm in a taut state relative to the frame; a continuous conductor coil deployed on both sides in spread-out configuration from the central area of the diaphragm toward its edges; and means substantially coterminous with the configuration supported by the frame and disposed adjacent one side of the diaphragm only for producing magnetic flux lines linking substantially all increments of the conductor coil to generate additive current build-up therein upon movement of the conductor relative to the flux lines.

5. The transducer of claim 4, wherein the conductor coil is deployed in the form of graduated interleaving spirals respectively disposed on opposite surfaces thereof; the spacing between adjacent turns of the spirals increasing from the outer edge to the center; and including external connections to the innermost ends of each spiral.

6. The transducer of claim 4, wherein the conductor coil is deployed in the form of interconnected substantially concentric circles with the circles on one surface being disposed in interleaved fashion relative to the circles on the opposite surface; the width of the conductor coil exceeding the spacing between adjacent circles; and including external connections to the ends of the conductor.

7. An extensive area transducer comprising, in combination, a diaphragm; means for maintaining the diaphragm flat and resiliently supporting it peripherally; a continuous conductor deployed on opposite surfaces of the diaphragm in the form of a spiral on each surface; said conductor penetrating the diaphragm at a location remote from the central portion of the diaphragm and said conductor having its free ends available for external connections; means supported in proximity to one of the flat surfaces of said diaphragm for directing magnetic flux therethrough to interlink the spiral lengths of the conductor with magnetic flux for producing a current in the conductor when relative movement is established between the diaphragm and said last-mentioned means.

8. An extensive area transducer comprising, in combination, a diaphragm; means for maintaining the diaphragm flat and resiliently supporting it peripherally; a continuous conductor deployed on opposite surfaces of the diaphragm in the form of a spiral on each surface; the spacing between adjacent turns of the conductor being less than the width of the conductor to permit overlay of the spirals; said conductor penetrating the diaphragm at least once; means supported in proximity to one of the surfaces only of said diaphragm for directing magnetic flux therethrough to interlink the spiral lengths of the conductor with magnetic flux; said last-mentioned means being oriented to direct flux about the conductor for producing a current in the conductor when relative movement is established between the diaphragm and said last-mentioned means; and means for paralleling the spirals to add the currents produced in each.

9. An extensive area transducer comprising, in combination, a diaphragm; means for maintaining the diaphragm flat and resiliently supporting it peripherally; a continuous conductor deployed on opposite surfaces of the diaphragm in the form of a plurality of concentric circles on each surface with the circles of one plurality being interleaved relative to the other; said conductor penetrating the diaphragm at least once; means supported in proximity to one of the surfaces of said diaphragm for directing magnetic flux therethrough to interlink the circle lengths of the conductor with magnetic flux for producing a current in the conductor when relative movement is established between the diaphragm and said last-mentioned means; and means for connecting the plurality of concentric circles in one of series and parallel relation.

10. The transducer of claim 9 wherein the means for directing magnetic flux comprises a plurality of magnetic poles in concentric arrangement with adjacent poles being oppositely polarized; the poles of one polarity being disposed in substantial alinement with the circular conductor segments on one side of the diaphragm and the poles of the other polarity being in substantial alinement with the circular conductor segments on the opposite surface of the diaphragm.

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