United States Patent

Winey

[15] **3,674,946**

[45] **July 4, 1972**

[54] **ELECTROMAGNETIC TRANSDUCER**

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[73] Assignee: **Magnepan Incorporated,** White Bear Lake, Minn.

[22] Filed: **Dec. 23, 1970**

[21] Appl. No.: **100,856**

[52] **U.S. Cl.** **179/115.5**, 310/25
[51] **Int. Cl.** **H04r 9/00**
[58] **Field of Search** ....310/15, 25, 27; 179/115.5 PV, 179/115.5 VC, 115.5 E, 115.5 ES; 335/279, 303, 306

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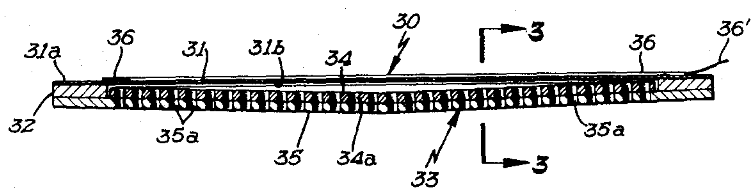
Primary Examiner—D. X. Sliney
Attorney—Williamson, Palmatier & Bains, George F. Williamson, H. Dale Palmatier and Herman H. Bains

[57] **ABSTRACT**

An electromagnetic transducer utilizing one or more vibratable diaphragms, each carrying one or more conductors which may be stacked upon each other on the diaphragm, and a flexible sheet magnet confronting the diaphragm and spaced therefrom and being magnetized in a direction through its thinnest dimension in elongate zones, following the configuration of the conductors on the diaphragm, the sheet magnet lying against a panel of ferromagnetic material; another diaphragm optionally located at the opposite side of the magnet, the diaphragm being stretched in many embodiments, and numerous vibratable areas with different resonant frequencies.

42 Claims, 34 Drawing Figures



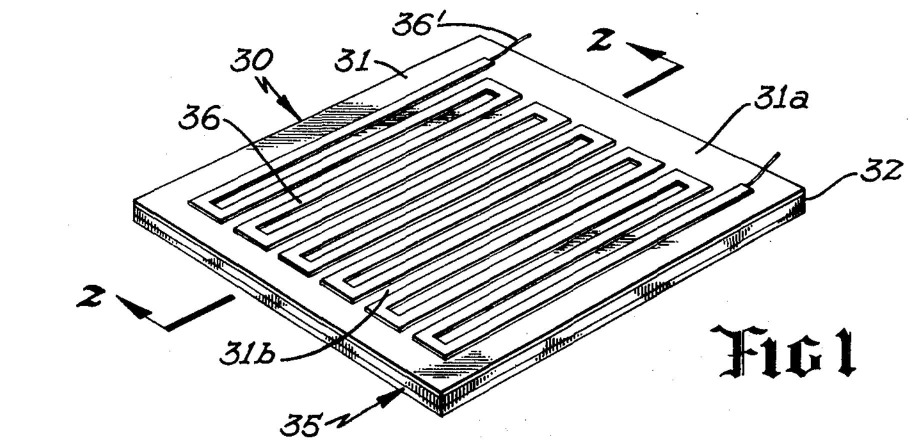


FIG 1

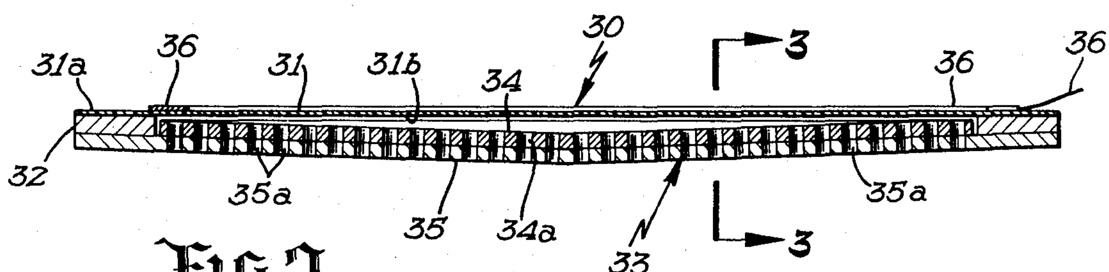


FIG 2

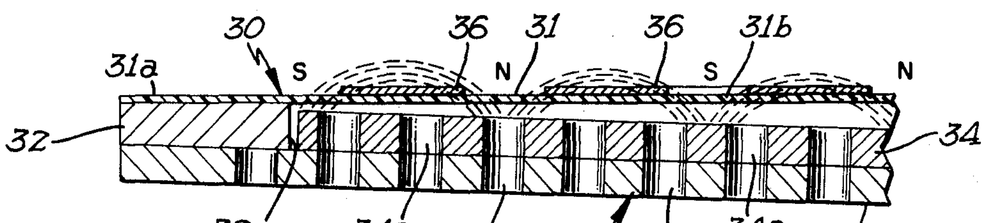


FIG 3

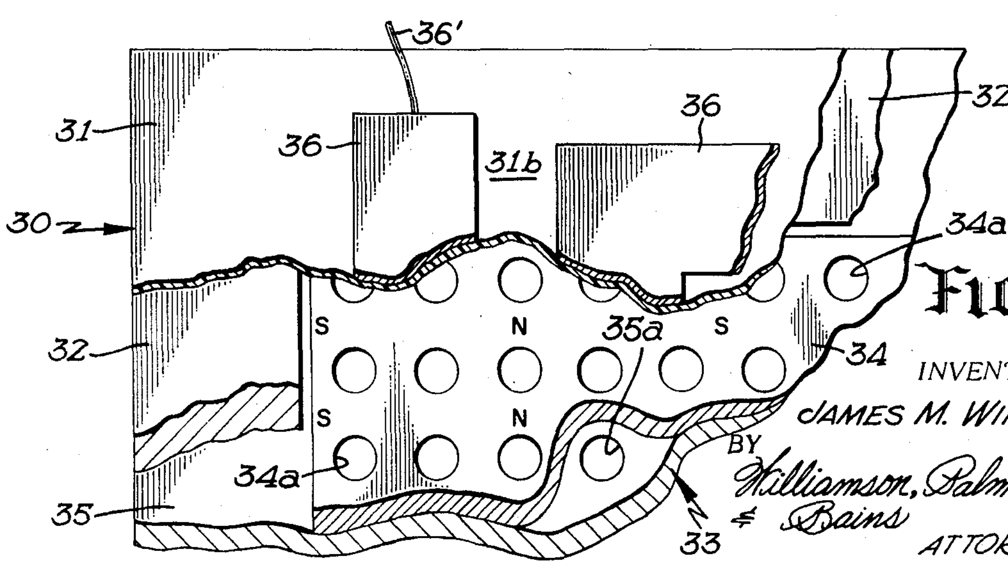


FIG 4

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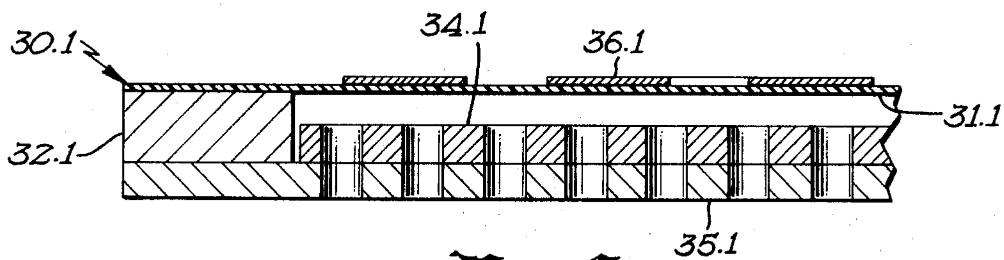

Fig 5

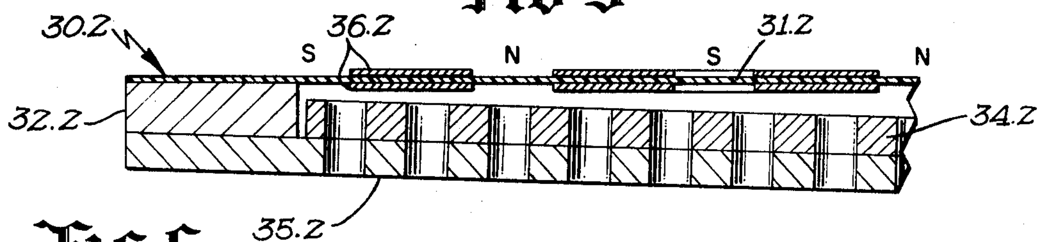

Fig 6

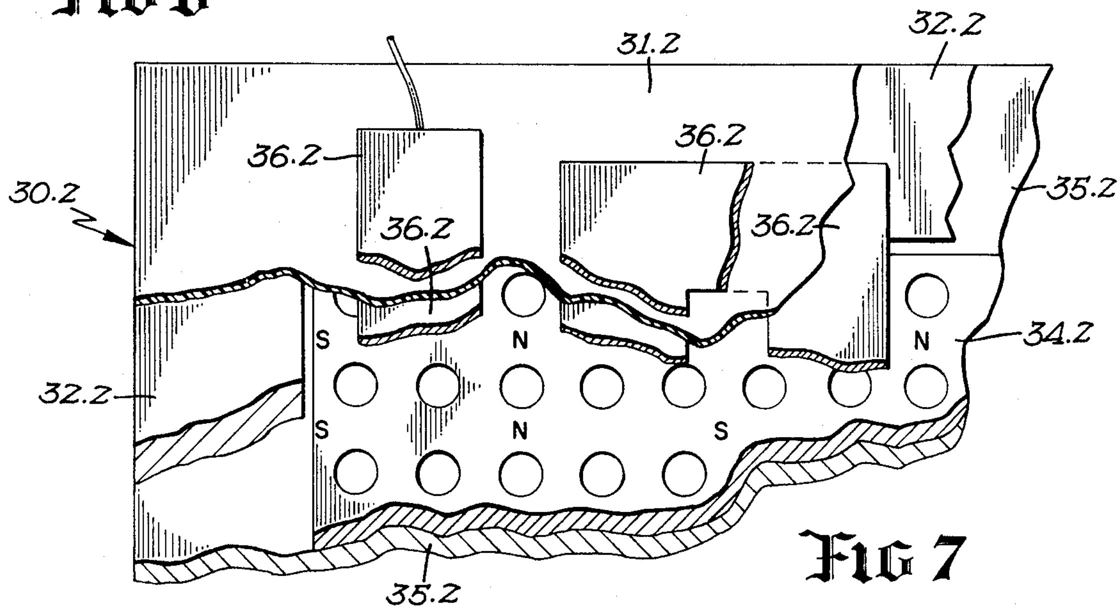

Fig 7

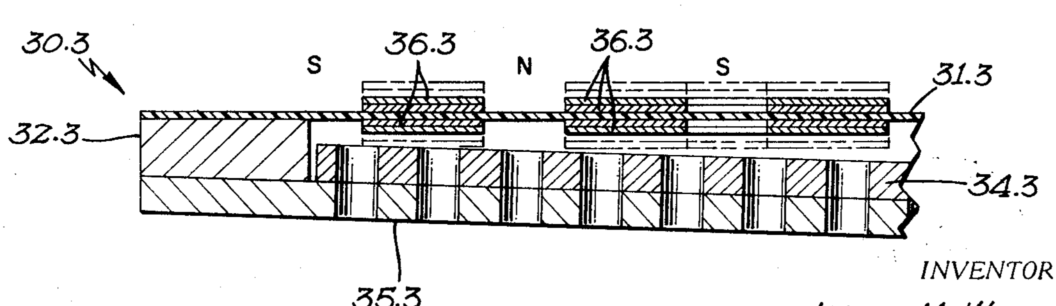

Fig 8

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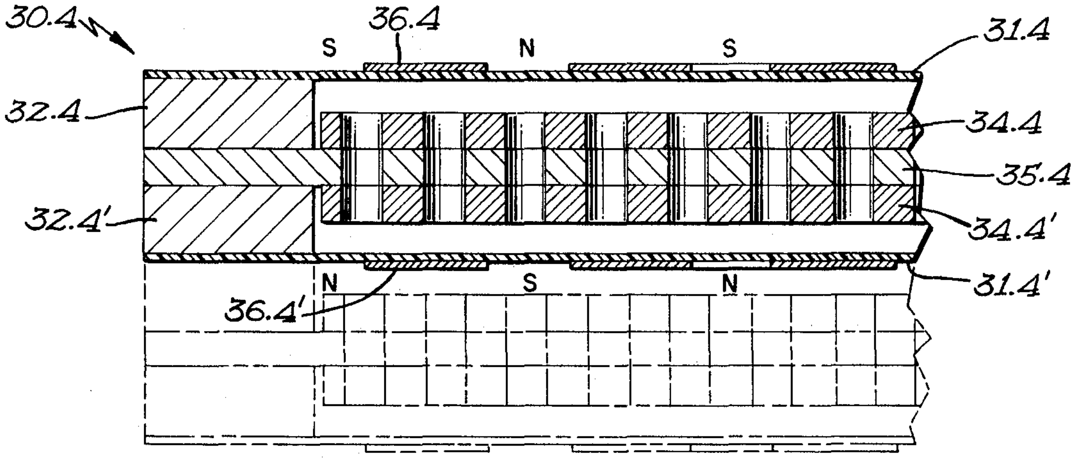

Fig 9

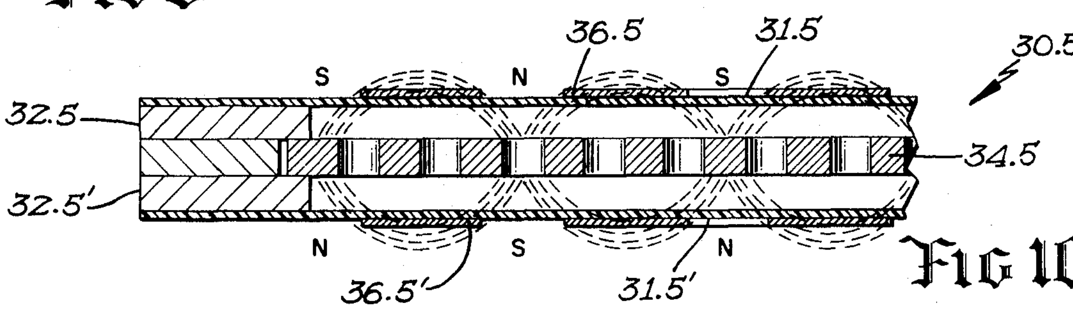

Fig 10

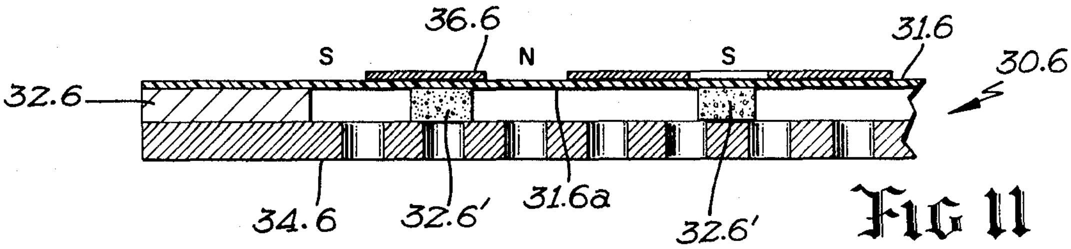

Fig 11

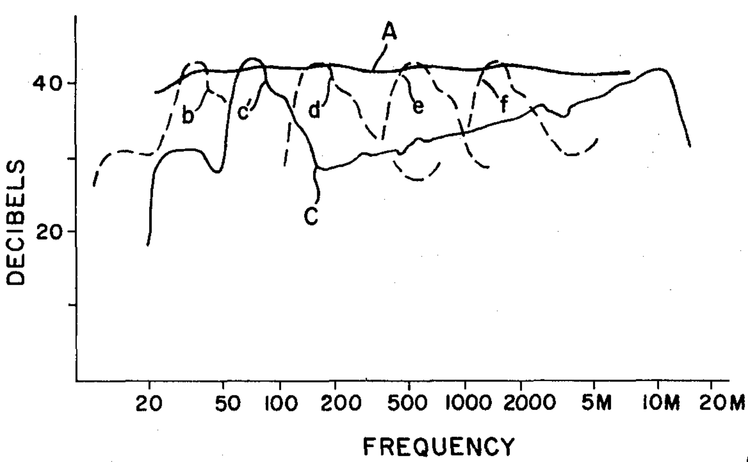

Fig 13

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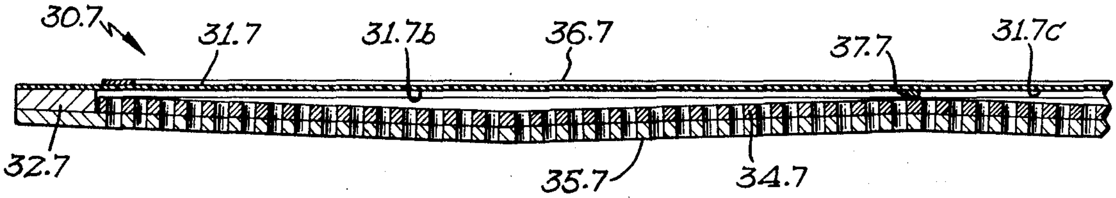


FIG 14

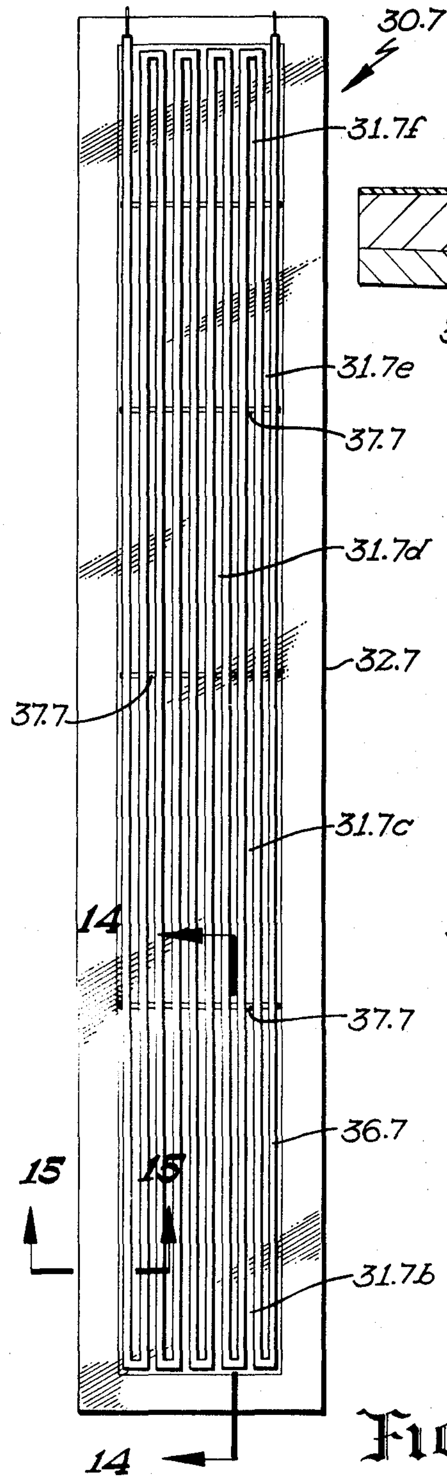


FIG 12

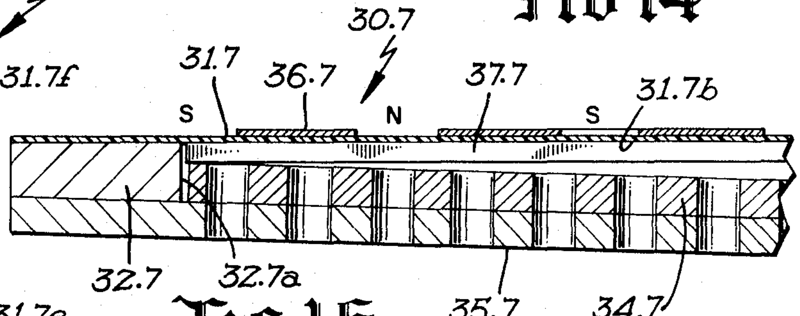
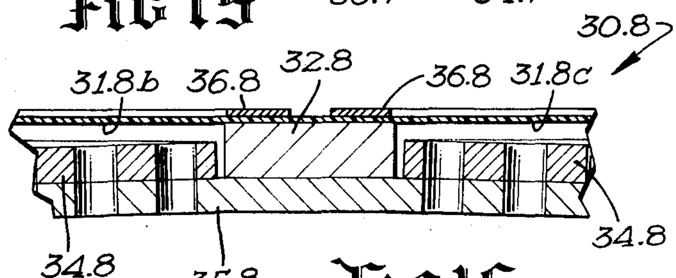


FIG 15



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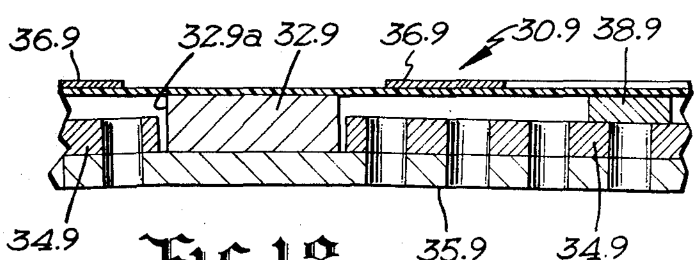

FIG 18

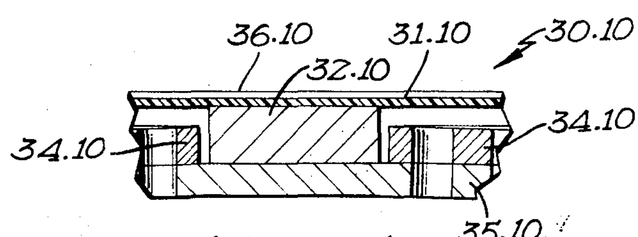

FIG 19

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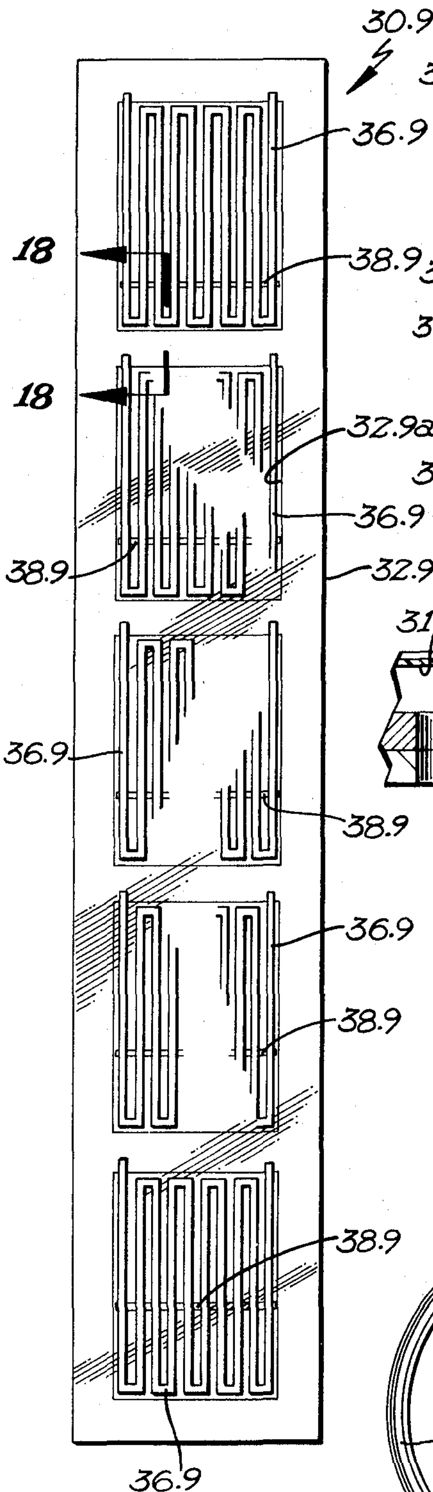

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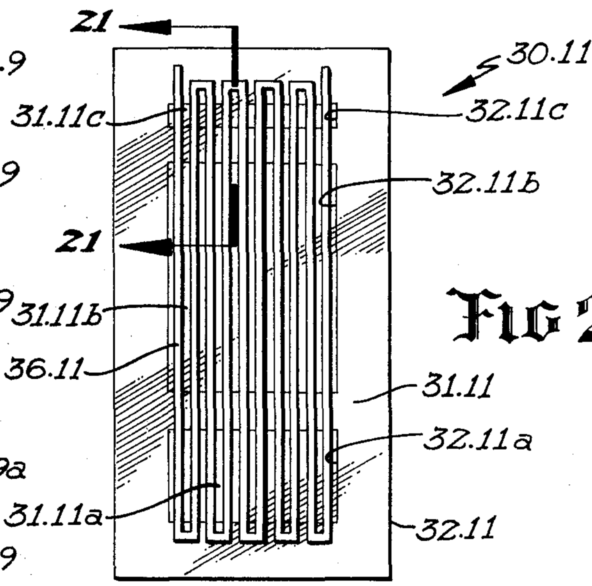

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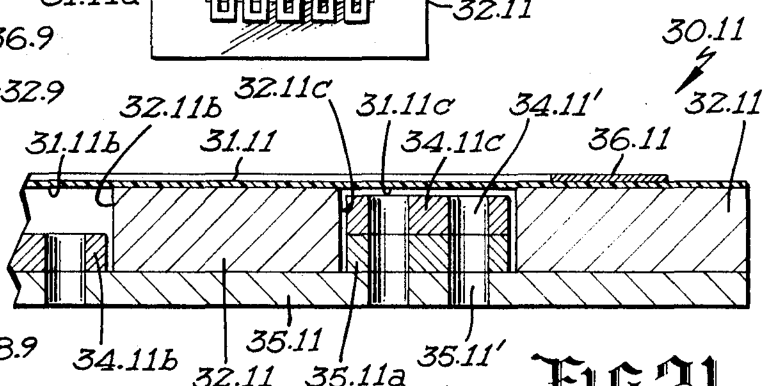

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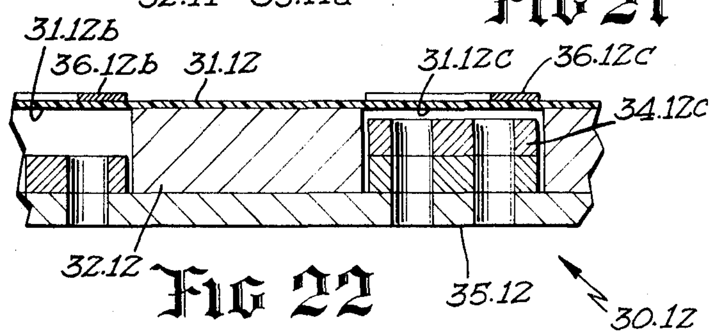

Fig 22

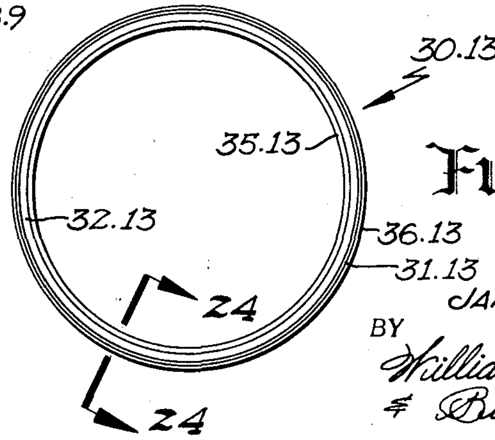

Fig 23

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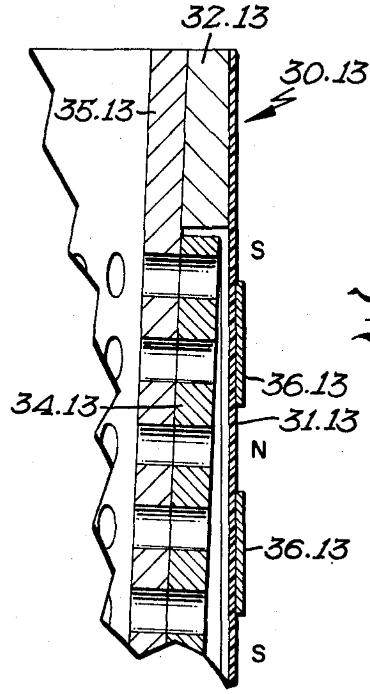


Fig 24

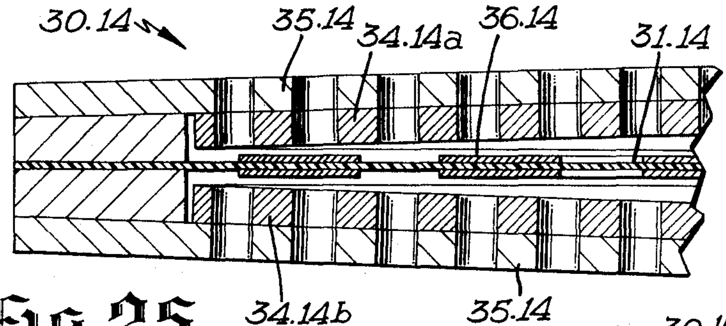


Fig 25

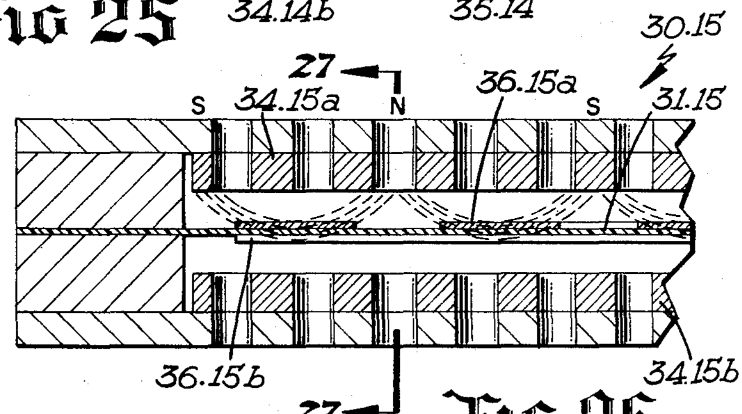
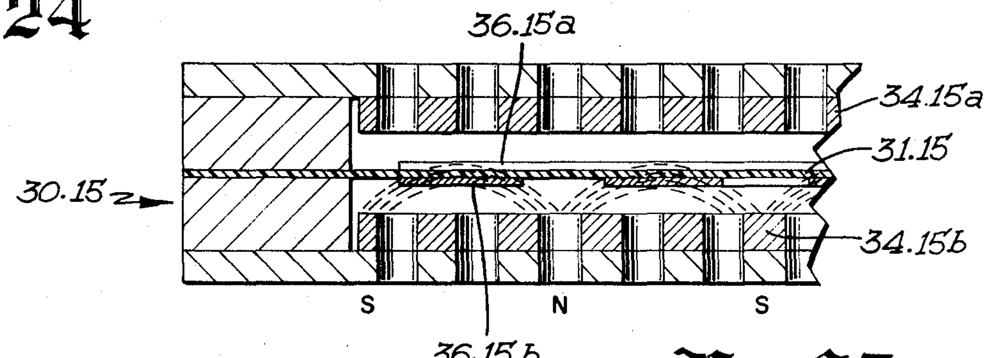


Fig 26



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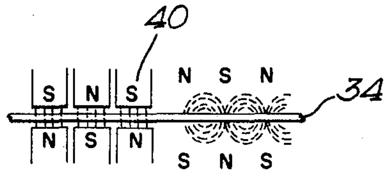

Fig 28

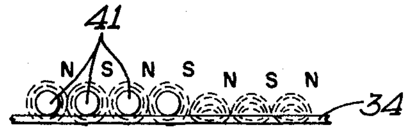

Fig 29

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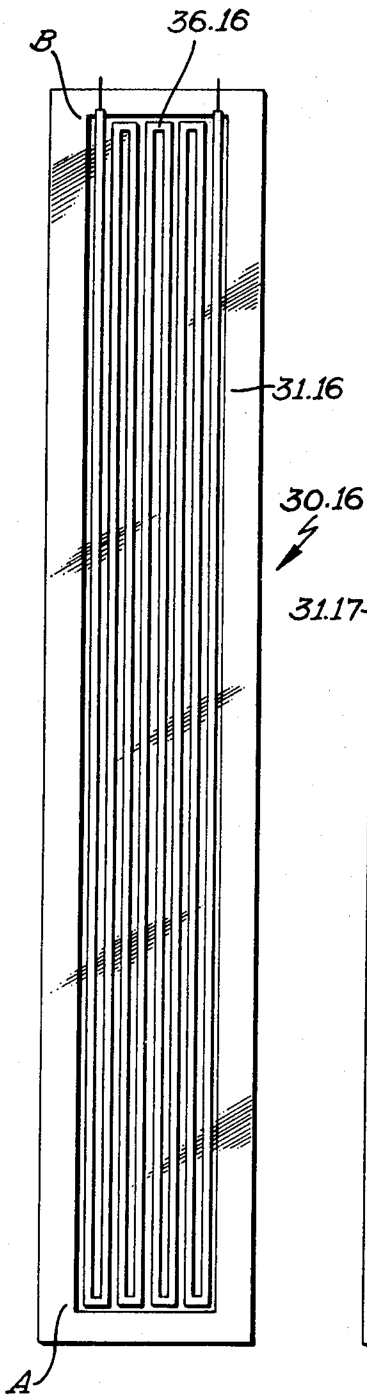

FIG 30

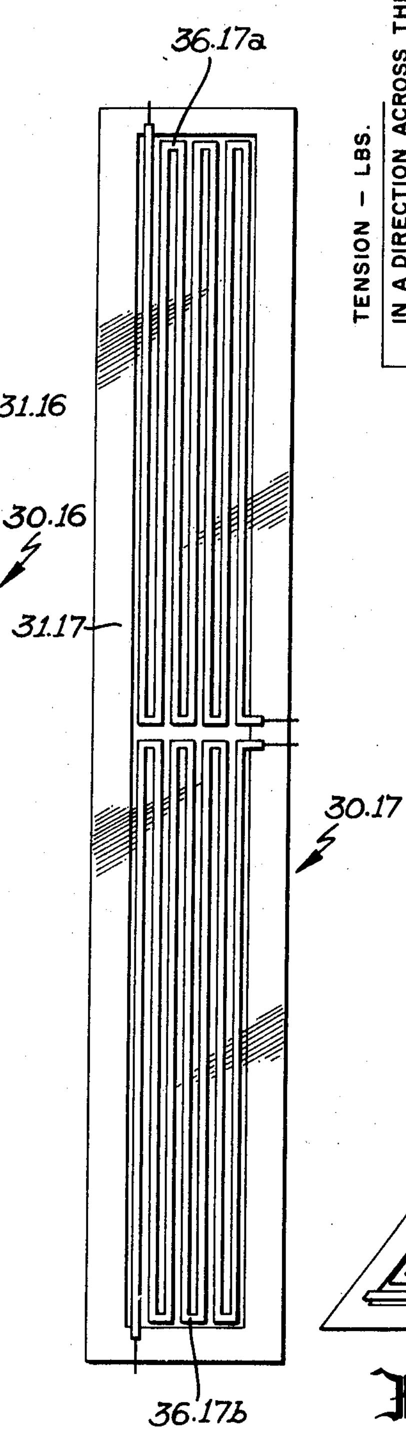

FIG 32

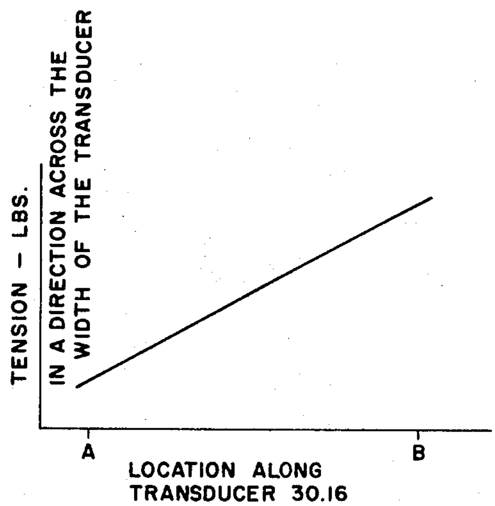

FIG 31

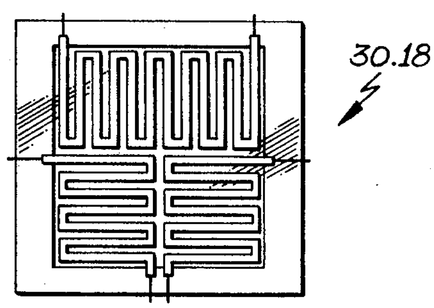

FIG 33

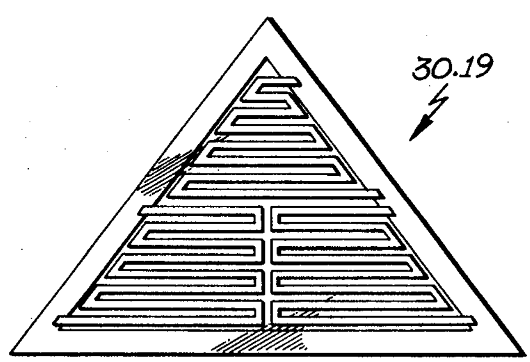

FIG 34

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ELECTROMAGNETIC TRANSDUCER

Electromagnetic transducers of the type using a vibrating diaphragm and a relatively flat and broad magnet have been known before, but, in view of the type of materials used in such transducers, such prior transducers were costly to produce, fragile to use and handle, and difficult to work with, particularly in the fabrication of such transducers. The magnets used in such transducers were made of a rigid, cast or sintered magnetic material, oftentimes a barium ferrite, which is necessarily relatively thick, on the order of three-eighths to one-half inch in many instances, and in large broad sheets more than a few inches in area, the ferrite material is considerably thicker in order to be self-supporting and capable of withstanding breakage. The extreme thickness of the magnetic panels has the effect to make a severe limitation as to the minimum width of the magnetized bands or zones, and the spacing between these magnetic bands. Because the material is thick, the width of these bands must be on the same general order as the thickness of the material.

In addition, the previously known electromagnetic transducers of this type had severe limitations because of the resonant problems encountered with the vibrating diaphragms, and these electromagnetic transducers have had poor polar distribution of generated sound. The vibrating diaphragm type of transducer produces an essentially directional sound pattern.

Also, problems have been encountered with the previously known transducers of this type in regard to the level of sound output producable.

These and other problems have been encountered and solved with the present invention.

BRIEF SUMMARY OF INVENTION

This invention has numerous important aspects. One of the important aspects is the use of the perforate flexible sheet magnet which may be of oriented or non-oriented synthetically fabricated material. The sheet material in the diaphragm is actually stretched beyond its original dimensions, not just pulled taut as is known previously. Also, the transducer uses stacked conductors on the diaphragm and stacked diaphragms that work together and produce increased energy output, with or without multiple stacked sheet magnets.

The present invention facilitates production of sound output over a broad range of audio frequencies, from the lowest audible frequencies, 16 to 20 cps. to at least 15,000 to 20,000 cps. Across this audible frequency range, outputs can be maintained at a relatively constant level.

These and other advantages will appear more fully in the appended specification in connection with the drawings which are described as follows.

BRIEF DESCRIPTION OF DRAWINGS

In the drawings, certain of the parts, and particularly the diaphragms, are shown disproportionately thick in order to be visible in the drawing. Approximate dimensional characteristics are set forth in the specification in order to make the invention understandable.

FIG. **1** is a perspective view of an electromagnetic transducer incorporating the present invention and specifically comprising a sound generating speaker.

FIG. **2** is an enlarged detail transverse section view taken at **2—2** in FIG. **1**.

FIG. **3** is an enlarged detail section view taken approximately at **3—3** in FIG. **2**.

FIG. **4** is an enlarged detail plan view of a portion of the speaker shown in FIG. **1** and with the several laminae broken away for clarity of detail.

FIG. **5** is an enlarged detail section view patterned after FIG. **3**, but showing a modified form of the invention.

FIG. **6** is another enlarged detail section view of still another modified form of the invention.

FIG. **7** is an enlarged detail plan view of the form of the transducer illustrated in FIG. **6**.

FIG. **8** is an enlarged detail section view of still another embodiment of the invention.

FIG. **9** is an enlarged detail section view of still another embodiment of the invention.

FIG. **10** is an enlarged detail section view of still another embodiment of the invention.

FIG. **11** is an enlarged detail section view of still another embodiment of the invention.

FIG. **12** is an elevation view of another embodiment of a transducer incorporating the present invention.

FIG. **13** is a frequency response curve relating to the transducer of FIG. **12**.

FIG. **14** is an enlarged detail section view taken approximately at **14—14** of FIG. **12**.

FIG. **15** is an enlarged detail section view taken at **15—15** in FIG. **12**.

FIG. **16** is an enlarged detail section view illustrating still another embodiment of the invention.

FIG. **17** is an elevation view of another form of transducer embodying the present invention.

FIG. **18** is an enlarged detail section view taken at **18–18** in FIG. **17**.

FIG. **19** is an enlarged detail section view illustrating still another embodiment of the invention.

FIG. **20** is an elevation view of a transducer constituting still another embodiment of the invention.

FIG. **21** is an enlarged detail section view taken at **21—21** in FIG. **20**.

FIG. **22** is an enlarged detail section view of still another embodiment of the invention.

FIG. **23** is a plan view of still another embodiment of the invention.

FIG. **24** is an enlarged detail section view taken approximately at **24—24** in FIG. **23**.

FIG. **25** is an enlarged detail section view of a transducer embodying still another form of the invention.

FIG. **26** is an enlarged detail section view of still another embodiment of the invention.

FIG. **27** is an enlarged detail section view taken approximately at **27—27** in FIG. **26**.

FIG. **28** is a diagrammatic view showing the manner of magnetizing in the magnetic fields of the flexible sheet magnet.

FIG. **29** is an enlarged diagrammatic view showing another mode of magnetizing and the magnetic fields of the sheet magnet.

FIG. **30** is an elevation view of another embodiment of a transducer incorporating the present invention.

FIG. **31** is a graph diagrammatically indicating the tension applied in a direction transversely across the width of the diaphragm in the transducer of FIG. **30** and at the various locations along the length of the transducer.

FIG. **32** is an elevation view of still another form of transducer embodying the present invention.

FIG. **33** is an elevation view of another embodiment of transducer incorporating the present invention.

FIG. **34** is an elevation view of an additional embodiment of a transducer incorporating the present invention.

DETAILED DESCRIPTION OF THE INVENTION

In the drawings the spacings and sizes of the elements are somewhat disproportionate as compared to actual dimensions, so as to make the elements clearly visible and understandable in the drawings. The spacings, sizes and thicknesses, especially of the diaphragms and conductors must be considered to be relatively diagrammatic.

One form of the invention is shown in FIGS. **1–4**. The transducer is indicated in general by numeral **30**. The transducer includes a diaphragm **31** which may be constructed of any of a number of film type materials and may have a thickness ranging from a few microns to approximately 1½ mills in thickness. The diaphragm **31** may be constructed of polyester film, known by its common name, Mylar, and this particular film is preferably stretched when used as the diaphragm. The polyester film may be stretched as much as 5 percent in excess of its original dimensions to stay within the elastic limits, but it has been found successful to stretch the film approximately 1 percent in excess of its original dimensions so as to have a somewhat lower resonant frequency and also this minimal stretch will prevent any material give or creep in the material over a period of time so that the tension on the material will remain approximately constant for long periods of time.

The diaphragm 31 is stretched in both directions of its length and width, but it should be understood that the diaphragm may be stretched in only one direction, and merely pulled taut in the other direction to eliminate wrinkles. Because the transducer 30 is nearly as wide as it is long, and reasonably small in size, the diaphragm 30 is substantially uniformly tensioned and stretched throughout its entire area. However, the diaphragm may be non-uniformly tensioned and stretched if the transducer has an appropriate shape such as the long and narrow shape hereinafter more fully described in connection with FIG. 30. In such a shape, the tension is applied in a direction across the width of the transducer, and the tension may be uniformly varied from one end of the transducer to the other. As a result of the non-uniform tensioning of the diaphragm, the diaphragm will not have any single set of resonant frequencies, but various portions of the diaphragm will resonate at various frequencies so as to make possible the utilization of these resonant frequencies in improving the output of the transducer at the extremely low audible frequencies and to make the transducer output more nearly uniform throughout the audio range.

Alternately, the diaphragm 31 may be constructed of other synthetic material known as saran, or may be constructed of plyofilm which is basically a rubber type material; or the diaphragm may be constructed of paper or catgut, or polyethylene. In addition, it may be desirable in certain instances to construct the diaphragm 31 of sheet styrofoam which may be formed with corrugations around the periphery at which point the styrofoam diaphragm will flex. The foregoing is a list of but a few examples of materials from which the diaphragm can be formed, it being important that the diaphragm be relatively light in mass so that it can move quickly at relatively high audio frequencies.

The transducer 30 has a peripheral frame serving as a spacer strip 32 to which the periphery 31a of the diaphragm is adhesively secured, but could, of course, be mechanically clamped. The frame or spacer strip 32 is sufficiently rigid as to withstand the permanent tension on the diaphragm 31.

The frame 32 defines an enlarged central opening 32*a* confronting the vibratable area 31*b* of the diaphragm.

An acoustically transparent backing or perforate magnetic panel means 33 is secured to the strip 32 in closely spaced relation to the diaphragm 31, and includes a perforate,oriented or non-oriented, non-sintered flexible plastic sheet magnet 34 lying flush against a perforate, stiff panel 35 of ferromagnetic material such as light gauge galvanized sheet iron. The stiff panel 35, which may serve as the frame in many instances, covers the entire opening 32*a* of the frame and is secured by adhesive to the frame strips 32 which may be constructed of styrene or other rigid material. As well illustrated in FIG. 2, the panel 35 is panned or dished slightly so that the upper surface thereof is slightly concave. Although the thickness of the panel 35 has not been found to be extremely critical, it has been found that the panel may be of approximately 18 to 24 gauge galvanized sheet metal, or approximately 0.050 inches thickness. The panel 35 is creased slightly in a direction diagonally between the corners so as to maintain the panned or dished shape. The dished shape has also been successfully produced by anchoring the edges of the panel 35 securely, and depressing the center of the panel beyond the elastic limit so that the dished shape deformation is permanent. It will be noted that, because of the type of material used in the pole piece panel 35, the panel 35 cannot maintain its shape with absolute precision, and there may be some minor undulations in the character of the upper surface thereof without adversely affecting the transducer 30.

The flexible plastic sheet magnet 34 has a thickness on the same order as the thickness of the panel 35 and it has been found that thickness of 0.050 to 0.060 is satisfactory. The flexible sheet magnet 34 is formed of any suitable material, but it has been found that a plastic rubber bonded barium ferrite magnetic material known by its trademark Plastiform sold by Minnesota Mining & Manufacturing Company of St. Paul, Minn., has proven to be satisfactory. This flexible plastic sheet magnet is extremely ductile and may be easily cut, slit, punched, shaped, drilled, milled and otherwise fabricated into the desired shapes with a minimum of difficulty and machinery. The plastic flexible sheet magnet is sufficiently thin as to be readily pliable and will, by virtue of its own magnetism, when magnetized, pull itself flush against the face of the metal pole piece panel 35, without regard to any minor undulations in the surface of the panel and will conform to the dished or panned shape of the panel caused by the diagonal crimping from corner to corner. There need be no milling or smoothing of the panel 35 of sheet magnet 34 to obtain the proper relationship therebetween. As a result of the magnetic attraction between the sheet magnet 34 and the metal panel 35, the sheet magnet will assume the same dished shape as the panel, and there is essentially no gap whatever between the adjoining faces of the sheet magnet 34 and the panel 35 so that the magnetic characteristics of the magnet and its magnetic fields as relates to and is caused by the sheet magnet 34 is optimized and is relatively constant over the entire surface area of the sheet magnet 34.

Although the sheet magnet 34 is illustrated in a unitary construction, it should be understood that the sheet magnet could be made up of numerous strips of the flexible rubber bonded barium ferrite magnetic material or an equivalent magnetic material.

It will be recognized that the perforations 34*a* in the sheet magnet are aligned with the perforations 35*a* in the metal panel 35 so as to permit adequate movement of air through these perforations as the diaphragm 31 vibrates.

Although the drawings illustrate substantially uniform spacing between uniformly sized perforations or apertures in the sheet magnet and metal panel, the apertures may be spaced farther apart or may be smaller in size near the edge of the diaphragm where the excursions of the diaphragm are rather minimal. Likewise, it may be desirable in certain instances to plug or omit certain of the perforations or apertures in the sheet magnet and metal panel near the center of the speaker where the excursions of the diaphragm are at a maximum so as to dampen the diaphragm movement and sound production at resonant frequencies of the diaphragm which might actually otherwise cause slapping of the diaphragm against the sheet magnet 34.

The dished shape of the sheet magnet 34 and panel 35 is primarily to accommodate the maximum excursions of the diaphragm 31, which generally occur during production of low frequency audio sounds. In the transducer 30, the maximum spacing between the diaphragm 31 and the center of the sheet magnet 34, as illustrated in FIG. 2, is approximately 0.040 inches; but at the outer edge of the sheet magnet 34, the spacing between the magnet and the diaphragm need only be approximately 0.009 inches. In many instances, the outer edge of the diaphragm may lie against the sheet magnet.

The diaphragm 31 has a number of conductors 36 adhesively secured thereto. The conductors 36 are shown in FIGS. 1–4 to be only one lamination thick, but could be stacked in insulated relation onto the diaphragm, somewhat in the manner illustrated in FIGS. 6 or 8. The conductors are arranged on the vibratable area 31*b* of the diaphragm in closely spaced and juxtaposed parallel runs such that the current in adjacent runs of the conductor moves in opposite directions. The conductors 36 are applied to the diaphragm after the diaphragm has been tensioned and stretched, and are constructed of a metallic foil with an adhesive backing applied directly to the diaphragm. The ends of the foil conductor 36 are connected to leads 36′ for the purpose of connecting the transducer into the output of an audio amplifier so as to supply a signal to the transducer. If certain stretchable conductors are used they may be attached to the diaphragm before tensioning; otherwise the diaphragm may be tensioned in a direction transverse to the runs of the conductors. Other types of conductors have been found to be successful and may include wire printed conductors and conductor formed printed circuit techniques and conductors formed by vapor deposits and similar techniques.

The closeness of spacing between the runs of the conductor 36 is related to the flexibility of the sheet magnet 34 because the sheet magnet may be relatively thin as illustrated because of its flexibility, and because of the thinness, the magnetic zones or bands of the sheet magnet 34 may be relatively narrow and close together. As illustrated in FIG. 3, the sheet magnet 34 is magnetized through its thinnest dimension in elongate zones arranged in the sheet magnet 34 in the same configuration as the configuration and spacing of the runs of the conductor 36 on diaphragm 31. It will be noted that the magnetized zones or bands in the sheet magnet 34 define pole faces at the top surface of the sheet magnet, and these pole faces alternate between north and south in the areas between adjacent runs of the conductor, thereby creating the magnetic fields and flux lines which intersect the conductors 36 and coact with the fields produced adjacent the conductors when current flows therein in order to produce the movement or vibration of the diaphragm.

It has been found that with a sheet magnet 34 of approximately 0.060 inches thickness, the spacing between the adjacent magnetized zones or bands in the sheet magnet may be approximately five-sixteenths of an inch, center to center, and a conductor strip, approximately three-sixteenths of an inch wide and spaced apart by one-eighth of an inch operates satisfactorily. It has also been found that the perforations 34*a* and 35*a* should be close enough together and of sufficient large size as to provide 20 to 25 percent open area in order to produce low frequency audio sounds by vibration of the diaphragm. The perforations 34*a* and 35*a* may be approximately one-sixteenth of an inch in diameter on one-eighth inch spacings in order to achieve the desired proportion of open area. Although this amount of open area is not needed adjacent the edges of the sheet magnet 34 because the excursions of the diaphragm are considerably less than at the center, manufacturing techniques may make the uniform spacing more practical. Adjacent the edge of the sheet magnet 34, only 5 percent open area may be necessary. There need be no correlation between the size of and spacing between the perforations 34*a* and the spacing of the magnetic zones or bands in sheet magnet 34.

The vibratable area 31*b* of the diaphragm may be approximately 8 inches wide. Spacing between the sheet magnet and the diaphragm may be on the order of 0.040 inches at the center of the sheet magnet and 0.009 inches at the edge of the vibratable area.

It will be understood that the magnetic panel 35, against which the sheet magnet 34 lies, provides a low reluctance path for the magnetic field at the lower side of the sheet magnet 34 and the effect is to draw the magnetic field and flux lines adjacent the top face of the sheet magnet 34 inwardly and concentrate them near the face of the sheet magnet. These flux lines then pass through the area of the runs of conductor 36 so that as the electrical current passes through the runs of the conductor 36, the field caused by the current intersects and cooperates with the magnetic fields of the sheet magnet 34 as to produce motion in the diaphragm 31, and as the current and electrical field produced thereby changes direction rapidly, the vibration of the diaphragm is induced.

The low reluctance path has essentially no gaps whatsoever because the flexible sheet magnet 34 lies flush against the panel 35 across its entire length and breadth and therefore the magnetic fields along the zones of the sheet magnet 34 are optimized essentially uniform so as to contribute materially to the uniformity of the vibration of the diaphragm across its entire vibratable area.

Although the transducer 30 is illustrated to be rectangular or nearly square in configuration, it should be realized that the transducer could have other common shapes such as that of a circle, ellipse or triangle, or other irregular shapes such as a kidney shape or the shape of a leaf of a tree.

In FIG. 5, the transducer 30.1 is essentially the same as that described in connection with FIGS. 1–4, except that the magnetic panel 35.1 is essentially flat rather than dished. Correspondingly, the flexible sheet magnet 34.1 is likewise essentially flat, and the spacing between the sheet magnet and the diaphragm 31.1 is essentially constant across the length and breadth of the transducer 30.1. In this form of the transducer, the flexible sheet magnet 34.1 also lies flush against the panel 35.1 and maintains a constant relationship with the panel without any need for machining or flattening of either of the adjoining faces of the sheet magnet or panel. The spacer 32.1 is likewise somewhat larger in this form of the invention as compared to that previously described.

In FIGS. 6 and 7, the transducer 30.2 is essentially the same as that illustrated in FIGS. 1–4, excepting that the diaphragm 31.2 has conductors 36.2 on both the upper and lower surfaces thereof. This arrangement of interconnected conductors is one way of stacking conductors on the diaphragm so that increased signal current can be carried to produce additional reaction between the electric fields of the current in the conductors and the magnetic fields so as to increase the excursion and output of sound from the diaphragm 31.2.

In the form illustrated in FIG. 8, a plurality of conductors 36.3 are stacked upon each other and insulated from each other on both the top and bottom surfaces of the diaphragm 31.3. In dotted lines, additional stacks of conductors are illustrated. It will be noted that all of the conductors in any one stack are clustered together so that the interaction between the electric fields and the magnetic fields of the sheet magnet 34.3 is increased so as to increase the magnitude of output caused by vibration of the diaphragm which actually has larger excursions due to the increased interaction between the fields.

The form of transducer 30.4 in FIG. 9 is essentially the same as illustrated in FIGS. 1–4 except that the pole piece panel 35.4 is flat rather than dished and the sheet magnet 34.4 is likewise flat. In this respect, this form of the invention is quite similar to that illustrated in FIG. 5. Also, in FIG. 9, an additional sheet magnet 34.4′ is applied to the rear side of the panel 35.4, and another diaphragm 31.4′ is similarly positioned in confronting relation with the sheet magnet 34.4 and spaced therefrom by the spacer 32.4′. Similarly, the diaphragm 31.4′ carries conductors 36.4′ which carry signal currents, the electric fields of which interact with the magnetic fields of the sheet magnet 34.4′ to produce vibration of the diaphragm 31.4′, and because the same signals are supplied to the conductors 36.4 and 36.4′, the diaphragms move in synchronism with each other, and in the same direction, causing air to pass through the perforations in the panel 35.4 and through the sheet magnets as the sound is produced. It will be understood that additional stacked conductors may be utilized in this type of transducer 30.4, and also additional stacks of sheet magnets and diaphragms may be applied to this transducer in the manner previously described.

The transducer 30.5 illustrated in FIG. 10 is substantially the same as that illustrated in FIGS. 1–4, except that in this form of the transducer, the frame and spacer strips 32.5 are secured by adhesives directly to the perforated, flexible sheet magnet 34.5. In this form of the invention, the frame and spacer strips 32.5 hold the flexible sheet magnet 34.5 taut and therefore the sheet magnet is stiff to be restrained from undesired movement or flexing. The flexible sheet magnet has many times the mass and thickness of the diaphragm 31.5 so that when audio frequency electric current signals are applied to the conductors 36.5, the diaphragm will vibrate to effect sound generation and the sheet magnet 34.5 remains essentially stationary.

As an optional aspect of the transducer 30.5 of FIG. 10, a second, stacked diaphragm 31.5′ is applied under tension and stretched to the frame strip 32.5 at the opposite side of the sheet magnet 34.5 from the diaphragm 31.5. The diaphragm 31.5' also carried conductors 36.5' which will ordinarily carry the same signal carried by conductors 36.5 so that the two diaphragms work together in producing the sound.

It will be noted that in the transducer 30.5, the magnetic fields of the magnetized zones or bands in the sheet magnet 34.5 at both sides of the sheet magnet are utilized. In the event that the second diaphragm 31.5' is omitted, the flexible sheet magnet may be magnetized in the manner illustrated in FIG. 29 wherein the magnetic fields from the zones or bands exist predominantly adjacent the upper surface of the sheet magnet.

In the form of the transducer 30.6 illustrated in FIG. 11, the diaphragm 31.6 is secured by spacers 32.6 and 32.6' directly to the flexible sheet magnet 34.6. Although the spacer strip at the periphery of the magnet and diaphragm 32.6 are ordinarily substantially rigid, they may be flexible so that the transducer 30.6 may assume a somewhat non-planar configuration. The vibratable area 31.6*a* is maintained in spaced relation with the confronting area of the flexible sheet magnet 34.6 by the spacers 32.6' which are small dots or cylindrical plugs of soft and yieldable material such as foam rubber or batted cotton fibers.

Although the spacers 32.6' restrict the large excursions of the diaphragm, the speaker generates a substantial energy output in the form of sound power. In this same general arrangement, the conductors may be stacked on each other and additional diaphragms may be stacked onto the rear side of the flexible sheet magnet 34.6.

The transducer 30.7 of FIGS. 12, 14 and 15, have a greatly enlarged diaphragm area for the purpose of very substantially increasing the quality and energy output of the speaker. This speaker frame 32.7 defines an overall interior opening 32.7*a* approximating 8 inches by 5 feet in dimensions, and the length of the opening may be extended to 10 feet to further increase the energy output. In this embodiment, it is contemplated that the transducer 30.7 may be incorporated into an upright panel structure which may be utilized as a room divider in a home or as a space divider in any other type of interior arrangement. The frame 32.7 may be constructed of rigid metal or rigid sheet plastic such as styrene, and the diaphragm 31.7 is tensioned and stretched in both longitudinal and transverse directions as it is secured by adhesive to the frame 32.7. Stretching in only one direction is also satisfactory. The pole piece panel 35.7 is also affixed to the rear side of the frame 32.7 and has an overall shape very nearly the same as that of the frame. The perforate flexible sheet magnet 34.7 extends, in this embodiment, throughout the entire length of the opening 32.7*a* and lies flush against the pole piece panel 35.7.

The diaphragm 31.7 is divided into a number of separate vibratable areas 31.7*b*, 31.7*c*, 31.7*d*, 31.7*e* and 31.7*f*, each of which has a different length and area as compared to each of the other vibratable areas. The several vibratable areas are defined by a plurality of rigid spacer strips 37.7 adhesively secured to the diaphragm and also to the top of the sheet magnet 34.7. The portion of the diaphragm which overlies each of the strips 37.7 is prohibited from vibrating, and therefore each of the vibratable areas 31.7*b*–31.7*f* vibrates independently. Because of the different sizes of the vibratable areas 31.7*b*–31.7*f*, each of these vibratable areas has a different set of resonant frequencies.

The conductors 36.7 extend throughout the length of the entire diaphragm and traverse the separate vibratable areas so as to apply the same signals to all of the diaphragm areas.

The pole piece panel 35.7 and the sheet magnet 34.7 are dished or panned adjacent each of the separate vibratable areas of the diaphragm.

In FIG. 13, which is a frequency response chart for the transducer 30.7, the curve C represents the frequency response chart for the vibratable area 31.7*c*. The peak C' of the curve C indicates the resonant peak produced at the fundamental resonant frequency of the particular vibratable area with which this individual frequency response curve is related. Each of the other vibratable areas has its resonant peak occurring at a different frequency, because of the difference in the areas of the diaphragm, and the separate resonant peaks are illustrated in dotted lines and denoted by letters *b*, *d*, *e* and *f*. It will be noted that the typical frequency response chart for the area 31.7*c* shows a decline in the output at frequencies just above the resonant peak, and then at progressively higher frequencies, the energy output from the diaphragm area progressively increases. Because of the averaging effect of the several vibratable areas of various sizes and the effect of their respective resonant peaks, the overall frequency response curve for the transducer 30.7 is relatively constant across the spectrum of audio frequencies as is indicated by the curve A.

It will be understood that the sound reproduction from a transducer having a multiplicity of various sizes of vibratable areas is far superior than the sound reproduction from a speaker or transducer having a single vibratable area.

FIG. 16 illustrates an alternate construction as compared to that illustrated in FIGS. 12, 14 and 15. The transducer 30.8 of FIG. 16 has the vibratable areas of the diaphragm separated from each other by an integral portion or divider bar of the frame 32.8, instead of the spacer strip illustrated in FIG. 14. The frame 32.8 is attached directly to the panel 35.8 of magnetic material, and, as in the transducer 30.7, the pole piece panel 35.8 is panned or dished opposite each of the vibratable areas of the diaphragm. In FIG. 16, the flexible sheet magents 34.8 are sized to conform to the size of the particular vibratable areas and lay against the pole piece panel 35.8.

Of particular importance in the transducer 30.8 of FIG. 16, the conductors 36.8 do not traverse from one vibratable area of the diaphragm to the other vibratable areas, but are isolated so that different signals can be applied to the conductors at different vibratable areas of the diaphragm. The output signal from an audio amplifier may be applied to a crossover network or a divider network so as to separate various frequencies in the signal from each other, and the various frequencies can be applied to the conductors of the various vibratable areas of the speaker to obtain an improved speaker operation, specifically improved frequency response, greater energy output, less distortion, and better polar distribution.

In a modified form of the transducer 30.8 of FIG. 16, the divider bar 32.8 between the adjacent vibratable areas of the diaphragm may be entirely eliminated such that the elongate diaphragm is only secured to the frame and perforate plate 35.9 at the periphery of the diaphragm as a whole. The separate conductors 36.8, being isolated from each other, define the vibratable areas of the diaphragm, and, as hereinbefore described, the several vibratable areas of the diaphragm may have different sizes so as to be resonant at various frequencies. It may be desirable to apply the same electric signals to the conductors of all of the vibratable areas; and it may otherwise be desirable to separate the various frequencies of the signal from each other by means of a cross-over network or divider network so as to apply the high audio frequency signals to the smaller vibratable areas of the diaphragm, and apply the lowest range of audio signals to the conductors of the largest vibratable area of the diaphragm, and the mid-range audio frequency signals to the conductors of a vibratable area of intermediate size. In dividing the diaphragm into separate vibratable areas for receiving separated portions of the audio frequency signal, it is generally proven satisfactory to divide the diaphragm only into three separate areas. In the alternate form of transducer which eliminates the divider bar 32.8 of the frame, the perforate sheet metal panel and the sheet magnet may be dished relative to the diaphragm as a whole rather than in relation to each of the vibratable areas; i.e., the metal panel and sheet magnet do not converge toward the diaphragm in a direction longitudinally of the transducer as a whole and at the boundaries of the separate vibratable areas defined by the conductors on the diaphragm.

A form of speaker similar to the described variation on FIG. 16 wherein the divider bar 32.8 of the frame is eliminated, is illustrated in FIGS. 30 and 32.

In the transducer 30.9 of FIGS. 17 and 18, the frame 32.9 defines a plurality of substantially equal size openings 32.9a. The diaphragm 31.9 traverses the entire frame and is tensioned in both longitudinal and transverse directions, but need be tensioned in only one direction. The conductors 36.9 on each of the separate vibratable areas of the diaphragm are isolated in relation to each other so that different signals can be applied to the conductors of various vibratable areas after the frequencies have been separated in a divider network or similar circuit.

In the transducer 30.9, each of the vibratable areas of the diaphragm is affixed to a rigid spacer strip which may be constructed of cardboard or styrene, or a similar material, and which is indicated by the numeral 38.9. These strips 38.9 are located at different locations in each of the openings of the frame and adjacent each of the vibratable areas of the diaphragm. The strips 38.9 prevent the diaphragm from vibrating at the point of connection so that at each of the openings 32.9a of the frame, the vibratable diaphragm is Divided into two separate areas. The relative sizes of these vibratable areas in each of the frame openings is different as can be observed in FIG. 17. These various sizes of vibratable areas of the diaphragm result in varying resonant frequencies for these various vibratable areas and, as a result, a smooth overall frequency response is obtained from the transducer 30.9.

As illustrated in FIG. 19 which is an alternate form, a variation on the transducer 30.9, the transducer 30.10 of FIG. 19 may have the conductors 36.10 arranged to traverse between the separate areas of the diaphragm and traverse the diaphragm from one opening in the frame to another. In FIGS. 20 and 21, as in the other forms of transducers, the proportions of the sizes of the elements are somewhat disproportionate in order to make them clearly visible and understandable in the drawings. The spacings and the conductor thicknesses as well as the diaphragm thicknesses must be considered to be relatively diagrammatic.

Another variation of the transducer 30.9 has a different tension and a different degree of stretching at each of the vibratable areas of the transducer; it may be necessary that the several vibratable areas of the diaphragm be separated from each other so that they can be individually tensioned and stretched, and where the tension at each of the vibratable areas is varied relative to each other, the strips 38.9 need not be utilized. The difference in tension on the several vibratable areas changes their relative resonant frequencies so as to increase the uniformity of the output of the transducer substantially across the range of audio frequencies.

The transducer 30.11 of FIGS. 20 and 21 has a frame 32.11 with several different sizes of openings 32.11*a*, 32.11*b*, 32.11*c*. The proportions of these openings vary with respect to each other so as to vary the sizes of the vibratable areas of the diaphragm 31.11. The openings as seen in FIG. 20 are approximately 8 inches wide and the smallest of these openings 32.11*c* is approximately 1 inch long and the largest opening 32.11*b* is approximately 10 inches long. As a result of substantially uniform tension on all portions of the diaphragm, the various vibratable areas of the diaphragm are stretched substantially uniformly. The conductors 36.11 traverse all of the vibratable areas of the diaphragm, and, of course, because the vibratable area 31.11*b* is the largest of the three vibratable areas, the maximum excursion of the diaphragm will be effected, so as to maximize the energy output of at least the low audio frequency signals. The smallest of the vibratable areas 31.11*c* will have high energy output for the high frequency audio signals, and particularly a higher energy output than produced by the other two vibratable areas for these high range audio frequencies. It will be particularly noted in this speaker that the perforate flexible plastic sheet magnet 34.11*c* has a lesser proportion of open area because of the wider spacing of the perforations 34.11′ therein; and, furthermore, the sheet magnet 34.11*c* is considerably closer to the vibratable area 31.11*c* of the diaphragm than is the perforated plastic flexible sheet magnet 34.11*b* from its corresponding vibratable area of the diaphragm. The pole piece panel 35.11 has openings 35.11′ corresponding to the spacing of the openings 34.11′, and a supplemental pole piece panel 35.11*a* lies flush against the pole piece 35.11 and also flush against the bottom surface of the sheet magnet 34.11*c* so as to act as a part of the pole piece panel 35.11 in its effect upon the magnetic fields in the sheet magnet 34.11*c*.

Because of the close spacing between the sheet magnet 34.11*c* and the vibratable area 31.11*c* and the conductors 36.11 thereon, and also because of the reduced proportion of open area of sheet magnet 34.11*c*, the magnetic field is stronger at the conductors and therefore the field generated by the current passing through the conductors has a greater effect upon the diaphragm so that a higher energy output from the vibratable area 31.11*c* of the diaphragm is produced, especially at the higher audio frequencies.

The effect of the different sized vibratable areas of the diaphragm 31.11 in transducer 30.11 is to improve the speaker operation as emphasized in connection with transducer 30.8 in FIG. 16. The sound output from the vibrating diaphragm of these flat transducers or speakers is relatively directional when the dimensions of the generating source are large as compared to the wave length of the signal, and therefore the use of relatively small vibratable areas of the diaphragm such as vibratable area 31.11*c* for the high range audio frequency sounds, and the large size vibratable area 31.11*b* for the extremely low range of audio frequency sounds and the intermediate sized vibratable area 31.11*a* for the mid-range audio frequency sounds, has the effect to improve the polar distribution of all the sounds produced by the transducer 30.11.

The polar distribution obtained with a transducer of the nature illustrated in FIGS. 20 and 21 is quite satisfactory.

In order to increase the energy output at the several vibratable areas of the diaphragm, the transducer 30.12 illustrated in FIG. 22 may be utilized, and this transducer is a variation on the form of transducer 30.11 shown in FIGS. 20 and 21. In this transducer, the conductors 36.12*c* on the smallest vibratable area 31.12*c* are separate from and of considerably less mass than the other conductors on the other vibratable areas of the diaphragm, such as the conductor 36.12*b* which is affixed on the largest vibratable area 31.12*b* of the diaphragm. The reduced mass of the conductor 36.12*c* permits the vibratable area 31.12*c* to respond to the high range audio frequency signals which are applied thereto and which have been separated from the audio signal as a whole by a suitable divider network or equivalent circuitry. This arrangement of separate conductors on the various sized vibratable areas, and the use of an extremely light conductor, such as a one-quarter mill foil, on the smallest vibratable area of the diaphragm produces a highly satisfactory output from the transducer 30.12. It will be understood that in both the transducers 30.11 and 30.12, the reduced open area in the flexible plastic sheet magnets 34.11*c* and 34.12*c*, the magnetic fields of these magnets can be stronger so as to have a greater effect upon the vibrating of the diaphragm areas. A separate piece of thinner, lighter diaphragm material may be substituted as the vibratable area 31.11*c* to further increase the energy output of high audio frequency signals.

As previously described in connection with FIG. 16, a variation on the transducer 30.12 illustrated in FIG. 22 would be the elimination of the crossbar 32.12 of the frame so that the diaphragm is attached to the frame only at the exterior periphery, and the several vibratable areas of the diaphragm are defined only by the conductors carried by the diaphragm. Each of these vibratable areas of the diaphragm will vibrate substantially independently of each other, according to the signal applied to the respective conductor. Of course, highly satisfactory polar distribution is obtained with this variation of the transducer.

Another variation of the transducer 30.12 of FIG. 22 is the use of conductors 36.12*c* which are considerably narrower than those illustrated and considerably narrower than the conductors used on the other vibratable areas of the diaphragm. These narrower conductors are arranged in runs considerably closer than that illustrated and considerably closer together than the relative spacing between adjacent runs on the other vibratable areas of the diaphragm; and similarly, the magnetic zones in the sheet magnet are considerably narrower and have closer spacings, as to conform to the width and spacing of the conductors on the diaphragm. As a result, the high frequency output of this vibratable area of the transducer is increased.

This same variation in width and spacing of conductors on the diaphragm and of the magnetic zones in the sheet magnet may also be used even though the spacer bar **32.12** of the frame is eliminated as hereinbefore described in the previous variation.

Another form of transducer is shown in FIGS. **23** and **24** and is indicated by the numeral **30.13**, and the transducer is substantially cylindrical in shape. The frame or spacer strip **32.13** is substantially cylindrically shaped, as is the pole piece panel **35.13**. This pole piece panel **35.13** is dished slightly between its edges so that the central portion thereof is spaced from the diaphragm **31.13** to a greater extent than the edges of the pole piece panel. The diaphragm **31.13** is substantially cylindrical in shape, and carries the conductors **36.13** in conformance with the shape of the magnetized zones or bands of the perforate flexible plastic sheet magnet **34.13**. The diameter of transducer **30.13** may be on the order of 12 inches or more. High frequency transducers of this type may be considerably less than 12 inches in diameter.

Of course, the polar distribution of the transducer **30.13** is very satisfactory because the energy output emanates in substantially all directions.

In the transducer **30.14** illustrated in FIG. **25**, stacked flexible sheet magnets **34.14***a* and **34.14***b* are disposed on opposite sides of a common diaphragm **31.14** carrying conductors **36.14** This arrangement of stacked sheet magnets substantially increases energy output and minimizes problems of modulation distortion that may occur in transducers using a single sheet magnet and wherein the vibratable area of the diaphragm may move toward and away from a single magnet at low frequencies has a decided effect upon the linearity of output of high frequency signals being simultaneously produced. In this transducer **30.14**, as the diaphragm moves at low frequencies the magnetic fields from the two stacked sheet magnets remains substantially constant regardless of the position of the diaphragm so as to minimize distortion of high frequency signals being simultaneously produced.

A variation of the transducer **30.14** of FIG. **25** is the substitution for diaphragm **31.14**, of a pair of parallel diaphragms confronting each other and spaced slightly from each other. A spacing of 0.020 inches is satisfactory (for purposes of comparison, the metal panel **35.14** is illustrated to be approximately 0.050 inches in thickness as is the metal panel **35** in FIGS. **2** and **3**). Both of the diaphragms in this variation will be stretched, but may have different tensions applied relative to each other; both diaphragms will carry conductors, although the number and size of conductors may vary relative to each other quite considerably, for instance, one conductor may carry stacked conductors and thus be relatively heavy, and the other diaphragm may carry only very small and thin conductors to be highly responsive to high frequency signals.

In the transducer **30.15** illustrated in FIGS. **26** and **27**, the diaphragm **31.15** has conductors **36.15***a* and **36.15***b* on the upper and lower surfaces thereof. The conductors **36.15***a* are in runs which extend transversely of the runs of conductors **36.15***b*. Both of the upper and lower conductors **36.15***a* and **36.15***b* carry the same signal, and the effect is to produce vibrating movement of larger areas of the diaphragm which may tend to remain stationary in the open spaces between the conductors. The magnetized zones or bands in the perforate flexible plastic sheet magnet **34.15***a* extend parallel to the runs of conductor **36.15***a* on the top side of the diaphragm; and the elongate magnetic bands or zones in the lower magnet **34.15***b* extend parallel to the runs of conductor **36.15***b*. Because of the transverse orientation of the magnetic zones or bands in the opposite sheet magnets **34.15***a* and **34.15***b*, there is essentially no interaction between these magnetic zones or bands, and the magnetic zones or bands in the sheet magnet **34.15***a* has essentially no effect upon the fields produced by current flowing in the lower conductors **36.15***b*; and the magnetic fields resulting from the magnetic bands or zones in the sheet magnet **34.15***b* has little or no effect upon the fields produced by current flowing in the upper conductors **36.15***a*.

The overall effect of this transducer is to reduce distortion and increase the energy output as the result of a predetermined signal input because larger areas of the diaphragm **31.15** are set into motion because of the crisscross arrangement of the conductors. This arrangement has particular advantage in transducers using a relatively loose diaphragm, as may be used in small sized transducers.

FIG. **28** is illustrative of the manner in which the perforate flexible plastic sheet magnet **34** is magnetized. Strong magnets **40** are positioned above and below the sheet magnet **34** so as to set up magnetic fields in the sheet magnet in a direction through its thinnest dimension. The pole faces produced at adjoining zones or bands and at the face of the magnets are opposite as indicated by the letters N and S. In this sheet magnet, the magnetic field is detectable at both the top and bottom sides of the sheet magnet.

In FIG. **29**, an alternate mode of establishing the magnetized zones or bands in the sheet magnet **34'** is illustrated. Conductors **41** are arranged in the configuration of the zones or bands to be produced in the sheet magnet **34'**, and then the conductors and sheet magnet are brought into proximity with each other so that the electric fields produced by large currents flowing in the conductors create magnetic fields in the sheet magnet **34'** such that the magnetic fields exist predominantly at the top surface of the sheet magnet **34'** and only minimally at the lower surface.

The elongate transducer **30.16** of FIG. **30** has the diaphragm attached to the spacer strip and to the rigid metal plate only at the periphery of the diaphragm. The conductors **36.16** are secured to the diaphragm **31.16** as previously described. Of course, the magnetic zones of the sheet magnet beneath the diaphragm conform in shape and spacing to the configuration of the conductors **36.16** on the diaphragm. The diaphragm is pulled taut in a direction longitudinally of the transducer, merely to remove the wrinkles from the material of the diaphragm; and the diaphragm is tensioned in a direction across the width of the diaphragm such that the tension in this transverse direction progressively increases from one end of the transducer to the other. As depicted in the graph of FIG. **31**, the tension at location A of the diaphragm is relatively low and is preferably only that which is required to remove wrinkles from the diaphragm material. At location B at the opposite end, the tension across the width of the diaphragm is substantially that described in connection with FIGS. **1–4** or slightly greater than that amount, and at locations between the opposite ends of the diaphragm, the tension and stretching of the diaphragm progressively varies such that the tension gradually increases in a direction from location A to location B. As a result of the varying tension, the various portions of the diaphragm are resonant at various sets of frequencies to obtain the advantages described in connection with FIGS. **12–14**, so as to obtain substantially uniform output across the full range of audio frequencies.

It will be understood that the width of the conductors on the diaphragm is proportionately less than that illustrated in the drawing, because of the practical considerations in actually making the ink drawing, and, likewise, the number of runs of conductor is considerably greater than that illustrated in the drawing. In FIG. **30**, the diaphragm has only a single vibratable area. It may be desirable to isolate a small number of runs of the conductor adjacent one of the longitudinal edges to receive the high range audio frequency signals so as to effect desirable polar distribution of the high frequency audio sounds produced. Similarly, a number of runs of the conductor adjacent the opposite longitudinal edge may be isolated and used to carry the mid-range audio frequency signals from the divider network; and to apply the low range audio frequency signals to the remainder of the runs of conductor on the diaphragm.

Similarly, in FIG. 32, the transducer **30.17** has the diaphragm **31.17** connected to the spacer strip and perforate panel only at the periphery of the diaphragm. The conductors **36.17***a* and **36.17***b* are isolated from each other and are applied to the opposite end portions of the diaphragm. The two conductors will receive the audio output signals from the two channels in a stereophonic system so that the sound will appear to emanate from various portions of the transducer **30.17** as is desirable in such stereo systems. The diaphragm **31.17** relies solely on the separate conductors **36.17***a* and **36.17***b* for defining the separate vibratable areas producing the different audio outputs of the stereo system.

It is contemplated that the transducer **30.17** has a size commensurate with that of transducer **30.7** of FIG. **12** and transducer **30.9** of FIG. **17**; but it will be understood that this dual channel transducer **30.17** may be constructed in a smaller size for use in earphones of headsets, it being understood that with a separate transducer **30.17** in each of two earphones of a headset, four different channels are available for reproduction of sound from suitably recorded magnetic tapes from which such signals are reproduced.

Transducers **30.18** and **30.19** of FIGS. **33** and **34** are illustrative of different conductor and vibratable area arrangements to provide multiple channels on one diaphragm and wherein the vibratable areas are only defined by the existence of isolated conductors which are connectable to the sources of electric signals related to multi-channel systems. As suggested in transducers **30.18** and **30.19**, the multiple channel signals and vibratable areas may be utilized for reproducing sound from an original source so as to reproduce the sound to get a feeling of height as well as a feeling of horizontal spread between the sources of the sound.

It will be seen that I have provided a new and improved electromagnetic transducer in the shape of a flat panel and without any appreciable depth as compared to its length and breadth, and which may be readily and easily manufactured because of the simple nature of materials used. The use of the flexible plastic sheet magnet, perforated to the desired degree, minimizes any gap consideration between the sheet magnets and the pole piece panels against which the sheet magnets lie, and without any machining or smoothening of the abutting faces of the sheet magnets and pole piece panels. These electromagnetic transducers can be constructed in many different shapes and configurations to increase the energy output as by stacking the conductors on the diaphragms, stacking the diaphragms on both sides of the magnetic panels, and providing for close spacing between the diaphragm and the sheet magnet by dishing the magnets to accommodate large excursions of diaphragm movement near the center of the vibratable areas while the spacing between the sheet magnet and the diaphragm adjacent the edge of the vibratable areas remains at a minimum. These electromagnetic transducers can be constructed to produce smooth frequency response characteristics and to produce very satisfactory polar distribution of the energy output.

What is claimed is:

1. An electromagnetic transducer comprising:

a flexible diaphragm having a vibratable area with a conductor affixed thereto and arranged in a certain configuration,

a perforate and stiff panel of magnetic material secured to the diaphragm at the periphery of the vibratable area and in confronting and spaced relation with the vibratable area,

and a perforate flexible sheet magnet lying against said panel in closely spaced relation with the diaphragm and being magnetized in a direction through its thinnest dimension and in elongate zones to form magnetic pole faces at the surface of the flexible sheet magnet, the pole faces conforming to the configuration of the conductors on the diaphragm, the flexible sheet magnet being magnetically drawn toward and held against the stiff magnetic panel regardless of non-uniform shapes of the stiff panel to minimize magnetic gap considerations adjacent said elongate magnetized zones.

2. The electromagnetic transducer according to claim 1 wherein the stiff panel is constructed of sheet metal of sufficiently light gauge as to be yieldable, the flexible sheet magnet maintaining a constant relationship with the metal panel regardless of flexing or yielding of the panel.

3. The electromagnetic transducer according to claim 1 wherein said panel has a preformed, non-planar shape.

4. The electromagnetic transducer according to claim 3 wherein said panel has a preformed dished shape, the flexible sheet magnet substantially conforming to the dished shape of the panel whereby the spacing between the conductor-carrying diaphragm and the sheet magnet varies from one portion to another of the vibratable area.

5. The electromagnetic transducer according to claim 1 wherein the perforations in the sheet magnet are oriented in rows, the elongate magnetized zones of the sheet magnet being spaced from each other by a distance not equal to center to center spacing between the rows of perforations.

6. The electromagnetic transducer according to claim 1 and including a plurality of conductors on the diaphragm, all of the conductors being clustered together and arranged in the configuration of the elongate zones and pole faces in the flexible sheet magnet and within the magnetic fields of said elongate pole faces.

7. An electromagnetic transducer comprising:

a flexible diaphragm having a vibratable area;

a plurality of conductors affixed to the diaphragm and arranged in closely spaced and juxtaposed runs in a predetermined configuration, certain of said runs extending in one direction and other of the runs extending transversely of said first direction;

first and second perforate magnetic panel means secured to the diaphragm in confronting and spaced relation with the vibratable area, and said first and second magnetic panel means being respectively disposed on opposite sides of the diaphragm, said magnetic panel means being magnetized in a direction through the thinnest dimension and in elongate zones to form magnetic pole faces at the surfaces of said magnetic panel means, the shape of the elongate zones and pole faces conforming to the configuration of the conductors on the diaphragm, and the elongate zones of the first and second magnetic panel means respectively extending transversely of each other, the conductors which extend transversely of each other extend parallel to the respective elongate magnetized zones in the first and second magnetic panel means.

8. A sound generating transducer comprising:

a pair of flexible diaphragms each having a vibratable area,

conductor means affixed on each of the diaphragms to receive audio frequency electric signals,

a stiff and acoustically transparent backing secured to and lying between said diaphragms and in closely spaced relation therewith, said backing confronting both diaphragms and having means defining polarity characteristics to alternately attract and repel the diaphragms to cause vibration of said vibratable areas upon application of audio frequency electric signals to said conductor means.

9. The sound generating transducer according to claim 8 and said backing including a perforate stiff panel of ferromagnetic material, and also including a pair of perforate flexible sheet magnets, each lying against the stiff panel in closely spaced relation with the diaphragm.

10. The sound generating transducer according to claim 8 and each of said diaphragms having a plurality of insulated conductors clustered together and arranged in said closely spaced juxtaposed runs of the predetermined configuration.

11. A sound generating transducer comprising:

a stiff and acoustically transparent backing having a broad and substantially flat shape,

a audio sound producing flexible diaphragm secured to the backing in confronting relation therewith and having a vibratable area spaced from the backing, the diaphragm having conductor means on the vibratable area, and said diaphragm being tensioned and stretched to dimensions in excess of corresponding dimensions while relaxed, but within the elastic limit of the diaphragm,

and said backing having means defining polarity characteristics to alternately attract and repel the diaphragm to cause vibration of said area upon application of an audio frequency electric signal to the conductor means.

12. The transducer according to claim **11** wherein the diaphragm is stretched in directions transversely of each other.

13. The transducer according to claim **11** wherein said diaphragm is stretched by approximately 1 percent in excess of its original dimensions.

14. The transducer according to claim **11** wherein the diaphragm is stretched to an extent wherein the resonant frequency of the vibratable area of the diaphragm is below the audible range.

15. The transducer according to claim **11** wherein the diaphragm is stretched to an extent wherein the resonant frequency of the vibratable area of the diaphragm is within the audible range.

16. The transducer according to claim **11** wherein said diaphragm has a plurality of vibratable areas, the diaphragm being substantially uniformly tensioned and stretched throughout said vibratable areas, and each of said vibratable areas having a size different than another vibratable area, the different sizes of the uniformly tensioned vibratable areas of the diaphragm causing the various vibratable areas to have varying resonant frequencies.

17. The transducer according to claim **11** wherein said diaphragm means is variously tensioned at various portions thereof causing such portions to have various sets of resonant frequencies.

18. The transducer according to claim **11** wherein the tension applied and stretching effected in the diaphragm means progressively varies between adjacent portions of the diaphragm whereby to accordingly vary the frequencies at which adjacent portions of the diaphragm resonate.

19. A sound generating transducer comprising:

diaphragm means including a plurality of vibratable diaphragm areas formed, respectively, to have various fundamental resonant frequencies distributed across the range of frequencies in the audio range, each of the vibratable areas having a fundamental resonant frequency separated significantly from the fundamental resonant frequencies of other vibratable areas, the vibratable areas carrying conductor means to receive audio frequency electric signals,

and an acoustically transparent backing secured to the diaphragm means in confronting and spaced relation with the vibratable diaphragm areas, said backing having means defining polarity characteristics to alternately attract and repel the diaphragm to cause vibration of the vibratable diaphragm areas upon application of an audio signal to the conductor means.

20. The sound generating transducer according to claim **19** and the vibratable diaphragm areas being variously tensioned and stretched in various amounts to have various resonant frequencies.

21. The sound generating transducer according to claim **19** wherein the sizes of said vibratable areas vary relative to each other whereby to vary the resonant frequencies thereof.

22. The sound generating transducer according to claim **19** wherein the several vibratable areas of the diaphragm including the conductor means thereon have various masses relative to each other to effect various resonant frequencies.

23. The sound generating transducer according to claim **19** and including means between said vibratable areas restraining the vibrating movement of the diaphragm means relative to the backing.

24. The sound generating transducer according to claim **19** wherein the conductor means on the several vibratable areas are isolated from each other for connection to sources of various electric signals.

25. The transducer according to claim **19**, wherein said diaphragm means is formed of a plurality of different weights of diaphragm film material to have various resonant frequencies at the several areas thereof.

26. An electric signal-sound transducer, comprising:

a flexible diaphragm having a vibratable area,

an acoustically transparent backing confronting the diaphragm and connected to the edges of the diaphragm, the diaphragm and backing having interacting means including an electric signal-carrying conductor means inducing coordination between vibration of the diaphragm and modulation of the electric signal, one of said vibration and modulation being the cause of the other of said vibration and modulation, and

the diaphragm-confronting face of the backing having concavity to permit full vibration or excursions of the diaphragm without interference from the backing.

27. The transducer according to claim **26** wherein said conductor means are on the diaphragm.

28. The transducer according to claim **27** wherein said conductor means are elongate and are arranged in juxtaposed runs on the diaphragm to carry an electric current, and said panel means having magnetic zones conforming to the arrangement of conductors on the diaphragm, the direction of magnetization being through the thinnest dimension of the panel means to coact with the current in the conductors for producing vibration of the diaphragm.

29. A sound generating transducer comprising:

diaphragm means including a plurality of vibratable diaphragm areas, the size of each vibratable area being different than the size of another of the vibratable areas to have a resonant frequency different than the resonant frequencies of the other areas which frequencies are distributed across the audio range, each of the vibratable areas of the diaphragm means carrying conductor means to receive audio frequency electric signals,

frame means with openings corresponding to the sizes of the various vibratable diaphragm areas and being secured to the diaphragm means at the peripheries of such vibratable areas,

and a stiff and acoustically transparent backing secured to the frame means in confronting and spaced relation with the vibratable diaphragm areas and having means defining polarity characteristics to alternately attract and repel the diaphragm to cause vibration of said vibratable areas upon application of audio frequency electric signals to the conductor means.

30. The sound generating transducer according to claim **29** and the diaphragm means having reduced thickness at the smaller vibratable areas to produce high energy output at high range audio frequencies.

31. The sound generating transducer according to claim **29** and the spacing between the diaphragm and the backing being less at the small vibratable areas of the diaphragm than at the larger vibratable areas of the diaphragm means.

32. The sound generating transducer according to claim **29** and the acoustically transparent backing having a lesser percentage of open area adjacent the smaller vibratable areas than at the larger vibratable areas of diaphragm means.

33. The transducer according to claim **29** and said diaphragm means being in an elongate shape and being formed in a one piece integral and unitary construction, the elongate diaphragm means having a plurality of vibratable areas spaced from each other in a direction longitudinally of the elongate diaphragm means, each such vibratable area having a size different than other vibratable areas, the frame means also having an elongate shape and being secured to the diaphragm means, the frame means having a panel defining separate openings each confronting a respective vibratable area of the diaphragm means and corresponding to the size thereof.

34. The transducer according to claim 29 and the diaphragm means being elongate in shape and being formed in a one piece, integral and unitary construction, the elongate diaphragm means having a plurality of vibratable areas spaced from each other in a direction longitudinally of the elongate diaphragm means, each such area having a size different than other vibratable areas,

the frame means also having an elongate shape and being secured to the diaphragm, and rigid spacer strips affixed to the diaphragm between adjacent vibratable areas to secure the edge of the vibratable areas against vibrating.

35. The transducer according to claim 29, and the diaphragm means being elongate and being formed in a one piece integral and unitary construction, the elongate diaphragm having a plurality of vibratable areas of equal size spaced from each other,

the frame means also having an elongate shape and being secured to the diaphragm, the frame means having a panel defining separate openings of equal size, each confronting a respective vibratable area of the diaphragm means,

and a rigid strip traversing each opening in the frame and affixed to the diaphragm means to divide the diaphragm into areas of non-uniform size within each of the openings.

36. An electromagnetic transducer comprising:

a perforate flexible sheet magnet magnetized in a direction through its thinnest dimension and in elongate narrow zones spaced from each other to form magnetic pole faces at the surface of the flexible sheet magnet, said zones and faces being arranged in a reproducable configuration,

a diaphragm overlying the sheet magnet in spaced relation, the diaphragm being constructed of light weight film material having a mass many times less than the mass of the sheet magnet so as to be vibratable at audio frequencies while the sheet magnet remains substantially stationary,

conductor means on the vibratable areas of the diaphragm and arranged in the configuration of the zones and pole faces of the flexible sheet magnet,

and spacer means between the sheet magnet and diaphragm and secured thereto to maintain the vibrating diaphragm in spaced relation from the sheet magnet.

37. The electromagnetic transducer according to claim 36 and the spacer means including a plurality of spacing elements disposed between and engaging the sheet magnet and the diaphragm and being distributed over the face of the sheet magnet.

38. The electromagnetic transducer according to claim 36 and also including means exerting tension on the flexible sheet magnet in multiple transverse directions.

39. An electromagnetic transducer comprising:

a flexible diaphragm with a vibratable area and formed into a shape which is at least partially cylindrical,

conductors on the diaphragm and arranged in closely spaced juxtaposed runs in a predetermined configuration,

and perforate magnetic panel means also formed into a shape which is at least partially cylindrical to follow the contour of the flexible diaphragm and being spaced from the diaphragm, said magnetic panel means being magnetized in a direction through its thinnest dimension and in elongate zones to form magnetic pole faces at the surface of the magnetic panel means, the elongate zones and pole faces being arranged in the configuration of the conductors on the diaphragm, and means maintaining the magnetic panel means in spaced relation with the vibratable area of the diaphragm.

40. An electromagnetic transducer comprising:

a flexible diaphragm having a vibratable area with a conductor affixed thereto and arranged in closely spaced and juxtaposed runs in a predetermined configuration, and

an acoustically transparent backing secured to the diaphragm in confronting and spaced relation with the vibratable diaphragm areas, said backing having a plurality of spaced and juxtaposed strips of flexible material magnetized in a direction transversely of the strip to define elongate magnetic pole faces confronting the diaphragm and causing alternate attracting and repelling of the diaphragm as audio frequency signals are applied to the conductors, and

said backing also including means of stiff magnetic material underlying said strips and against which said strips are magnetically drawn.

41. The electromagnetic transducer according to claim 40 and said acoustically transparent backing having a preformed dished shape to permit substantial excursions of the diaphragm during vibration without interfering with the backing.

42. A sound generating transducer comprising:

a diaphragm including a plurality of adjacent vibratable areas formed to vibrate independently of each other, each of said vibratable areas having conductor means thereon to receive audio frequency electric signals, the conductor means of each respective vibratable area being electrically isolated from the conductor means of the other vibratable area for connection with one channel of a stereophonic amplifier system as a source of audio frequency electric signals, and

an acoustically transparent backing secured to the diaphragm means in confronting and spaced relation with the vibratable diaphragm areas, said backing defining polarity characteristics to alternately attract and repel the diaphragm to cause vibration of the vibratable diaphragm areas upon application of the audio signals of different stereophonic signal channels to the conductor means of the several areas.

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