Aug. 1, 1967 W. J. ASHWORTH **3,334,195**

MAGNETIC SPEAKER CONSTRUCTION

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FIG. 1

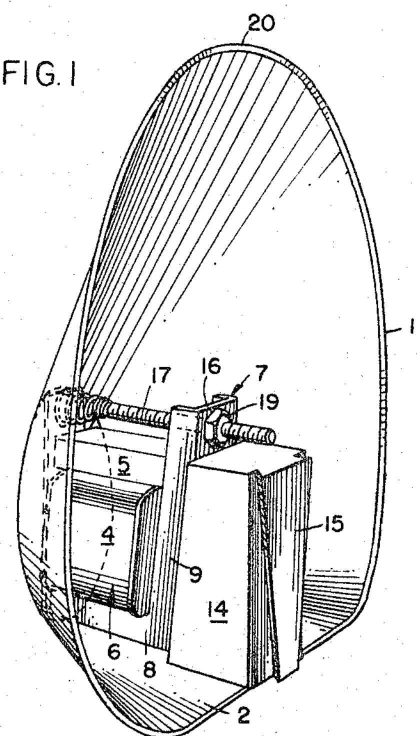

FIG. 2

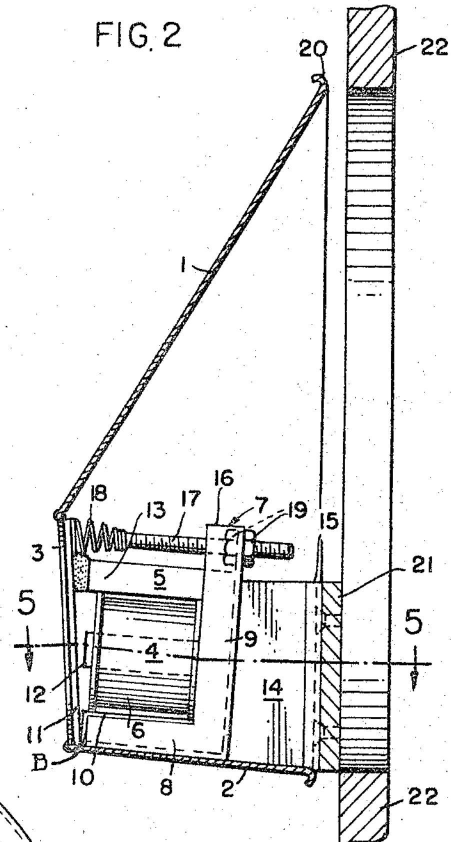

FIG. 3

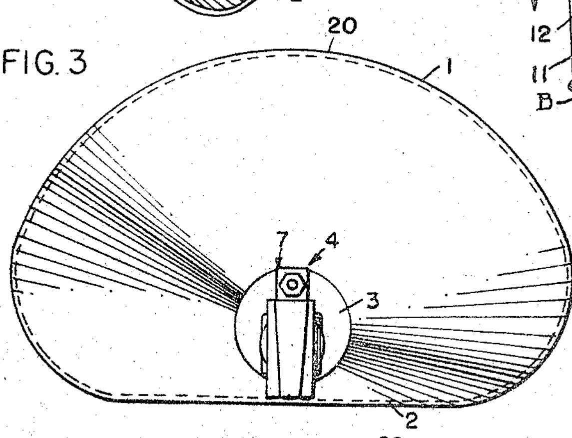

FIG. 5

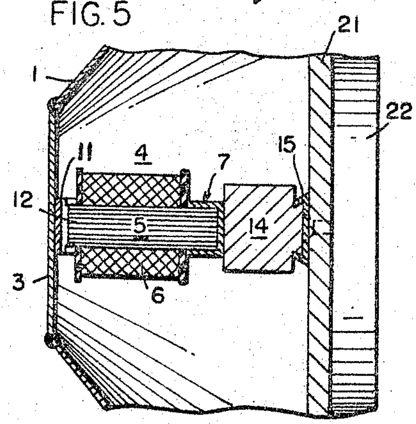

FIG. 4

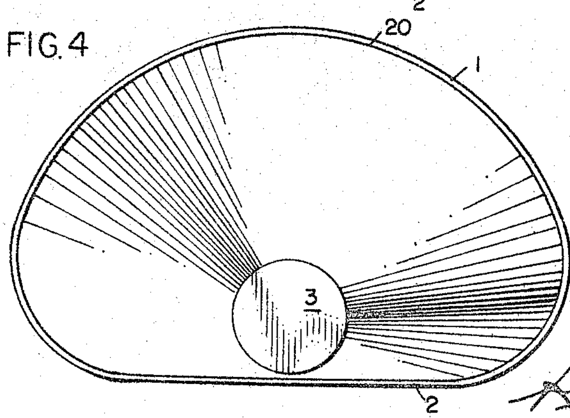

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FIG. 6

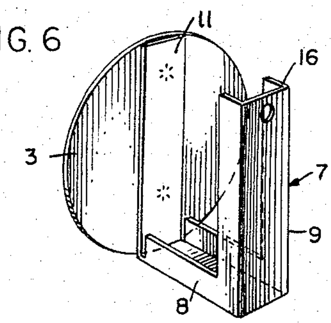


FIG. 9

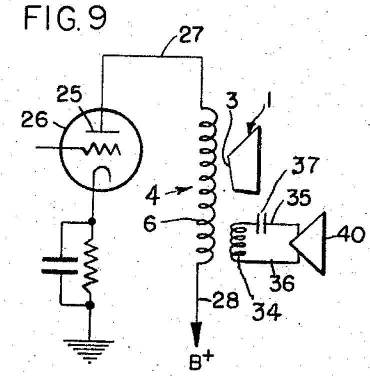


FIG. 7

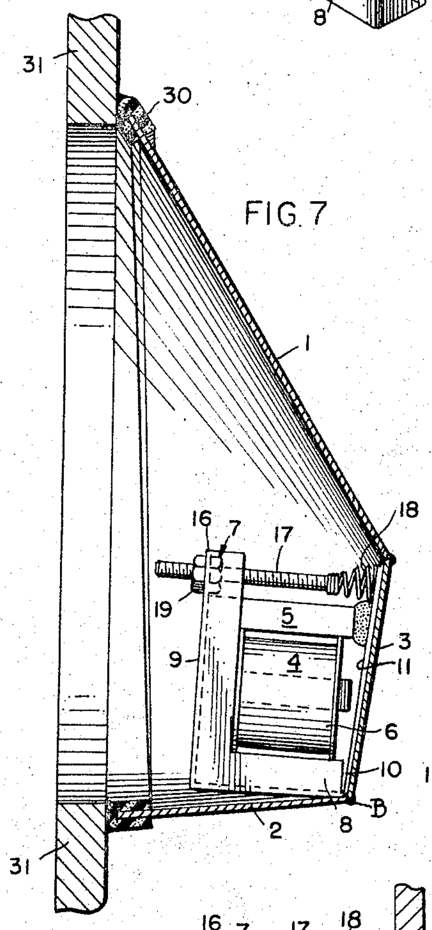


FIG. 8

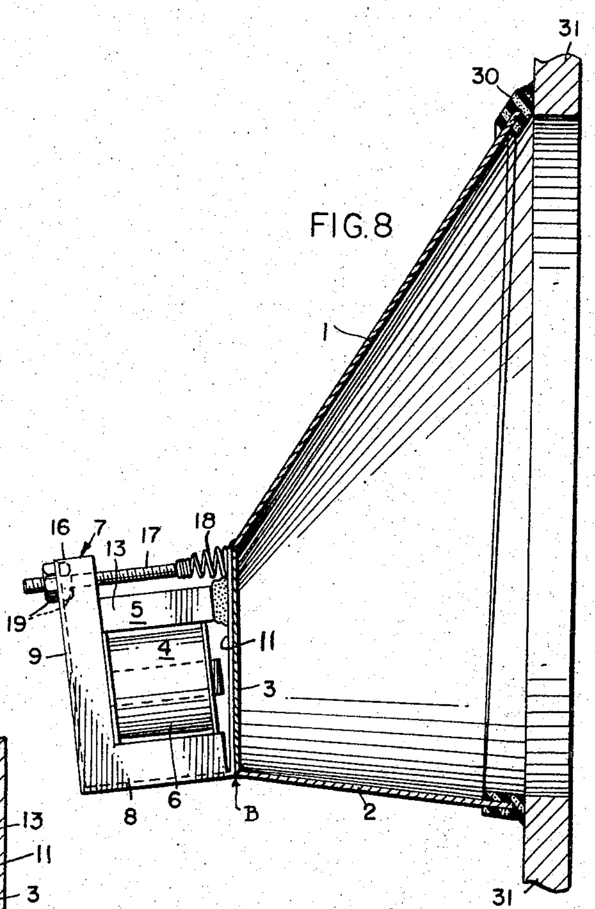
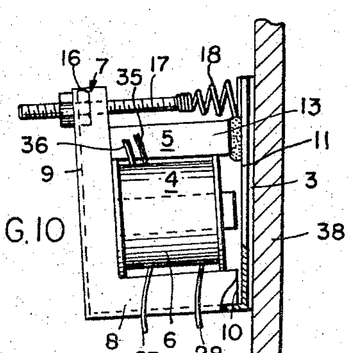


FIG. 10



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3,334,195
MAGNETIC SPEAKER CONSTRUCTION

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18 Claims. (Cl. 179—115)

This invention relates to audio translating devices applicable for use in converting electrical impulses into sound.

The primary objects of this invention are to provide a quality loud speaker having an inexpensive arrangement of electromagnet driver and paper diaphragm; to provide an improved electromagnetic driver means for actuating a diaphragm; and to provide an improved cone-type speaker diaphragm having a wide range of sound wave propagation.

Specific embodiments of my invention are shown in the accompanying drawings in which:

FIGURE 1 is a perspective view of the preferred form of the driver-diaphragm assembly according to my invention;

FIG. 2 is an elevational view of the same, partly in section, showing the device in mounted position;

FIG. 3 is a front view of the improved speaker construction;

FIG. 4 is a rear view of the same;

FIG. 5 is a sectional view as taken on line 5—5 of FIG. 2;

FIG. 6 is a perspective view showing a preferred construction for the driving plate and electromagnet support combination;

FIG. 7 is a sectional view showing another way of mounting the improved speaker construction;

FIG. 8 is an elevational view partly in section of a modified arrangement of the cone and driver of the improved speaker;

FIG. 9 is a schematic wiring diagram for the improved speaker showing the connection with the output stage of an audio frequency amplifier and the use of a secondary coil on the electromagnet to drive a tweeter; and

FIG. 10 is an elevational view showing the improved speaker driving mechanism, wired as in FIG. 9, used to actuate a sounding board instead of a cone-type diaphragm.

My invention is intended to overcome the problems that have normally been associated with magnet type loud speakers, namely, the problem of obtaining sufficient movement of the diaphragm to produce a good low frequency response without using an excessive amount of driving power and at the same time obtain a good high-frequency response.

In the past it has been less expensive to build a magnetic type loud speaker than one of the dynamic type using permanent magnets, but the problem of obtaining a balanced frequency response over a broad range has been a significant drawback to the magnetic type of speaker construction. This, and other problems that have been associated, heretofore, with magnet type loud speakers are well known to the art and need not be further discussed. Suffice it to say, that with my invention these problems have been overcome and a balanced frequency response can be realized over a broad audio range; and at the same time the cost of building this loud speaker will be considerably less than that required to build a dynamic type loud speaker for covering the same sound range.

The essential concept of my invention is to provide a speaker having an improved cone-type diaphragm, in the form of an upright scoop or scallop shell, wherein the

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driver unit is mounted eccentrically and directly onto the diaphragm and the diaphragm-driver assembly is arranged for use in such a manner that the peripheral edge of the diaphragm is free to move when the diaphragm is actuated; and to provide an electromagnetic driver unit wherein the movable member, or armature, is hingedly mounted with respect to the electromagnet so as to oscillate about an axis normal to the axis of the magnetic pole and wherein the said movable member is adjustably restrained against movement other than by electromagnetic actuation.

As shown in FIGS. 1 to 5 inclusive, the improved speaker construction comprises a paper cone **1** substantially in the form of a scoop or band-shell made by truncating a hollow core and pulling in a portion of the side wall toward the cone axis to form a substantially flat base portion **2**, almost normal to the plane of the truncated part and comparable to the handle end of a scoop or in the hinge part of a scallop shell. The opening at the truncated end of this scoop-shaped diaphragm is closed by a magnetizable iron plate, here shown as a disk **3**, cemented to the edges of the truncated part, so as to be an integral part of the diaphragm unit. An electromagnet **4** is mounted interiorly of the diaphragm, substantially centered with the metal disk **3**, and comprises a laminated E-shaped frame or core **5** having three equally spaced arms or poles and on the center arm or pole of which is mounted an electrical winding, comprising, a coil **6**, whereby the electromagnet may be energized when the coil is connected to a signal source. As shown, the electromagnet frame **5** is supported in a U-shaped bracket **7**, having a base **8** and a rear leg **9** of an inwardly opening channel form adapted to snugly embrace the back and the lower arm or pole piece **10** of the E frame **5**, and having its other or forward leg **11** as a flat member bonded in diametric face to face relation onto the iron disk **3**. The bracket leg **11**, which functions as an armature for the electromagnet, diverges from the base **8** and relative to the leg **9** so as to dispose the iron plate or disk **3** in a plane inclined outwardly from the plane of the free ends of the electromagnet pole pieces and so that the free ends of the center pole **12** and the upper arm or pole piece **13** of the E frame **5** are spaced away from the adjacent face of the leg **11**. The channel-shaped base **9** of the bracket **7** is firmly attached to a mounting block **14**, which extends outwardly from the diaphragm beyond the plane of its outermost edge, and this mounting block is arranged for attachment to a fixed support by any suitable means, for example the dovetail fastener **15** shown in FIGS. 2 and 5.

Preferably the mounting bracket **7** is made of steel or iron and the leg **9** is formed to be of greater length than the back of the E frame **5** to provide an extension **16** projecting beyond the E frame and above the upper pole **13**. A screw **17**, extends through an aperture in the extension **16**, parallel with the upper leg or pole **13** of the E frame **5**, and the inner end of the screw **17** is connected to one end of a coiled spring **18** made of brass. The opposite end of the brass spring **18** is rigidly connected to the adjacent face of the flat leg **11** which, like the leg **9**, extends beyond the uppermost pole **13**. As shown, the screw **17** is longitudinally adjustable in the aperture of the bracket extension **16** by means of lock nuts **19**, threaded onto the screw **17** one on each side of the extension **16**. The function of the adjustable screw **17** is to adjust the angle between the plane of the armature, comprising the leg **11** and plate **3**, and the plane of the pole faces of the electromagnet **5** and, thus, the width of the air gap between the face of the pole piece **13** and the adjacent face of the leg **11**.

At this point it will be realized that as the electromagnet is activated by a variable current passing through the coil **6**, the frame or core **5** will become variably magnetized and so effect a variable magnetic attraction on the armature, or flat frame-leg **11** and the iron disk **3**, thereby imparting vibration to the cone **1** or diaphragm onto which the disk **3** is attached. The brass spring **18** serves as a resilient restoring means for the normal or inactive position of the leg **11** and disk **3**, as well as a connector for the spacing means **17** to adjust the gap between the electromagnet poles and the leg **11**; and the spring is of brass so as to avoid distortion in the sound from the diaphragm due to the spring resonating. Also brass is used in the spring to prevent any short circuit of the normal magnetic flux path generated by the electromagnet when it is energized.

The mounting block **14**, which may be of wood or any other suitable material, is firmly fastened to the back side of the bracket base **9** by any suitable means, such as cement or screw fasteners, and extends outwardly to a point beyond the plane of the free edge **20** of the diaphragm cone **1**. As shown in FIGS. 2 and 5, the outer end of the mounting block **14** is provided with one part of a conventional dovetail fastener **15** by which the entire speaker assembly may be attached to and supported by a fixed element **21** which may be a part of a speaker housing **22**. It will now be seen that, as so mounted, the speaker diaphragm or cone is supported entirely by the metal disk **3** and, except for the central part of its base portion **2**, is completely free to vibrate without interference. Thus the vibratory action of the diaphragm-cone is quite similar to that of a conventional hand fan, as it would be waved to create an air movement, the entire diaphragm oscillating with the disk **3** about an axis substantially coincident with the point B in FIG. 2, which is the hinge formed by the connection of the flat leg **11** to the frame base **8**. Preferably the frame **7** is a unitary element wherein the base **8** and the legs **9** and **11** are formed from a single metal piece.

As indicated in FIG. 10 the hereindescribed speaker is operated by connecting the coil **6**, of the electromagnet **4**, directly in circuit with the output of an audio amplifier, such as the plate **25** of an amplifier output tube **26**, the coil **6** having leads **27** and **28** for this purpose. When the amplifier is operating a constant DC will flow through the coil **6** and will thus magnetically energize the electromagnet frame **5**. This will cause the leg **11** and iron disk **3** to be attracted toward the pole pieces of the electromagnet in direct proportion to the amount of constant DC applied to the coil **6** and then normal position of the disk **3**, relative to the poles of the electromagnet, will be determined by the tension, or resistance, of the brass spring **18** and the axial adjustment of the screw **17** relative to the mounting bracket base **9**.

It will be understood that different types of amplifiers and different types of tubes will usually have different constant DC output characteristics. This requires adjustment of the screw **17**, according to the particular amplifier employed, in order to establish the optimum normal spacing of the disk-to-pole relationship under the constant DC influence. The optimum constant DC spacing of the disk relative to the poles of the electromagnet is determined by the desired range of sound intended to be reproduced by the speaker. When the range is to be such that the higher frequencies predominate the normal or constant DC position of the disk **3** should be closer to the poles, particularly the uppermost pole **13** of the E frame core shown in the drawings. The lower range of sounds is obtained by increasing the pole spacing when under the constant DC influence. Thus, since a varying audio frequency signal, applied to the amplifier, will produce a directly proportional varying current at the amplifier output, such varying current will be imposed on top of the constant DC to cause oscillation of the disk **3**, about the hinge B from the normal or constant DC position. It is for this reason that the normal position or starting point will directly influence the speaker range.

Where a close spacing of the disk **3** and poles is to be had, a small plate of foam rubber may be cemented on the ends of the poles to obviate metal to metal contact.

In those cases where a constant DC is not produced by the amplifier, such as in a push-pull type of amplifier, the same effect may be had by mounting a permanent magnet on the end of the center pole **12** of the electromagnet, the said center pole being cut away to accommodate the permanent magnet flush with the ends of the other poles of the E frame core.

The fan type oscillation of the diaphragm-cone, about the hinge axis B (FIG. 2), due to electromagnetic actuation of the iron disk **3**, results in a multiplication of movement amplitude at the periphery of the diaphragm and hence a relatively large displacement of air for reproduction of the lower sound frequencies and yet the extent of movement of the disk **3**, relative to the upper pole **13** of the electromagnet, is quite small compared to that which would be required for actuating a true cone. Thus less driving power is needed for my improved construction to reproduce the lower sound frequencies than is required in other magnetic speaker arrangements.

At this point it will be noted that the hinge axis B is parallel with and substantially within the plane of the flattened portion of the cone so that the vibrating, or oscillating, action of the cone occurs only in the cone areas above this "base part" **2** as viewed in FIGS. 2 and 3. Also the flat leg **11**, of the mounting bracket **7**, which is bonded to the metal plate **3**, is disposed perpendicularly with respect to the base part **2** of the cone and extends across the center of the plate **3** from substantially the lowermost edge thereof. Thus there are no areas of the diaphragm-cone surface that can move oppositely to the remaining air moving or fanning areas of the diaphragm and thus tend to cancel out the main sound producing effect.

Repeated tests, with a "6-inch" speaker construction according to my invention, have demonstrated that the frequency response of the sound reproduced by the diaphragm-cone drops off sharply at approximately 2000 cycles due to the inertia of the combined weight of the cone and the driving disk **3**. Beyond this point the sound of the improved speaker is radiated from the driving disk **3** up to a frequency of about 4500 cycles, the width of the frequency gap at the changeover point being small enough that it can not be distinguished by the human ear. Tests also show that the intensity of the sound produced by the disk over its frequency range above about 2000 cycles is approximately the same as the intensity of the sound produced by the diaphragm cone in the lower range of frequencies.

I have found that the effective range of frequencies reproduced by the metal driving disk **3** depends upon the natural resonant frequency of the disk, the intensity of the sound emitted by the disk decreasing sharply at the natural resonant frequency of the disk but sound reproduction continuing for several thousand cycles beyond the resonant point. Thus, to broaden the intensity range as well as the frequency range of the sound produced by the metal disk **3**, I make the disk of a relatively thin material with a natural resonant point of approximately 3000 cycles and I make the mounting bracket of a material such that the flat leg **11**, which is bonded to the face of the disk, will have a natural resonant frequency of approximately 4000 cycles. With this structure the metal component of the diaphragm-cone combination will emit sound at a high intensity of volume throughout a range of about 2000 cycles to approximately 6500 cycles, while the paper diaphragm-cone is generating sound in the range of about 60 to 2000 cycles.

The natural frequency of the metal disk may be varied by using different weights or thicknesses of metal, i.e., the greater the weight—the higher will be the resonant frequency.

In the construction of a "6-inch" speaker as used for the above mentioned tests and as above described the diaphragm-cone was made from a parchment-type paper ordinarily used for woofer-type loud speaker cones and the "fan-like" form was made from a right circular cone, having an altitude of about 2½ inches and a base diameter of about 7 inches. This cone was then truncated to provide a central opening 2 inches in diameter in which a 2-inch metal disk **3** was peripherally bonded to the cone at the edge of the opening, and the cone was then cut radially from the edge of the opening to form the base **2.** The E frame or core **5** of the electromagnet was made from standard ⅜ inch 24-gauge transformer laminations stacked one-half inch high; and the coil **6** was wound with 5000 turns of No. 39 magnet wire. The iron disk **3** was made from sheet iron .033 inch thick and 2 inches in diameter; and the mounting bracket **7** was made from 20-gauge sheet iron with the flat arm **11** one-half inch wide and 2 inches long. The coiled spring **18** was made with 5 turns of .045-inch diameter spring brass wire wound in a 5⁄16 inch outside diameter coil, one-half inch long.

In this speaker construction the screw **17** was adjusted to provide a gap of 1⁄32 inch between the end of the center pole **12** and the flat plate-carrying arm or leg **11** of the mounting bracket **7.** This provided an air gap of approximately 1⁄16 inch between the leg **11** and the uppermost pole **13.** For test purposes the speaker was driven with one watt of power input to the electromagnet.

I have found that the thickness of the metal disk **3** has some influence on the range of the speaker, not only due to the combined weight of the disk and cone but also because of the resonant frequency of the disk. The .033-inch thick, 2-inch disk has a resonant frequency of about 3000 cycles and therefore picks up at about 2000 cycles. A two-inch disk .043 inch thick has a resonant frequency of about 4000 cycles and therefore begins to take over as a sound reproducer at about 3000 cycles, while at the same time causing the paper diaphragm to drop its sound reproducing ability at about 1500 cycles. On the other hand, when a two inch disk less than .030 inch thick is used harmonic distortion begins to appear in the sound produced by the disk.

In the arrangement shown in FIG. 7 the improved speaker is attached to its support means by its peripheral edge, the periphery of the cone being enclosed in and cemented to a channel shaped ring **30** of polyethylene foam rubber which, in turn, is cemented to the baffle board **31** of a speaker enclosure. With this mounting of the speaker the electromagnetic motor is supported entirely by the diaphragm cone **1** through the metal disk **3.** I have found, however, that while the motor is entirely supported by the metal disk **3,** its inertia tends to keep it stationary in space while the disk **3** and the cone **1** vibrate. The flexibility of the polyethylene supporting ring permits a fan type movement of the diaphragm, including its peripheral margin, about the hinge axis B.

A modified speaker construction embodying my invention is shown in FIG. 8, of the drawings herein, wherein the electromagnetic motor is mounted on the back side of the disk **3** and wholly outside of the speaker cone. In this arrangement the speaker assembly is intended to be supported by the mounting bracket **7,** in a manner similar to that shown in FIG. 2, and the polyethylene ring **30** is not cemented to the baffle board **31** but functions as a cushion and air seal.

As indicated in FIG. 9, the electromagnet **4** takes the place of the usual output transformer of the amplifier and therefore, to take advantage of the transformer capability of the electromagnet, the coil **6** is made to include a secondary winding **34** having leads **35** and **36** which may be connected to a tweeter **40** for reproduction of sounds in the higher range than those produced by the diaphragm **1.**

Also, as shown in FIG. 9, a condenser **37** is preferably connected in one of the leads **35–36** to the tweeter **40** to function as a cross-over means whereby the efficiency of the main diaphragm for reproduction of the lower frequency sounds will be improved. It will be understood that the capacity of the condenser **37** will be selected according to the desired frequency at which the cross-over from the primary coil **6** to the secondary **37** is to occur and the cross-over frequency will be determined by the sound output characteristics and range of the main diaphragm. Thus, as will now be apparent, the improved driver unit will serve as an actuating means for a low frequency sound reproducing system as well as a transformer to operate a high frequency sound reproducer, with both functions being performed simultaneously.

In FIG. 10 the improved electromagnetic driver of my invention is shown as it would be used to operate a sound board **38,** such as a cabinet wall. In this case the metal disk **3** is cemented directly to the sound board **38** and the latter is caused to vibrate as a whole to produce sound. With this arrangement the sound reproduction will be mainly in the lower tone range, below 2000 cycles, and hence the secondary winding leads **35** and **36** will normally be connected with a separate tweeter **40** of the dynamic type for producing sound mainly in the frequency ranges above 2000 cycles. In such a case the condenser **37** will be selected for a capacity such as to bring the cross-over from primary to secondary, at the point where the main diaphragm output drops below a desired optimum.

The main advantages of my invention reside in the comparatively low cost of the speaker construction due to the improved electromagnetic driver and its connection with the diaphragm; the improved "fan-type" of diaphragm whereby a good base response is obtained, as well as good reproduction of the mid range and higher frequencies, without the need of a "step-up arm" or lever as in prior electromagnetic speaker constructions; and in the improved diaphragm and driver combination whereby the relatively small motor, required for adequate volume of sound, can be mounted directly onto the diaphragm thereby minimizing the space required for the sound reproducing system.

Other advantages are to be found in the fact that the need for the usual "basket" for supporting the cone and driver has been obviated; in the fact that the entire speaker assembly can be supported from the driver itself; in the fact that there are no structural features requiring precision manufacture or assembly; and in the fact that the driver can be readily adjusted to accommodate the different output characteristics of various audio frequency amplifiers.

Although several specific embodiments of this invention have been herein shown and described it will be understood that details of the constructions shown may be altered or omitted without departing from the spirit of the invention as defined by the following claims.

I claim:

1. An electromagnetic sound reproducing means comprising an electromagnet mounted on a support bracket having a base part extending parallel with the magnetic axis of the electromagnet and a leg part disposed normal to the said magnetic axis, a plate of magnetic material disposed transversely of the said magnetic axis and pivotedly connected adjacent its periphery on the base part of the support bracket for vibratory actuation by the electromagnet about the axis of the pivoted connection, and an axially resilient member connected between the leg part of said support bracket and the margin of said plate at a location spaced angularly about said magnetic axis from the pivoted connection of the plate on said base part for normally holding said plate in spaced relation with the electromagnet.

2. A sound reproducing means as defined by claim **1** wherein the electromagnet comprises a frame having a pole piece and an electrical winding thereon, said pole piece being disposed with its axis generally normal to the said plate.

3. A sound reproducing means according to claim **1** wherein the said plate is substantially rigid and the axially resilient member is axially adjustable to vary the normal spacing of the plate and the electromagnet.

4. A sound reproducing means according to claim **1** wherein the axially resilient member comprises a helically coiled element made of non-magnetic material.

5. A sound reproducing means according to claim **4** wherein the helically coiled element is disposed axially on the end of an axially adjustable rod extending from the leg part of the support bracket.

6. A sound reproducing means according to claim **1** wherein the electromagnet is provided with primary and secondary windings, the primary winding having leads for connection with a signal source and the secondary winding having leads for connection to a second sound reproducing means to be actuated solely from said secondary winding.

7. A sound reproducing means according to claim **1** wherein the support bracket comprises a U-shaped member having an integral leg part at each end of the base part and extending transversely of the said magnetic axis, and said plate is bonded directly onto the outer face of one of said leg parts.

8. A sound reproducing means according to claim **1** wherein the said plate is bonded to a diaphragm of scallop shape, the plate is located eccentrically of the diaphragm margins adjacent the base part thereof, and the diaphragm margins are free to move in the axial direction in response to vibrations of said plate.

9. A sound reproducing means according to claim **1** wherein the electromagnet comprises an E frame having a center pole and an electrical winding thereon, said frame having upper and lower arms terminating in free ends lying substantially in the plane of the end of said center pole, and the free ends of said arms being within the axially projected area of said plate.

10. An electromagnetic sound reproducer comprising

(1) an electromagnet having an iron frame in the shape of an E and an electrical winding disposed on the central arm thereof,

  (a) the faces of the free ends of the upper, lower, and central arms of the said frame lying substantially in a common plane,

(2) a support bracket for said electromagnet comprising a U-shaped member having a base part extending lengthwise of the lower arm of said frame and an integral leg at each end of said base part,

  (a) one of said legs extending across the faces of the free ends of the E frame arms and the other leg extending along the back of said E frame,

  (b) said legs being of substantially equal length and projecting beyond the upper arm of the E frame, and

(3) an axially resilient member connected between the projecting portions of said support bracket legs for normally holding the said one leg in spaced relation with the face of the free end of the upper arm of said E frame.

11. An electromagnetic sound reproducer as defined by claim **10** wherein the axially resilient member is axially shiftable for adjusting the normal spaced relation of the said one leg and the face of the said upper arm.

12. A sound reproducer as defined by claim **10** wherein the axially resilient member comprises a helical coil of a non-magnetic material.

13. A sound reproducer as defined by claim **10** wherein the axially resilient member comprises a helical coil of a non-magnetic material mounted axially on the end of a substantially rigid rod, and said rod is connected to the projecting portion of said other bracket leg for axial adjustment relative thereto.

14. A sound reproducer as defined by claim **13** wherein a flat plate of iron is bonded onto the outer surface of said one leg of the support bracket in face-to-face relation therewith.

15. A sound reproducer as defined by claim **14** wherein the said flat plate is connected to a diaphragm eccentrically with respect to the diaphragm margins.

16. A sound reproducer as defined by claim **14** wherein the winding on the said E frame comprises a primary coil and a secondary coil, the primary coil having leads for connection with the output of a amplified signal source and the secondary coil having leads for connection to the actuating coil of a separate speaker, and one of the leads of said secondary coil including a condenser.

17. A sound reproducer of the class described comprising a diaphragm generally of the shape of a scallop shell, a plate secured eccentrically on said diaphragm adjacent the base porton thereof, and means for oscillating said plate about an axis lying in the plane of the plate and substantially parallel with the said base portion of the diaphragm.

18. A sound reproducer substantially as defined by claim **17** wherein the peripheral portions of said diaphragm are free to oscillate in the direction generally normal to the plane thereof.

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