Dec. 12, 1967 W. J. ASHWORTH 3,358,084

ELECTROMAGNETIC SOUND REPRODUCER

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FIG. 1

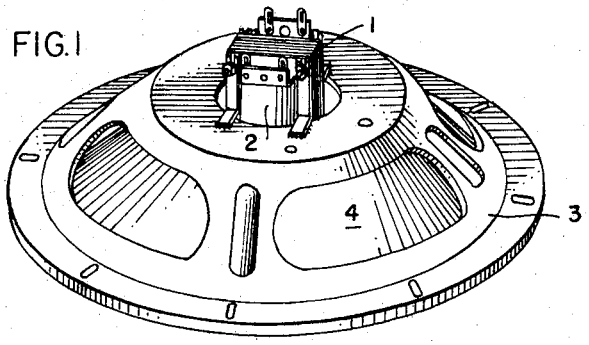


FIG. 2

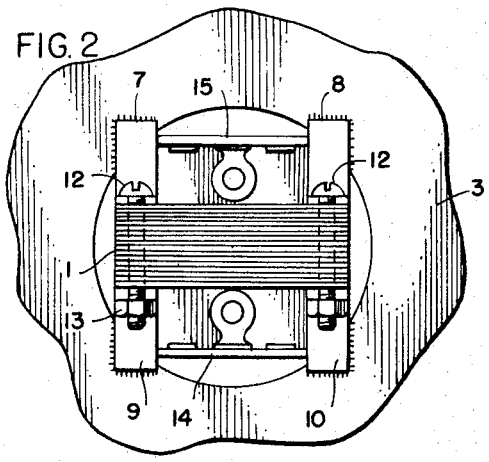


FIG. 3

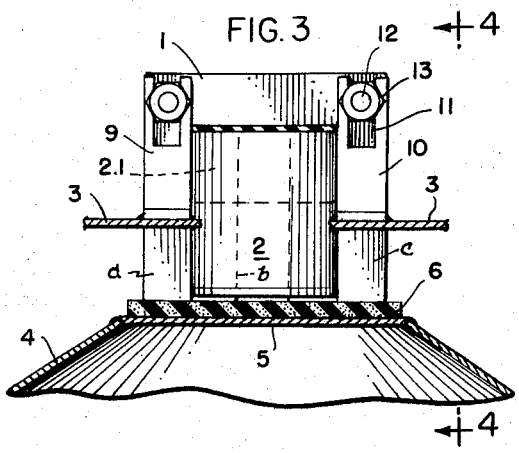


FIG. 5

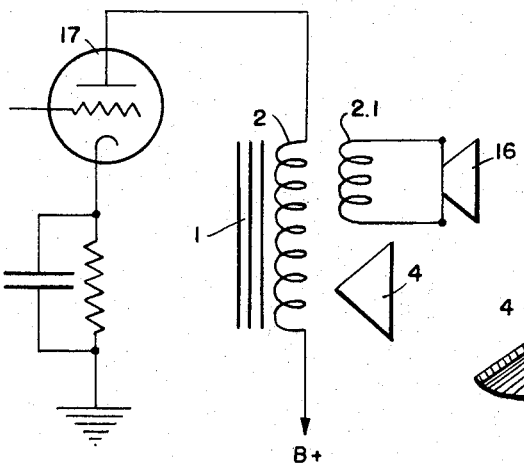
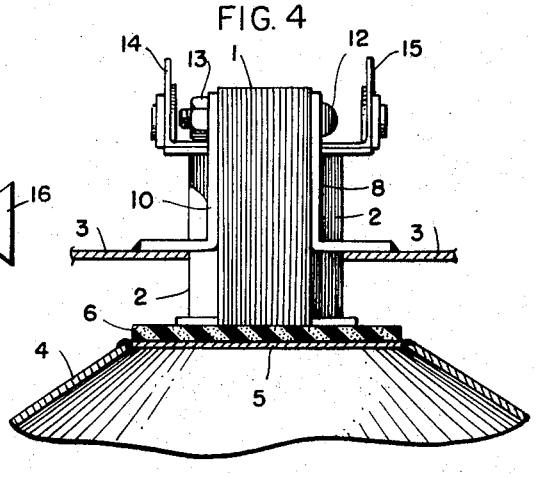


FIG. 4



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ELECTROMAGNETIC SOUND REPRODUCER

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FIG. 6

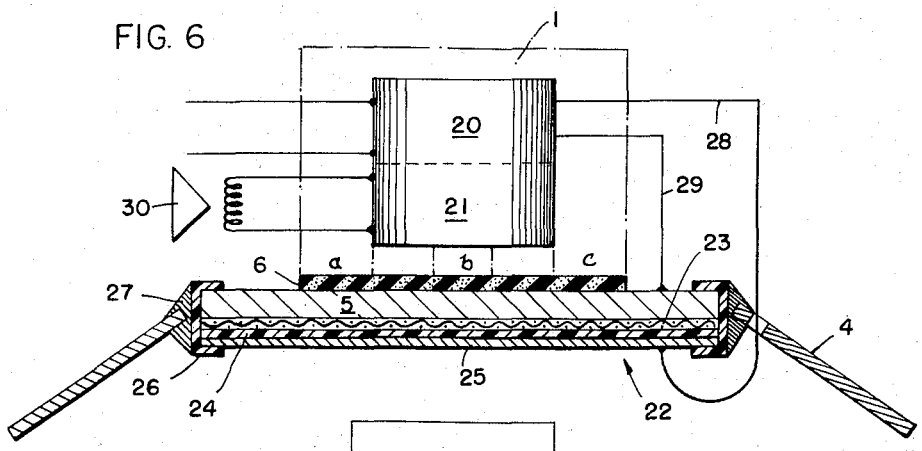


FIG. 7

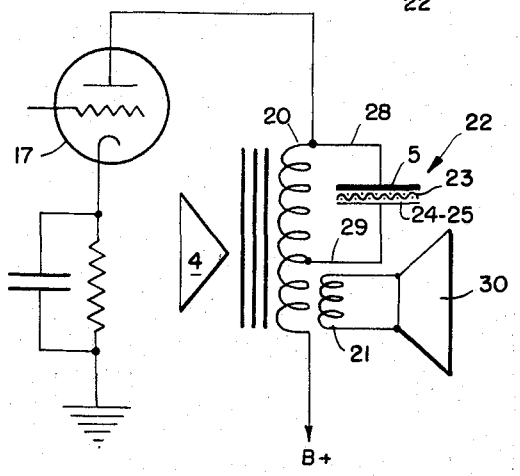
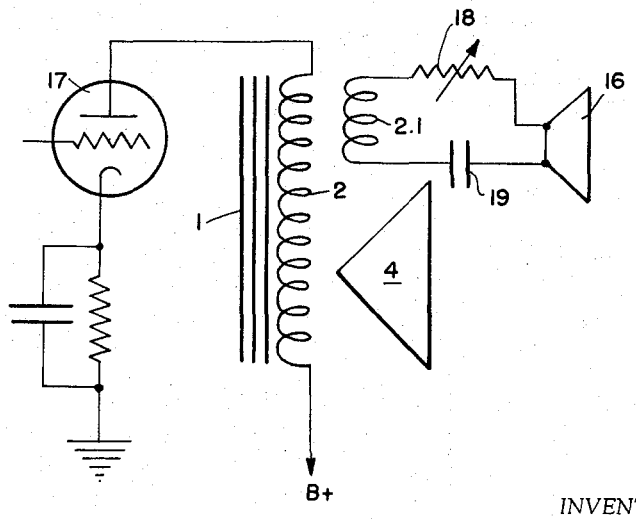


FIG. 8



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ELECTROMAGNETIC SOUND REPRODUCER

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FIG. 9

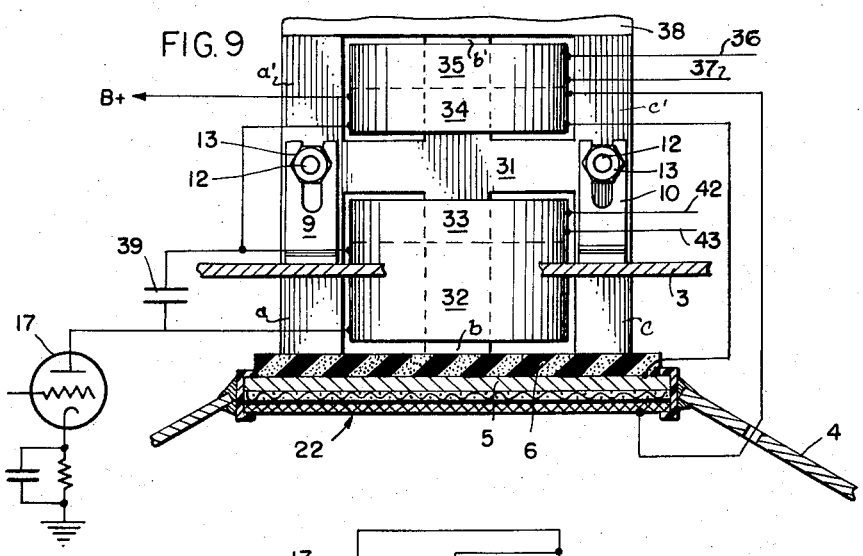


FIG. 10

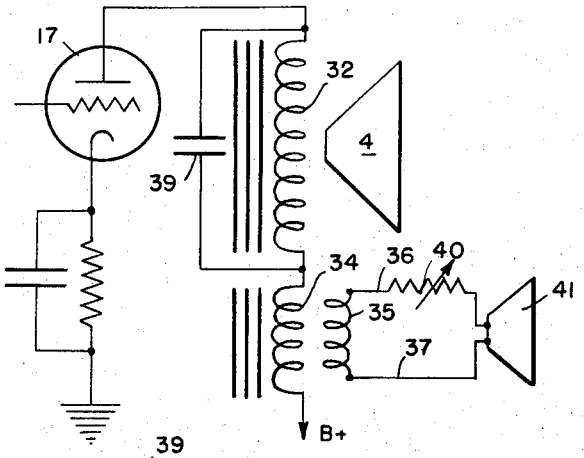
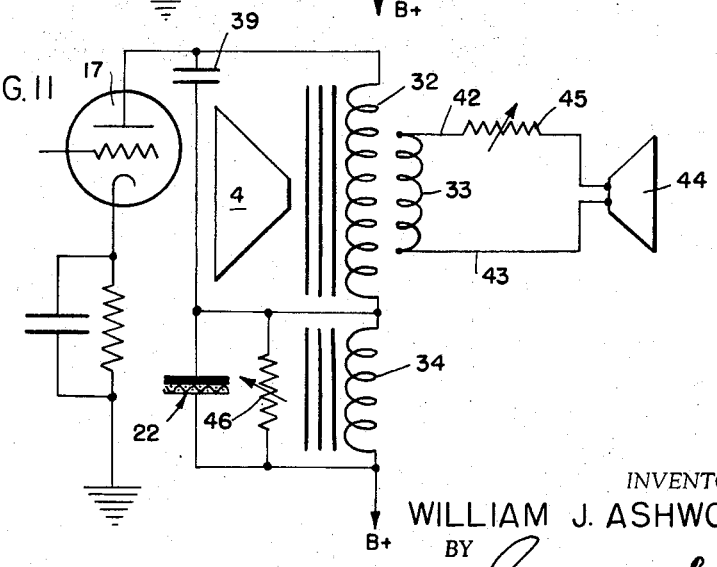


FIG. 11



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3,358,084

ELECTROMAGNETIC SOUND REPRODUCER

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17 Claims. (Cl. 179—1)

ABSTRACT OF THE DISCLOSURE

An electromagnetic sound reproducer having a flexible diaphragm mounted in a supporting frame and including a centrally disposed iron plate secured to the forward face of the diaphragm, characterized by an adjustable mounting of the electromagnet on the supporting frame for varying its position relative to the said plate; by embodying an electrostatic speaker means on the forward face of said plate; and by including a secondary winding on the electromagnet for driving an auxiliary speaker system.

The main objects of this invention are to provide a relatively inexpensive and improved device for producing sound wherein an electromagnet is employed for actuating a paper cone or other form of diaphragm directly from the power output of an audio frequency amplifier; to provide such a device having an extended range of sound reproduction; and to provide such a device which has the sound reproducing characteristics of both a mid-range speaker and tweeter.

Other objects and adavntages of this invention will be more fully disclosed in the following specification and the accompanying drawings in which specific embodiments of the invention are shown and wherein:

FIGURE 1 is a perspective view of a loud speaker according to my invention;

FIG. 2 is a fragmentary end view of the loud speaker shown in FIGURE 1, as it appears from the rear;

FIG. 3 is a partly sectioned side view of the same;

FIG. 4 is a partly sectioned fragmentary view of the same as taken along line 4—4 of FIGURE 3;

FIG. 5 is a schematic electrical diagram showing the speaker of FIGS. 1 to 4 connected for operation by the output stage of an audio-amplifier;

FIG. 6 is a partly sectioned fragmentary side view of a modification of the speaker shown in FIGURE 3, with the electromagnet wound as a transformer, the coils and electrical connections being shown in solid outline and the electromagnet frame being shown in phatom;

FIG. 7 is a schematic electrical diagram of the construction shown in FIGURE 6 illustrating its operating connection with the output section of an audio-amplifier;

FIG. 8 is a schematic electrical diagram showing modification of the circuit of FIGURE 5 to incorporate a tone control for a conventional dynamic speaker driven by the secondary winding of the electromagnet;

FIG. 9 is a partly sectioned side view of a loud speaker according to my invention showing a further modification;

FIG. 10 is a schematic electrical diagram for an H frame electromagnet-transformer arrangement as shown in FIGURE 9 but using the secondary of the high frequency coil to drive a separate speaker of the dynamic type; and

FIG. 11 is a schematic electrical diagram showing the circuitry for the system of the H frame construction illustrated by FIGURE 9.

As shown in FIGS. 1 to 5 inclusive, the improved speaker construction comprises an electromagnet consisting of an E-frame **1**, and a coil **2** mounted on the back side of a conventional steel speaker basket **3**, in which a parchment cone **4** is mounted in the usual manner, a soft iron magnetizable disk **5** cemented to the truncated apex

at the rear of the speaker cone **4**, a rubber spacer element **6** interposed between the back side of the iron disk **5** and the poles *a*, *b* and *c* of the electromagnet **1**, a set of support brackets **7**, **8**, **9** and **10** for supporting and adjustably positioning the electromagnet frame **1** axially with respect to the iron disk **5**. As shown, each of the said brackets is provided with a rearwardly opening slot **11** for receiving bolts **12**, extending through the base of the E-frame **1**, and the said frame is clamped to the brackets by means of nuts **13** threaded on the bolts **12** for holding the electromagnet in place when it is properly positioned. A pair of insulated terminal boards **14** and **15** are suitably secured to the base of the E-frame for terminating the ends of the coil windings in the conventional manner.

Thus, as indicated in FIG. 1, and shown more in detail in FIG. 3, the steel speaker basket **3** supports the frame **1** of the electromagnet in fixed spaced relation with the back side of the iron disk **5** which in turn is wholly supported by the paper cone **4**. The rubber spacer element **6**, which may be of medium density sponge rubber, is interposed between the iron disk **5** and the ends of the poles of the E-frame **1** so as to obviate any possibility of mechanical contact between the poles and the disk.

The improved speaker construction may be driven by any conventional amplifier system in the manner indicated in FIG. 5 wherein the output of an amplifier tube **17** is directly connected with one of the leads of the primary coil **2** of the electromagnet. Thus, as a varying audio-current is generated by the amplifier it will pass through the coil **2** of the electromagnet and magnetically energize the E-frame **1** of the electromagnet assembly. Magnetic energization of the E-frame **1** will cause its poles to exert a pull on the soft iron disk cemented to the rear end of the speaker cone **4**. The disk **5** will be attracted toward the electromagnet directly in proportion to the current and frequency generated at the amplifier output, and as the current and frequency vary the iron disk **5** will be caused to oscillate in a direct relation, with an in and out motion, axially of the speaker cone **4**. Thus the amplitude of movement of the iron disk will be proportional to the intensity of the audio-current passing through the coil **2**, and the frequency of vibration of the speaker cone will be in direct relation with the frequency of the audio-current passing through the coil **2**.

As will be apparent, the rubber spacer element **6** disposed between the iron disk **5** and the adjacent ends of the poles of the E-frame **1**, not only obviates the possibility of any metal to metal contact between the disk and the E-frame poles that might result from an audio-signal of an extreme amplitude, but also serves as a spring to help restore the diaphragm or cone **4** to its original position after an audio-signal pulse has passed through the coil **2**. From various tests and experiments it has been found that the optimum thickness for this rubber spacer element, when made of sponge or foam rubber, is approximately one-eighth inch.

As is well known in the art the oscillation, or in and out movement, of the paper cone or diaphragm **4** will generate pulsing waves of air movement and thus produce audible sound.

As is well known for class A operation of the amplifier, a constant DC current will flow through the tube and, in the case of the present invention, will continuously flow through the electromagnet coil **2** so as to provide a constant energization of the E-frame **1**. This will exert a constant pull on the iron disk **5** causing it to assume a certain normal operative position somewhat closer to the ends of the E-frame poles than would be the case if the electromagnet were not energized. It is from this normal operative position that the iron disk **5** will oscillate, axially of

the diaphragm or cone **4**, when a varying audio-current is passed through the coil **2**. The amount of constant DC current flow from the amplifier and through the coil **2** will depend upon the point at which the tube **17** is biased, and also upon the characteristics of the tube itself. Thus there is an optimum spacing between the iron disk **5** and the ends of the E-frame poles for each tube type and its accompanying constant DC component.

From this it will be seen that the spaced relationship of the electromagnet and the iron disk **5** will vary according to the particular amplifier and circuit employed for driving the speaker. It is for this reason that the support brackets **7**, **8**, **9** and **10** are slotted at their outward ends so that the electromagnet assembly can be adjusted in or out relative to the steel basket **3** and the iron disk **5** for optimum performance under a given set of amplifier characteristics and conditions.

In some cases it might be desirable to drive more than one speaker from the same input signal to the amplifier and, as indicated in FIG. 5, this can readily be accomplished by providing a secondary winding **2.1** on the electromagnet frame **1**. The electromagnet thus becomes an output transformer, for driving a conventional dynamic type speaker **16**, as well as an electromagnet to activate the iron disk **5** and thus drive the main speaker cone **4**.

When a conventional dynamic speaker, such as the speaker **16**, is driven by the secondary winding **2.1**, a variable resistor may be connected in series with the secondary winding and the conventional dynamic speaker can thus be tuned by increasing or decreasing the resistance in the speaker circuit. Such an arrangement is shown in FIG. 8 wherein the variable resistor **18** is connected in series with the secondary winding **2.1** and the dynamic type speaker **16**. Usually, when used in combination with the improved magnetic speaker herein disclosed, the speaker **16** will be of the tweeter type designed to reproduce the high audio-frequencies. Thus, as the dynamic speaker is tuned in or out, by varying the resistance **18**, the tone of the sound produced by the speaker is varied from base to treble. In this manner the resistor **18** acts as a simple, but very effective, tone control. As shown in FIG. 8, the condenser **19** is intended to block the low frequencies from the speaker **16** and to pass only the higher frequencies, i.e. above about 2000 cycles.

In the speaker construction shown in FIG. 6 the assembly is designed to incorporate an electrostatic type speaker so as to provide a higher frequency response than would ordinarily be expected from the arrangement shown in FIGS. 1 to 5 inclusive. In this construction the electrostatic speaker **22** is embodied with the iron disk **5** and comprises a fine wire screen **23** disposed against the inner face of the iron disk **5** and overlaid with a sheet of polyethylene material **24**, the exposed surface of which is provided with an electrically conductive coating **25**. As shown, the disk **5** and the layer of screen and coated polyethylene material are secured in assembled, sandwiched, relation by means of an anular non-conductive frame **26**, of plastic or other suitable material, which in turn is suitably secured to the truncated apex of the speaker cone **4** as, for example, by means of an epoxy cement **27**.

As shown in FIG. 6 and in the schematic diagram of FIG. 7 the electrostatic speaker **22** is energized by a tap **28–29** taken off from the primary winding **20** of the actuating electromagnet, the lead **28** being connected with the coated surface **25** of the polyethylene sheet **24** and the lead **29** being connected directly to the rearward face of the iron plate **5**. Also, as shown in FIG. 7, the secondary winding **21** of the electromagnet-transformer unit can be connected with the voice coil of a conventional dynamic speaker **30**, which in this case may be a speaker of the mid-range type.

The operation of the electrostatic speaker **22** need not be expained since, per se, it is of conventional construction and is well known in the art.

A further modification of this invention is illustrated in

FIG. 9, wherein the electromagnetic speaker driving means is shown as an electromagnet and a transformer disposed in back to back relation with their primary coils connected in series between the output plate of the amplifier **17** and B+. In this case the electromagnet and the transformer are embodied in a single H form of frame **31**, constructed of stampings made from transformer steel and assembled in the conventional manner. As shown the device comprises two sections the lower section being the larger and having primary and secondary windings **32** and **33** mounted on the central pole *b*. This lower section of the double or H type construction serves as combination electromagnet and transformer and drives a speaker cone **4** through the iron plate **5** in the same manner as the construction shown in FIGS. 1 to 6 inclusive a rubber spacer or cushion member **6** being disposed between the ends of the poles *a*, *b* and *c* and the metal plate **5** as previously described.

The upper section of this H frame arrangement is a conventional transformer provided with a primary coil **34** and a secondary coil **35** each of which is somewhat smaller than the corresponding coils of the lower section. As shown in FIG. 9 the primary coil **34** of the upper section functions solely to energize the secondary coil **35** which in turn is connected by leads **36** and **37** to the opposite sides of the electrostatic speaker system **22** incorporated with the iron plate **5** which is mounted on the speaker cone **4**. This combination of the electrostatic speaker **22** and the metal plate **5** is the same as shown and described with respect to FIG. 6.

As shown a steel bridge or I **38** is extended across the ends of the poles *a'*, *b'*, *c'* of the upper section of the H frame structure, so as to provide a continuous flux path for this section, since it functions solely as a transformer in so far as speaker operation is concerned.

As shown in FIG. 9 the H type frame of the unit **31** is mounted on the back side of the basket **3** in the same manner as the electromagnet structure shown in FIGS. 1 to 4 inclusive, that is, by means of brackets, indicated at **9** and **10** in FIG. 9, and clamping screws and nut **12** and **13**. Thus the electromagnet-transformer assembly **31** is adjustable axially in and out with respect to the basket **3** so as to adjust the spacing between the ends of the electromagnet poles *a*, *b* and *c* and the iron plate **5** as may be desired to accommodate the characteristics of the amplifier **17** and to tune the speaker cone **4** for the desired range of response.

In this last connection the adjustment of the H frame toward and away from the metal plate **5** effects a variation of the resonance frequency of the cone **4**. Thus, by increasing the distance between the ends of the poles and the metal plate **5**, the frequency response of the speaker cone **4** is lowered and conversely, by decreasing the space between the ends of the pole pieces and the plate **5** the frequency response of the speaker cone is raised. In this manner the operation of the speaker cone **4**, by the assembly illustrated in FIG. 9, is precisely the same as in the case of the constructions illustrated in FIGS. 1 to 4 inclusive, and in FIG. 6.

Although the combination electromagnet-transformer frame **31** is a unitary structure and the primary coils **32** and **34** are connected in series, it will be understood that each of the sections, together with its respective coils, is magnetically isolated from the other. The object of this H frame, double transformer-electromagnet arrangement, however, is to provide a unitary sound reproducer having means having a greatly extended range wherein one section will be responsive to low frequency audio-signals while the other section will be responsive to high frequency audio-signals. To carry out this function of the assembly a condenser **39** is connected in parallel with the primary coil **32** of the lower section. Thus, when a varying audio-signal is passed through the serially connected primary coils **32** and **34**, of the lower and upper sections, a separate magnetic field is set up in each section

and the high frequencies are by-passed to the upper section for independent reproduction by that section.

The primary coil **32** of the lower section is made up of a large number of turns of wire and thus effects a high impedance to low frequency signals and at the same time effects a very low impedance to high frequency signals because of the by-passing of the high frequencies by the condenser **39**. The condenser **39** also serves to lower the resonance frequency of the coil **32** thereby increasing its inductance at the lower frequencies. As the result only the lower frequencies of approximately 2,000 cycles and below develop a voltage across the coil **32**.

The coil **34** of the upper transformer section also carries the same varying audio-signal passing through the coil **32**, and since the coil **34** has a much smaller number of turns than the coil **32**, it has a very low impedance to low frequencies and a high impedance to the high frequencies. Thus, the coils **32** and **34** become a voltage divider with the low frequency signals developing voltages across the large coil **32**, and the high frequency signals developing voltages across the smaller upper section coil **34**.

It will now be seen that the coil **32** on the lower transformer section magnetically energizes the lower portion of the H frame, which in turn causes the iron plate **5** on the speaker cone **4** to oscillate in and out and thereby drive the cone **4** to produce the low frequency sounds. Simultaneously the secondary coil **35** of the upper transformer section, because of its high frequency activation, drives the electrostatic speaker **22** mounted on the forward face of the iron disk **5** to produce sounds in the high frequency or tweeter range.

In cases where the electrostatic speaker **22** is not employed, the secondary **35** of the upper transformer section of the arrangement shown in FIG. 9 may have its leads **36–37** connected with a conventional tweeter, of the dynamic speaker type, for reproduction of the high frequency sound. The circuitry for such an arrangement is illustrated in FIG. 10, and as there shown a variable resistor **40** may be connected in series between the coil **35** and the tweeter **41** to serve as a cut-out and tone control meaans for the tweeter.

It will also be understood that the lower or electromagnet section may be wound with a secondary coil **33** for activation by the primary **32**, and that the leads **42–43** from the secondary winding **33** may be connected directly to a dynamic speaker **44** of the mid-range type. In this case a variable resistor **45** may be connected in series with the coil **33** and the speaker **44**, as shown in FIG. 11, to serve as a tone control means.

A further arrangement is indicated in FIG. 11 wherein the electrostatic speaker **22** is connected as a tap across the primary coil **34** of the upper or high frequency section of the double structure **31**. In this case a variable resistor **46** is used to shunt the electrostatic speaker **22** and thus function as a tone control means as well as a means for cutting out the electrostatic speaker entirely.

The design of the unitary electromagnet-transformer structure of FIG. 9, according to the sound range desired for the several speaker devices, will be readily understood by those skilled in this art. However, as an example of a typical arrangement such as shown in FIG. 9, the primary coil **32** may be made using 5,000 turns of No. 38 wire, and the primary coil **34** may be wound with 2,000 turns No. 38 wire, the coils being wound on the center poles *b* and *b'* of an H frame ⅝ inch thick made from laminations of 24-gage transformer steel. In such a unit the secondary winding **33** on the electromagnet may be made suitably of 200 turns of No. 30 wire and the secondary winding **35**, of the high frequency transformer section, may consist of 190 turns of No. 30 wire. In such a construction the condenser **39**, connected across the primary coil **32**, may be a .05 mfd. device.

It will be understood that in cases where the improved sound reproducer devices disclosed herein, are used with a push-pull type of amplifier, a small one ounce permanent magnet should be mounted on the outer end of the center pole *b* to provide a constant DC component for the force which activates the iron plate **5** mounted at the truncated apex of the speaker cone **4**.

Particular advantages of the herein disclosed invention reside in the low cost, ease of assembly, and ready adjustability of the magnetic speaker construction to match amplifier characteristics; in the simplified arrangement for speaker tone control by means of a single unit which replaces the base and treble controls as used in the conventional amplifiers; in the arrangement of the electrostatic speaker on the forward face of the iron plate by which the magnetic speaker is actuated thus providing an extremely simple low cost coaxial speaker arrangement for reproduction of both low frequency and high frequency sounds; and in the arrangement of the speaker driving means in the form of a unitary combination of back-to-back transformers which serve as an automatic voltage divider for the actuation of respective low frequency and high frequency sound reproducing devices.

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

I claim:

1. An electromagnetic sound reproducer comprising a diaphragm of resilient flexible material for imparting sound impulses into the ambient air, a plate of magnetic material secured to said diaphragm, an electromagnet having an iron frame with a primary winding thereon, said electromagnet spaced a predetermined distance from said plate for magnetic attraction between said plate and said electromagnet, means of supporting said diaphragm and means for holding said electromagnet in a spaced relation with said plate, wherein the said electromagnet provides coupling means for operatively connecting to at least one auxiliary sound reproducer, wherein said electromagnetic sound reproducer imparts a predominantly lower frequency sound into the ambient air than said auxiliary sound reproducer which imparts a predominantly higher frequency sound into the ambient air than said electromagnetic sound reproducer, wherein at least one of said auxiliary sound reproducers is of the predominantly capacitive type with means for operatively connecting said electromagnetic sound reproducer to an energy source.

2. An electromagnetic sound reproducer according to claim **1** wherein said coupling means is secondary winding for energization by said primary winding and wherein said secondary winding is operatively connected to at least one auxiliary sound reproducer.

3. An electromagnetic sound reproducer according to claim **1** wherein at least one auxiliary sound reproducer is operatively connected to said primary winding by taps on said primary winding, wherein said taps are said coupling means.

4. An electromagnetic sound reproducer according to claim **3** wherein said electromagnet has a secondary winding for energization by said primary winding and said secondary winding is operatively connected to at least one auxiliary sound reproducer.

5. An electromagnetic sound reproducer according to claim **1** wherein means are interposed between said coupling means and said auxiliary sound reproducer to control the energy delivered to at least one said auxiliary sound reproducer.

6. An electromagnetic sound reproducer according to claim **5** wherein said energy control means is at least one variable resistor.

7. An electromagnetic sound reproducer according to claim **5** wherein said energy control means is at least one condenser.

8. An electromagnetic sound reproducer according to

claim 5 wherein said energy control means includes at least one variable resistor and one condenser.

9. An electromagnetic sound reproducer according to claim 1 wherein said auxiliary sound reproducer is affixed to the sound radiating surface of said electromagnetic sound reproducer.

10. An electromagnetic sound reproducer according to claim 1 wherein said auxiliary sound reproducer is affixed to the structure of said electromagnetic sound reproducer.

11. An electromagnetic sound reproducer according to claim 1 wherein at least one permanent magnet is deposed in the magnetic circuit of said electromagnet.

12. An electromagnetic sound reproducer according to claim 1 wherein means are provided for varying the spacing between the said electromagnet and said plate.

13. An electromagnetic sound reproducer construction comprising a diaphragm of resiliently flexible material, a plate of magnetic material secured to said diaphragm, means for mounting said diaphragm, two electromagnets magnetically isolated, said electromagets having primary windings in series, said first, electromagnet being mounted in a spaced relation with said plate for magnetic attraction between said first electromagnet and said plate when said primary winding of said first electromagnet is energized by an energy source and means for driving at least one auxiliary sound reproducer from the winding on said second electromagnet.

14. An electromagnetic speaker as defined by claim 13 wherein the electromagnet and the transformer are constructed on a common frame, and said frame is mounted for varying the spacing between the electromagnet and the plate.

15. An electromagnetic sound reproducer according to claim 13 wherein at least one auxiliary sound reproducer is of the predominantly capacitive type.

16. An electromagnetic sound reproducer according to claim 13 wherein at least one auxiliary sound reproducer is affixed to the sound radiating surface of said electromagnetic sound reproducer.

17. An electromagnetic sound reproducer according to claim 13 wherein at least one said auxiliary sound reproducer is affixed to the structure of said electromagnetic sound reproducer.

References Cited

UNITED STATES PATENTS

2,787,786	6/1953	Zeininger	179—115
3,092,693	6/1963	Hayasaka	179—114

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