Jan. 4, 1949. W. E. GILMAN 2,458,158

MAGNETICALLY SHIELDED ELECTRODYNAMIC SOUND REPRODUCER

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FIG. 1.

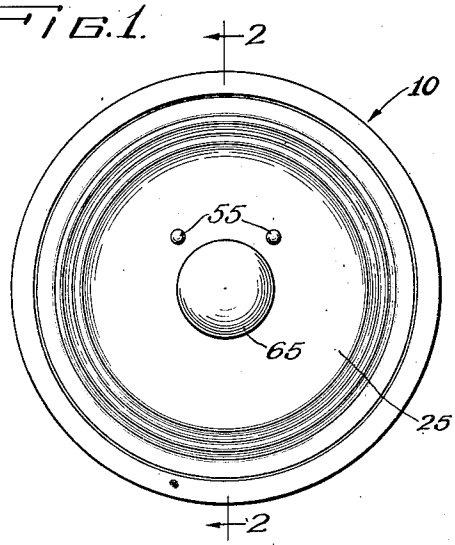


FIG. 2.

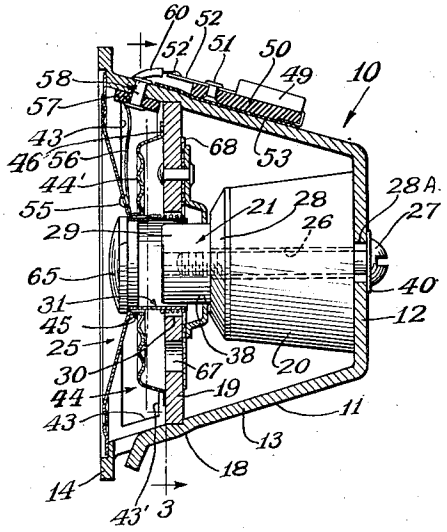


FIG. 3.

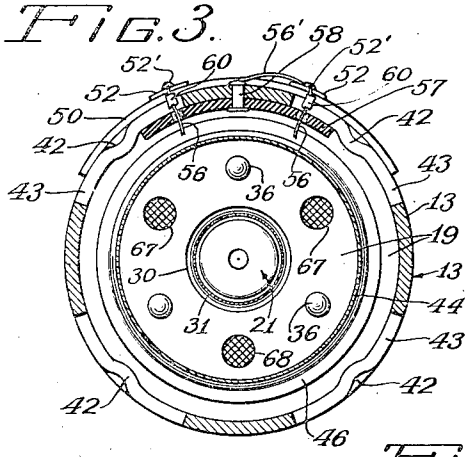


FIG. 4.

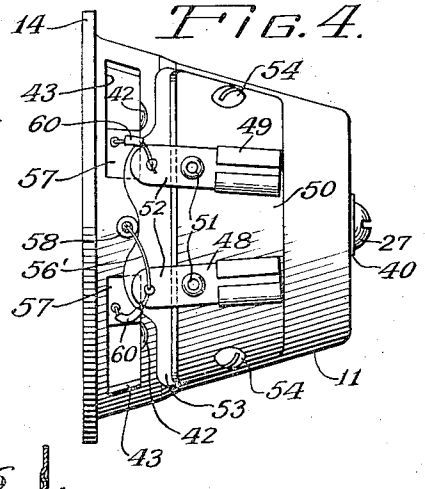


FIG. 5.

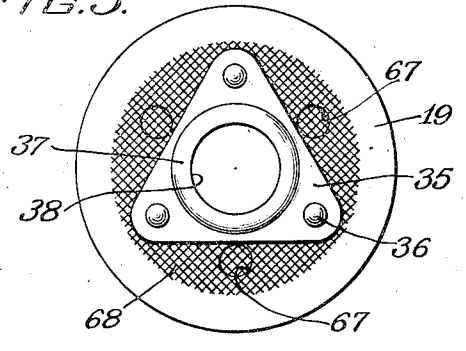
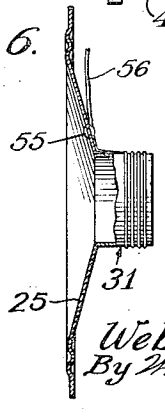


FIG. 6.



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Fig. 7.

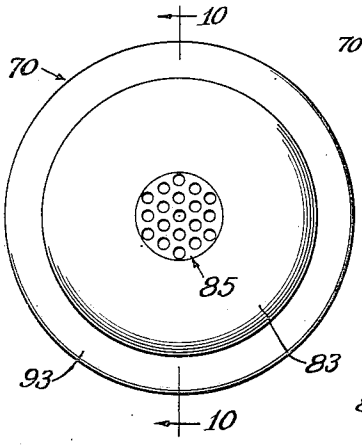


Fig. 8.

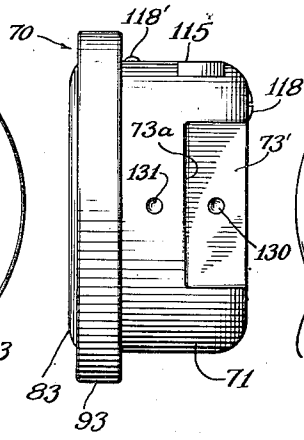


Fig. 9.

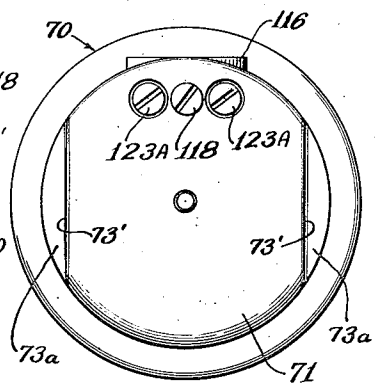


Fig. 10.

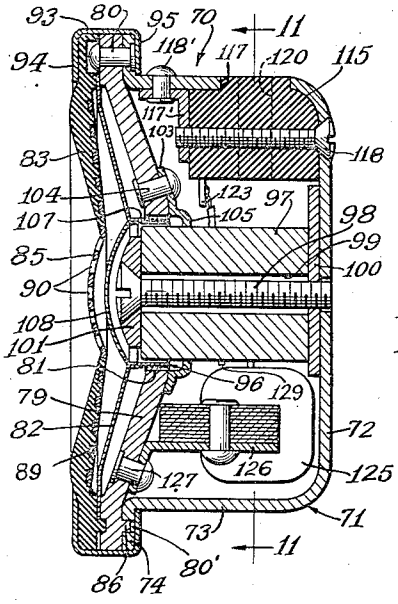


Fig. 11.

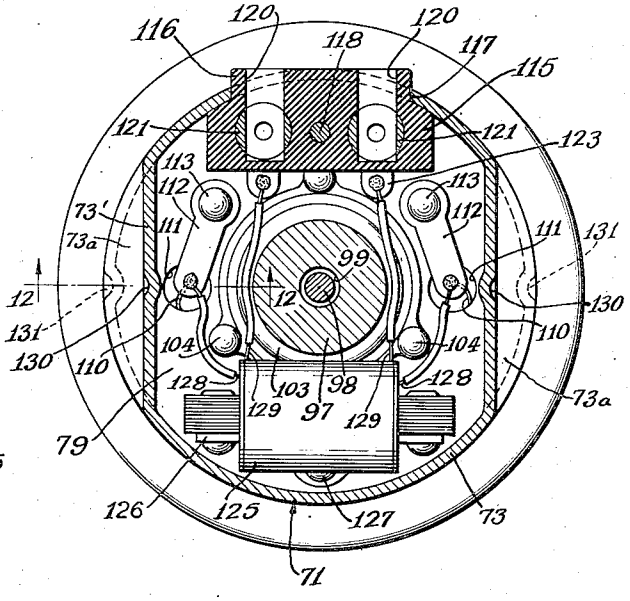
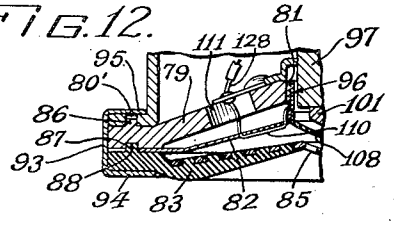


Fig. 12.



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FIG. 13.

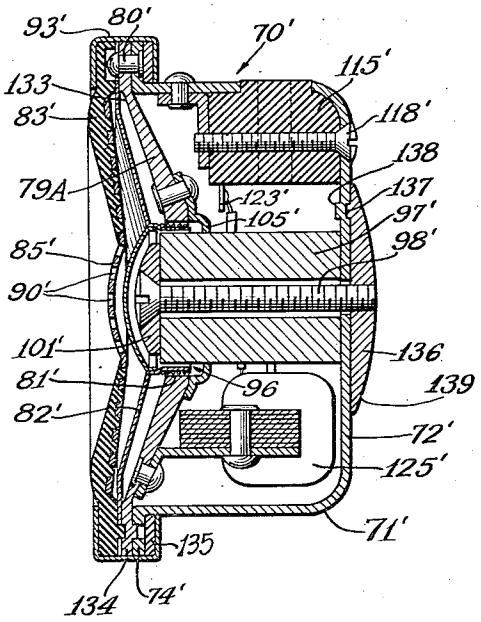


FIG. 14.

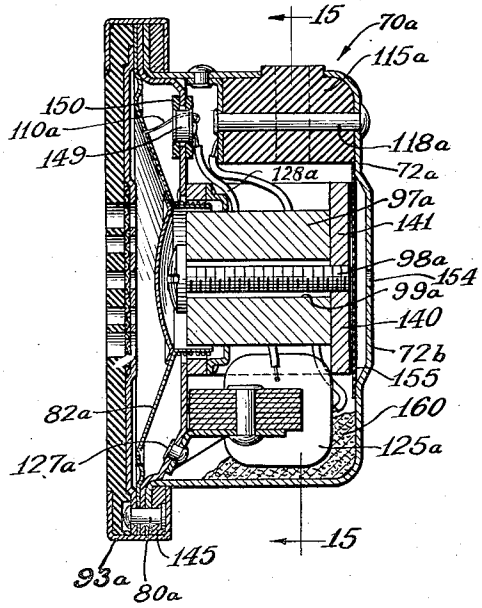


FIG. 15.

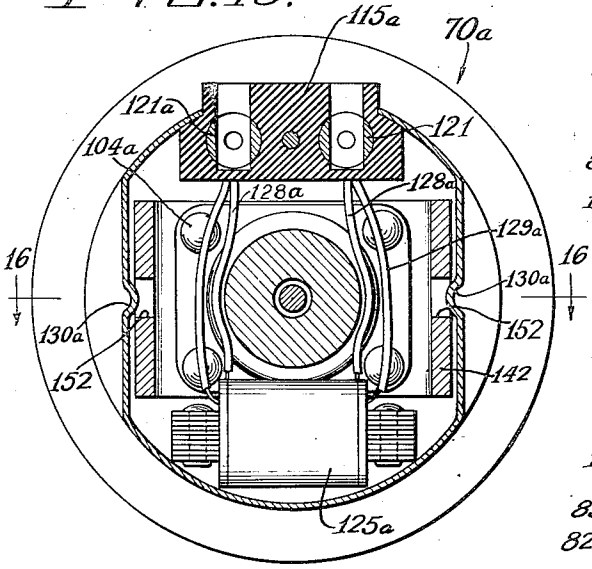
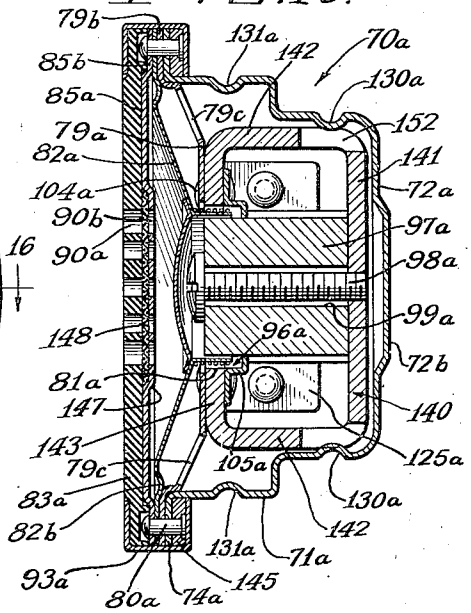


FIG. 16.



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2,458,158

UNITED STATES PATENT OFFICE

2,458,158

MAGNETICALLY SHIELDED ELECTRO-DYNAMIC SOUND REPRODUCER

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Application November 25, 1942, Serial No. 466,903

5 Claims. (Cl. 179—115.5)

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This invention relates to transducers and particularly to transducers of the dynamic type as contrasted with the magnetic type thereof.

In dynamic transducers as heretofore constructed it has been recognized that in order to obtain the desired sound transducing capacity it has been necessary to resort to relatively large dimensions in the transducers, with the result that the weight of such transducers has been excessive when compared with the output capacities thereof. Where size and weight were determining and vital factors, it has been customary to resort to the use of magnetic type transducers, even though fidelity and range of frequency response have been sacrificed through this procedure, and accordingly it is an important object of this invention to enable dynamic transducers to be employed even where weight and size are determining factors in the selection of the type of transducer to be used; and further objects related to the foregoing are to enable dynamic transducers to attain a substantially flat frequency response curve and a substantially flat impedance curve over a wide range of frequencies such as those frequencies utilized in ordinary practice and particularly over the range of frequencies used in conversation; and to enable an output capacity to be attained in dynamic speakers which is comparable to the output capacity of other types of transducers of comparable size and weight.

One factor which has contributed in a large measure to the foregoing disadvantages and limitations inherent in prior dynamic speakers has been found to be in the relatively complicated manner of construction and assembly of the elements of the magnetic circuit, and with such prior constructions the elements of the magnetic circuit have been enclosed within a housing which has added objectionable size and weight to the transducers. A further object of this invention is therefore to simplify the construction of the magnetic circuits of dynamic transducers, and an object related to the foregoing is to accomplish this simplification in such a manner that an element of the magnetic circuit may function as the housing of the transducer. Further and related objects are to form the magnetic yoke of a dynamic transducer with an annular or circular transverse cross section, to incorporate positioning means in such an annular magnetic yoke whereby mounting of the outer pole piece or plate may be readily and accurately accomplished, to provide a transducer wherein the operative elements are fully shielded, and to accomplish such shielding through use of the housing not only as a housing but also as a magnetic shield.

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In accordance with prior practice it has been customary to provide an independent diaphragm support which, after assembly upon the magnetic yoke, has been used to support and position the diaphragm and the voice coil. Through the exercise of proper care and skill in the formation and assembly of the parts it has, of course, been possible to attain accuracy of relationship of the parts in such prior transducers, but even then, the cost and added size resulting from the use of such prior diaphragm supports have been objectionable. In view of this it is a further object of the present invention to enable means formed integrally with or as a part of an element of the magnetic circuit of such transducers to function as a diaphragm support. According to one aspect of my invention it is a more specific object to enable the diaphragm to be supported by means formed integrally with the magnetic yoke; and a further object related to the foregoing is to form the magnetic yoke in a generally cup-like form such that the diaphragm may be supported upon the rim of the cup-like magnetic yoke while the outer pole piece or pole plate may be located within and supported by the cup-like yoke in spaced relation to the rim thereof.

A further object of this invention is to simplify the mounting and location of the outer pole piece or pole plate in dynamic transducers and a more specific object is to accomplish this through the provision of means formed in the cup-like magnetic yoke in spaced relation to the bottom wall thereof and cooperating with the separately formed outer pole piece to locate the same accurately with the relation to the magnetic yoke.

A further object of this invention is to utilize the outer pole piece or pole plate to support the diaphragm, thereby to eliminate the cost of production and assembly which has heretofore been involved in the production and assembly of a separate diaphragm support.

A further object is to enable a relatively small permanent magnet to be used in a transducer in such a relation that an extremely high flux density is produced in the magnetic gap of the transducer; and objects related to the foregoing are to enable a transducer to be so constructed that the space within the housing is efficiently utilized, thereby to produce maximum flux density in the magnetic gap and to attain this result in relatively small transducers; to so mount the per-

manent magnet that the magnet serves as the inner side of the magnetic gap; and to utilize permanent magnets of cylindrical form which may be economically produced and which serve the function usually performed by a separate inner pole piece.

It has been pointed out hereinbefore that dynamic transducers embodying this invention may be utilized either as microphones or speakers, and when a transducer is used as the speaker or earphone of a headset, many difficulties have heretofore been encountered which have objectionably increased the cost of production of such speakers and have limited the usefulness of the speakers. One objection which has been found in prior speakers of the dynamic type has been that in order to utilize such speakers or earphones with remotely located receiving apparatus it has been necessary to utilize voice coils having a relatively high ohmic resistance, and in order to provide such a high resistance it has been necessary to employ numerous layers of relatively fine wire, with the consequent difficulties in winding the coils. Accordingly it is a further object of this invention to enable voice coils having a relatively small ohmic resistance to be employed in speakers which are to be used as parts of a headset, and a further object related to the foregoing is to accomplish this result through the incorporation of a transformer within and as a part of the speaker so that the length of the leads from the speaker to the receiver is rendered immaterial in a practical sense.

Speakers which are adapted for use as parts of a headset are ordinarily arranged for cooperation with a headband of a particular size and construction, such headbands being in many instances provided with a clip assembly at the ends thereof adapted to be snapped into association with cooperating means provided on the speaker. Such clip assemblies are relatively well standardized as to their dimensions, but in certain classes of work it has been found that clip assemblies having two different dimensions are frequently encountered, and as a result it has been found that speakers or earphones are often unsuitable for use with the headbands which are available. Therefore it is an object of this invention to enable speakers or earphones to be readily utilized in connection with clip assemblies of different dimensions, and an object related to the foregoing is to accomplish this in a simple and expeditious manner. More specifically, it is an object of this invention to utilize a cup-like magnetic yoke which has the side walls thereof so formed as to provide different engaging means of different dimensions whereby clip assemblies of different sizes may cooperate with either one or the other of such engaging means.

A further object is to simplify the assembly of the diaphragm and voice coil element so that accuracy of interrelation of these elements may be readily attained.

A further object is to enable a transducer to be rendered waterproof in the sense that the internal electrical elements cannot be reached by water or moisture.

A further object of this invention is to simplify the assembly of the cap plate upon the open end of the speaker housing, and an object related to this is to employ interlocking means for rotatively relating the cap plate to the housing and to employ a simple clamping means to hold such interlocking means together.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings which, by way of illustration, show preferred embodiments and the principles thereof and what I now consider to be the best mode in which I have contemplated applying those principles. Other embodiments of the invention embodying the same or equivalent principles may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

In the drawings:

Fig. 1 is a front elevational view of a transducer embodying the features of Fig. 2 of the invention;

Fig. 2 is a sectional view taken substantially along the line 2—2 of Fig. 1;

Fig. 3 is a sectional view taken along the line 3—3 of Fig. 2;

Fig. 4 is a plan view looking downwardly in Figs. 1 and 2;

Fig. 5 is a view showing one face of the outer pole piece;

Fig. 6 is a sectional view of the diaphragm and voice coil assembly;

Fig. 7 is a front elevational view illustrating another alternative embodiment of the invention;

Fig. 8 is a side elevational view of the transducer shown in Fig. 7;

Fig. 9 is a rear elevational view of the transducer shown in Fig. 7;

Fig. 10 is a cross sectional view taken substantially along the line 10—10 of Fig. 7;

Fig. 11 is a cross sectional view taken substantially along the line 11—11 in Fig. 10;

Fig. 12 is a fragmental sectional view taken along the line 12—12 of Fig. 11;

Fig. 13 is a cross sectional view similar to Fig. 10 and illustrating an alternative embodiment of the invention;

Fig. 14 is a cross sectional view similar to Fig. 10 and illustrating an alternative embodiment of the invention;

Fig. 15 is a sectional view taken along the line 15—15 of Fig. 14; and

Fig. 16 is a sectional view taken along the line 16—16 of Fig. 15.

In the form of the invention illustrated in Figs. 1 to 6 inclusive of the drawings, the invention is embodied in a transducer 10 adapted for use either as a microphone or as a speaker, this particular transducer being intended and adapted primarily for use in portable radio broadcasting and receiving units so as to avoid duplication of transducers therein. In accordance with the present invention the transducer 10 has its elements so formed and related that the magnetic circuit is formed in part by a cup-like member 11 made from a ferrous metal such as steel which constitutes the magnetic yoke and embodies a bottom wall 12 and an annular side wall 13. Thus the cup-like magnetic yoke 11 may function as a housing for the operative elements of the transducer. The side wall 13 is tapered from its juncture with the bottom wall 12 to a somewhat larger diameter at the outer end thereof, and the bordering edge of the outer end of the annular side wall 13 has an outwardly projecting annular flange 14 formed integrally therewith and parallel to the bottom wall 12 to facilitate mounting of the transducer 10 in the unit in which it is to be employed. At a point spaced from the rear or bottom wall 12

and from the flange 14, the side wall 13 has an annular rabbeted groove 18 formed therein to receive the outer peripheral edge of a soft iron disc 19 which serves as the outer pole piece or pole plate of the transducer, and it will be observed that when the pole piece 19 is mounted in the rabbeted groove 18, the pole piece 19 is spaced a substantial distance from the bottom wall 12 of the yoke to afford space within which a permanent magnet 20 and a soft iron inner pole piece 21 may be disposed. It will also be observed that when the pole piece 19 is thus mounted it is spaced from the end flange 14, thereby to afford space within which a diaphragm 25 may be disposed.

The permanent magnet 20 is in the present case frusto-conical in form and has its larger end seated against the inner face of the bottom wall 12 of the cup-like magnetic yoke, thereby to establish an efficient magnetic contact with the magnetic yoke when the magnet 20 is drawn firmly against the bottom wall 12. The permanent magnet 20 has a recess 26 extending therethrough which may be in the form of a lateral slot or in the form of a bore, and a screw 27 is extended through a relatively large opening 28A formed in the bottom wall 12 so as to project through the recess or bore 26 and into threaded engagement with the inner pole piece 21. The inner pole piece 21 has a relatively wide and thick flange 28 formed on one end of a cylindrical body 29 so that when the screw 27 is tightened a relatively large area contact is established between the small end of the magnet 20 and the flange 28 of the inner pole piece 21. The cylindrical portion 29 of the inner pole piece 21 is arranged to extend into a central circular opening 30 formed in the outer pole piece or pole plate 19 centrally thereof, and thus an annular magnetic gap is afforded between the inner and outer pole pieces, and a voice coil structure 31 carried on the diaphragm 25 is arranged to extend into this annular magnetic gap.

In order to assure accuracy of formation and dimensions of the magnetic gap, the pole piece 19 has a locating plate 35 formed from a non-magnetic material such as brass and secured in position on the inner face of the pole piece 19 by rivets 36. The locating plate 35 has an offset portion 37 spaced from the plane of that face of the pole piece 19 upon which it is mounted. The portion 37 of the locating plate 35 has a circular opening 38 formed therein arranged to snugly embrace the periphery of the cylindrical portion 29 of the inner pole piece 21, and in practice the openings 30 and 38 formed respectively in the pole plate 19 and the locating member 35 are simultaneously cut to their final size by a suitable trimming tool so as to insure concentric location of the two openings 30 and 38.

In the assembly of the transducer 10, the permanent magnet 20 and the inner pole piece 21 are first placed in position within the cup-like magnetic yoke 11 and the screw 27, bearing a lock washer 40, is inserted through the opening 28 in the wall 12 and through the recess or bore 26 of the permanent magnet 20 and into threaded engagement with the inner pole piece 21. The screw 27 is not tightened at this time, however, for it will be recalled that the locating ring 35 is relied upon to accurately position the pole piece 21. The outer pole piece or plate 19 is then placed in position in the groove 18 with the locating plate 35 engaged with the cylindrical portion 29 of the pole piece 21, and the pole piece 19 is fixed into the rabbeted groove 18 with a press fit. While such a press fit in many instances affords the desired mechanical and magnetic connection between the pole piece 19 and the annular side wall 13 of the magnetic yoke, I prefer to swage the metal of the wall 13 as at 42 in order to firmly connect the side wall 13 with the pole piece 19. Such a swaging operation may be conveniently performed along the edges of air relief slots or openings 43 which are formed in the side wall 13 intermediate the flange 14 and the rabbeted groove 18, and to facilitate this swaging operation, the edges 43' of the openings 43 are preferably spaced slightly outwardly from the outer face of the pole plate 19. Thus after the outer pole piece 19 has been secured permanently in position within the cup-like magnetic yoke 11 and in the accurately determined location afforded by the rabbeted groove 18, the pole piece 21 will also be located accurately through the action of the locating plate 35. Thus after this has been done, the screw 27 may be tightened to produce the desired magnetic connection between the pole piece 21 and the wall 12 of the magnetic yoke and the opposite ends of the magnet 20.

The diaphragm 25 is preferably provided with an auxiliary supporting structure operable to damp the vibratory movement of the diaphragm and thereby maintain the voice coil 31 in its optimum relation to the magnetic gap, and this end is attained in the transducer of Figs. 1 to 6 through the provision of a flexible suspension member 44 mounted on the outermost face of the pole plate 19 and engaging the diaphragm just outwardly of the voice coil structure. Thus the suspension member 44 is generally disc-like in form and is made from a flexible sheet material such as paper impregnated with a material such as a thermo-setting plastic. The suspension member 44 has a central opening therein defined by an integral cylindrical portion 45 which is adapted to surround the voice coil structure 31 in spaced relation thereto so that the free edge of the cylindrical portion 45 may engage the inner face of the diaphragm 25. At the other end edge of the cylindrical portion 45 the suspension member extends outwardly to afford a flexing portion 44' which preferably includes a plurality of concentric corrugations, and at the outer edge an angularly disposed portion extends from the portion 44' to merge with an outwardly projecting flat mounting flange 46. The suspension member 44 is mounted on the pole plate 19 with the cylindrical portion 45 concentric with the annular magnetic gap 30, and this may be accomplished through the use of a thermo-plastic adhesive which is applied to the flange 46 thereof, and when the suspension member is to be secured in position, the flange 46 thereof is pressed against the pole plate 19 under considerable heat and pressure so that the thermo-plastic material bonds the flange 46 to the pole plate 19.

After the foregoing assembly operations have been performed, the diaphragm 25 may be placed in position and the leads from the voice coil may be connected to the respective terminals 48 and 49 which are carried on an insulating terminal plate 50 secured on the outside of the wall 13. It should be observed that while the elements of the terminal block might be put in place on the wall 13 prior to the assembly of the elements of the magnetic circuit, I prefer to do this after the pole plate 19 and the suspension 44 are in place since by such procedure the outer

surface of the housing 11 may be freely used for centering and supporting purposes during assembly of these parts. Thus the terminals 48 and 49 are secured on the terminal plate 50 by rivets 51 so that connecting arms 52 of the terminals 48 and 49 project beyond one edge of the terminal plate; and the terminal plate 50 is positioned on the housing 11 with an interposed layer 53 of insulating material, and is secured in place by screws 54 extended through the terminal plate 50 and threaded into the wall of the housing 11.

In preparation for its mounting in position in the housing 11, the diaphragm has a pair of small metal rivets 55 secured therein as shown in Figs. 1, 2 and 6 and the ends of the voice coil are connected thereto, as by solder, and at the same time flexible woven lead wires 56 are soldered to the respective rivets 55 on the rear face of the diaphragm 25. The lead wires 56 are extended loosely and in a radial relation toward the openings 43 which are adjacent to the terminal block 50 and are drawn through openings in opposite ends of a relatively stiff insulating sheet 57 which is secured by a rivet 58 on the inner face of the wall 13 so as to extend at its opposite ends partially across two of the openings 43. The openings in the insulating sheet 57 through which the lead wires 56 are extended are so positioned as to maintain the lead wires out of contact with the metal of the housing 11, and preferably a drop of solder is placed on the wires 56 outside of the insulating sheet 57 to prevent undue looseness of the lead wires between the sheet 57 and the rivets 55. Short insulating sleeves 60 are then placed on the extended ends of the wires 56 which are then threaded through outwardly extending openings in the arms 52 of the terminals 48 and 49 and are soldered thereto at 52' on the outer surfaces of the arms. The lead wire 56 which is thus connected to the terminal 48 is extended as at 56' and is soldered to the rivet 58 to afford a ground connection in accordance with usual practice.

The diaphragm 25 and the cylindrical voice coil support, in this embodiment of the invention, are separately formed as shown in Fig. 6, and are secured together by means such as adhesive, and it will be observed that the diaphragm 25 has a central opening therein which in the finished transducer is closed by a cap 65 as shown in Figs. 2 and 4. When the leads 56 are being connected as just described the diaphragm 25 and the voice coil structure are located loosely in position, and after the connections between the wires 56 and the terminals 48 and 49 have been completed a plurality of relatively thin shims made from paper or like material are placed in position between the cylindrical portion 29 of the inner pole piece and the inner surface of the voice coil form, thereby to accurately locate and center the voice coil structure in the annular magnetic gap 30. The bordering edge of the diaphragm 25 is then secured in position in a rabbeted annular groove formed in the flange 14, and this may be accomplished through utilization of a thermo-plastic adhesive, the procedure being the same as that described hereinbefore in connection with the mounting of the suspension member 44. The shims are then removed and the cap 65 is secured in place by adhesive to complete the assembly of the transducer.

In the transducer 10 which is thus provided the space between the diaphragm 25 and the suspension member 44 is freely vented by the openings 43, while the space behind the suspension

member 44 is vented into the relatively large volume chamber afforded behind the pole plate 19 by a plurality of openings 67 formed in the pole plate 19. In some instances the damping of the diaphragm 25 may be improved by restriction of the air flow through the openings 67, and this may be accomplished by gluing or otherwise securing a sheet 68 of fabric across the openings 67 as shown in Figs. 2, 3 and 5.

In Figs. 7 to 12 of the drawings the invention is illustrated as embodied in a transducer 70 adapted particularly for use as a speaker or earphone in a headset. In this embodiment of the invention a cup-like member 71 made from a ferrous material such as steel affords a housing for the principal elements of the speaker and also serves as a magnetic yoke for the magnetic circuit. The housing 71 is formed as by suitable stamping and drawing operations to provide a bottom wall 72 and a generally annular or cylindrical side wall 73 which is flanged outwardly at 74 at its outer end. In this embodiment of the invention the outer pole piece or pole plate 79 is mounted on the flange 74 rather than directly upon the side wall of the housing, and is secured in place thereon by rivets 80 extended through openings appropriately spaced about the flange 74 and the mounting edge of the pole plate 79. The pole plate 79 is dished inwardly as shown in Figs. 10 and 12 so that the central portion thereof in which a circular opening 81 is formed is spaced inwardly of the housing 71, and through this arrangement space is afforded for the mounting of a diaphragm 82 between the pole plate 79 and a cap plate 83 which closes a substantial portion of the open end of the housing 71 and affords an open central area 85 through which sound energy may pass.

In the assembly of the pole plate 79 and the cap plate 83 on the housing 71, the flange 74 is provided with a plurality of openings 80' of a size adapted to receive the rivets 80, but such rivets 80 are employed only in alternate ones of the openings 80', the others of such openings being engaged by projections 86 formed at appropriate points about the mounting edge of the pole plate 79. The projections 86 are provided by what are known as half-punches so that on the opposite or outer face of the pole plate 79 these half-punching operations produce sockets 87 which are arranged to receive complemental projections 88 formed on the cap plate 83.

The cap plate 83 is, in accordance with this invention, formed so as to afford an effective magnetic shield for the internal elements of the speaker 70 and this is accomplished by molding the cap plate 83 from a plastic material so as to incorporate a foraminous iron or steel plate 89 through substantially the entire area of the cap plate. In the molding operation the openings 90 throughout the central area 85 are maintained free of the plastic material, but throughout the balance of the area of the plate 89 the plastic extends through the openings 90 so as to be interlocked with the plate 89. The outer face of the plate 89 is preferably covered and concealed by the plastic material except in the central area 85, and the plastic material is formed to provide clearance sockets 91 for the heads of the rivets 80 and to provide projections 88 for engagement with the sockets 87 in the pole plate 79.

After the diaphragm 82 has been secured in place by adhesive or the like on the outer face of the mounting edge of the pole plate 79, the cap plate may be put in position, suitable notches

preferably being formed in the edge of the diaphragm to afford clearance for the rivet heads and the projections 88. To secure these parts together, a clamping ring 93 is put in position with one flange 94 engaging the outer face of the cap plate 83 and another flange 95 is formed at the other edge of the ring, as by spinning, to engage the rear face of the flange 74. Thus the housing 71 is effectually closed and the internal elements of the speaker are shielded by the plate 79 which is incorporated in the cap plate 83. These internal elements of the speaker are, of course, mounted within the housing 71 prior to the final closure of the housing as aforesaid, and these elements include means cooperating with the cup-like magnetic yoke afforded by the housing 71 and with the pole plate 79 to afford an annular magnetic gap within which a voice coil structure 96 carried by the diaphragm 82 may operate.

Thus, as shown in Figs. 10, 11 and 12, a cylindrical permanent magnet 97 is disposed in the housing 71 substantially coaxial therewith, and a screw 98 is extended through a longitudinal bore 99 in the magnet 97 and into threaded engagement with a stationary nut provided by a plate 100 which is welded to the bottom wall 72 of the housing. The head of the screw 98 is seated in the counterbored central opening of a washer 101 and the screw is initially left fairly loose until the proper centered position of the magnet 97 has been determined. In accordance with the present invention as illustrated in Figs. 10, 11 and 12 the outer end of the magnet 97 is utilized as the central pole piece of the magnetic circuit, and hence this end of the magnet extends into the opening 81 formed in the outer pole piece or pole plate 79. To insure an accurately formed magnetic gap the pole plate 79 has a locating plate 103 secured by rivets 104 on the rear face thereof, this locating plate being formed from a non-magnetic material such as brass to afford an offset annular portion 105 arranged to snugly embrace the magnet 97. Hence when the pole plate 79 is secured in place on the housing 71 the locating plate 103 acts to center the magnet 97 in the opening 81 of the pole plate 79, and thus an accurately formed magnetic gap is afforded. The screw 98 may then be tightened to produce an effective magnetic path between the bottom wall of the housing and the adjacent end of the magnet 97.

The voice coil structure 96 is preferably formed with its cylindrical voice coil form molded integrally with the flexing portion of the diaphragm as described in detail in my Patent No. 2,440,439, issued April 27, 1948, and this voice coil form includes an annular external shoulder 107 facing away from the diaphragm 82 as to serve as a guide for locating the voice coil on the form. This external shoulder 107 is formed by offsetting the material of the voice coil form, and hence a corresponding internal shoulder is also formed so as to face toward the diaphragm. Thus when the screw 98 has been tightened, a diaphragm button 108 having a cylindrical flange 109 thereon may be mounted in closing relation to the outer end of the voice coil form merely by inserting the flange 109 into the form until it engages the internal shoulder, in which position it is secured by means such as adhesive. The diaphragm button 108 in this instance constitutes a part of the loading portion of the diaphragm structure and is slightly domed to impart strength thereto. With this arrangement the head of the screw 98 and the washer 101 are shaped to provide a domed form generally complemental to the internal form of the diaphragm button 108 and spaced uniformly therefrom. The open central area 85 of the foraminous plate 89 is also slightly domed as shown in Fig. 10 to conform with the shape of the diaphragm button 108.

The ends of the voice coil, formed by wires 110, are preferably led through the diaphragm 82, near the voice coil form, as shown in Fig. 12, and on diametrically opposite sides of the form and are led outwardly in generally opposite directions along the forward or outer face of the diaphragm, to points substantially aligned with openings 111 formed in the pole plate 79. At these points the wires 110 are led back through the diaphragm. The portions of the wires 110 which are thus located on the forward or outer face of the diaphragm are preferably covered by a water proof surface coating. The ends of the wires 110 are led through the openings 111 where they are soldered to the free ends of connecting clips 112, the other ends of the clips 112 being secured to the rear face of the pole plate 79 by rivets 113.

The voice coil lead wires 110 must, of course, be electrically associated with a receiver or other source of signal current, and this is accomplished by means including a terminal block 115 mounted within the housing 71. As shown in Figs. 10 and 11, the terminal block 115 is molded from insulating material to include a neck portion 116 which projects outwardly from the housing 71 through a complemental slot 117 formed in the side wall 73 thereof, and a screw 118 extending through the wall 72 and a bore in the terminal block 115 is threaded into one arm of an angle bracket 117', which is in turn held in place by a rivet 118' which passes through the side wall 73 and the other arm of the angle bracket. This serves to hold the terminal block firmly in position.

The terminal block 115 has two parallel bores or sockets 120 formed therein and opening outwardly through the neck portion 116, and these sockets are arranged to intersect with and extend through metallic sleeves 121 which are molded in the terminal block in spaced and insulated relation to each other. The sockets 120 are of a size adapted to snugly receive metallic connector tips of the type conventionally used in radio and telephone work, and these tips may be held in place by screws 123A which are threaded into the metal blocks or sleeves 121 and extend into the sockets 120 and have their heads accessible on the outside of the back wall 72 of the casing 71. The tips of the connecting wires may thus be held in position in the sockets 120 and in electrical association with the respective metal sleeves 121; and to provide for connection of the metal sleeves 121 to the voice coil, each sleeve 121 has a metallic ear or clip 123 extending therefrom into an accessible position within the housing 71.

It has been pointed out hereinbefore that earphones or speakers are often used in remote locations with respect to the receiver with which they are associated, and in the past it has been the practice to employ high resistance voice coils in such earphones in order to produce a properly matched impedance in the plate circuit of the amplifier. This prior practice has resulted in an exceedingly high cost and large weight and size in dynamic speakers, but in accordance with the present invention these objections are avoided through the provision of a transformer 125 included within the housing 71 and employed as an electrical coupling between the metal terminals

121 and the lead wires 113 of the voice coil. Thus, as shown in Figs. 10 and 11, the transformer 125 embodies mounting bracket 126 which is fixed upon the pole plate 79 by a rivet 127 or the like. The transformer 125 is so disposed on the pole plate 79 that when the pole plate is put in position in the housing 71 the transformer will be disposed within the housing in a position diametrically opposite from the terminal block 115. Prior to the mounting of the pole plate 79 in the housing the lead wires 128 from the secondary winding of the transformer 125 are connected to the respective connector clips 112, there being insulating sleeves surrounding the intermediate portions of the wires 128, and the ends thereof being connected to their respective clips 112 as by soldering. The lead wires 129 from the ends of the primary winding of the transformer 125 are relatively long, and prior to the mounting of the pole plate 79 in the housing 71, insulating sleeves are placed on the wires 129 and the extreme ends of the wires 129 are connected by soldering to the respective clips 123 of the terminals 121. Thus when the assembly of the parts has been completed the speaker of this invention embodies means for matching the impedance of the receiver with which it is to be used, and hence the voice coil may be of a relatively small size and resistance and the other elements of the speaker may be correspondingly reduced in size. Thus the present speaker is adapted for use under all of the conditions encountered in practice, and particularly where long leads are to be interposed between the receiver and the speaker.

When speakers of the kind shown in Figs. 7 to 12 are in use they are ordinarily mounted on the ends of a headband of conventional construction, and such headbands embody clip assemblies having spaced and resiliently related trunnions which are adapted to be engaged with aligned bearing sockets provided on the opposite sides of the housing of each speaker. Each such clip assembly is adapted to engage bearing sockets having a predetermined spacing, and it has been found in practice that in a particular class of work there may be two different standards used in the spacing of the trunnions of the different headbands encountered. Hence in many instances the speakers or earphones must be matched with the headbands available, thereby causing objectionable delay in setting up or repairing a communication system. However, in accordance with this invention, the casing 71 is so formed as to afford two different sets of bearing sockets spaced different distances apart so as to enable different styles or sizes of clip assemblies to be employed therewith. In accomplishing this desirable result the wall 73 of the housing 71 is offset inwardly at diametrically opposite points to form substantially parallel wall sections 73'. These wall sections 73' are disposed in symmetrically related positions on opposite sides of the opening 117 and the terminal block 115, and as shown in Fig. 8, the wall sections 73' extend from the bottom wall 72 toward the flange 74 for a distance slightly less than one-half the distance between the bottom wall and the flange 74. Thus the wall 73 is of cylindrical form between the ledge 73a and the flange 74. A pair of aligned bearing sockets 130 are formed in the wall sections 73' substantially centrally thereof for cooperation with clip assemblies of one predetermined dimension or standard, while similar aligned bearing sockets 131 are formed in the areas of the wall 73 substantially midway between the ledges 73a and the flange 74 for cooperation with clip assemblies of a different predetermined dimension or standard. Thus the speaker 70 of this invention may be readily put to use with headbands of two different standards to thereby facilitate set-up or repair of radio and like communication systems.

As pointed out hereinbefore, the total weight of a transducer is ofter a controlling factor in determining whether or not it is suitable for use in a particular situation, and while the embodiments illustrated in Figs. 1 to 12 have maintained the high and desirable performance characteristics usually associated with dynamic transducers while materially reducing the weight of such transducers, an even greater weight reduction may be attained through the use of the embodiment of the invention illustrated in Fig. 13. In this form, the invention has been embodied in a transducer 70' which is most of its structural characteristics is similar to the transducer 70 hereinbefore described, and in all instances where such correspondence exists the same reference numerals with a prime suffix have been applied in Fig. 13.

Thus the transducer 70' has a housing 71' which is cup-shaped and is flanged at its open end as at 74'. In this form of the invention the housing 71' also serves as the magnetic yoke of the device, and a pole plate 79A is mounted on the open end of the housing as by rivets 80'. The pole plate 79A is dished inwardly in the same general manner as in the transducer 70, thereby to locate the central opening 81' thereof about one end of the permanent magnet 97' and in an inwardly spaced relation to the cap plate 83'. In this embodiment, however, the pole plate 79A is formed so that it is relatively thin near its outer edge, as indicated at 133, and gradually increases in thickness toward the central opening 81'. With this arrangement an effective magnetic path is afforded from the outer edge or flange 134 to the magnetic gap, and yet a substantial reduction in material and in weight is effected. It will be observed that the flange 134 is in this embodiment substantially thinner than the corresponding part shown in Fig. 10, and in order to maintain the same thickness or size in the clamping ring 93', a spacer ring 135 of cardboard or fiber is positioned about the housing and against the flange 74'.

It will be recognized that a substantial portion of the weight in a transducer such as that to which this invention pertains is embodied in the housing, as 71', and in order that the weight of the housing may be minimized, a relatively wide and flat nut 136 is utilized to receive the end of the screw 98'. The nut 136 has a lug 137 thereon adapted to engage a socket formed by a half-punch 138 in the bottom wall of the housing, thereby to hold the nut against rotation as the screw 98' is tightened. The nut 136 is so formed as to bear firmly against the outer face of the bottom wall 72' over a wide area, thereby to afford an efficient magnetic path from the magnet 97' through the wall 72' and to the nut 136, and because of its thickness the nut 136 serves to afford ample cross sectional area in the magnetic path near the central axis of the housing. The nut 136 is tapered or rounded to a thin outer edge, as indicated at 139, but such taper is gradual so that the nut extends outwardly to point where the effective cross sectional area of the wall 72 is sufficient to provide an efficient magnetic path.

With this arrangement it is in many instances possible to somewhat reduce the wall thickness of the housing 71', and as a result, the weight of the transducer as a whole may be minimized while maintaining efficient operation and performance thereof.

In locations adjacent to magnetically sensitive apparatus such as magnetic direction finding or indicating equipment, it is esential that stray magnetic fields adjacent to such sensitive apppa-ratus be eliminated or at least minimized. With the transducers illustrated in Figs. 10 and 13 it will be evident that the housing 71 or 71' serves as the primary path for the magnetic flux so that stray magnetic fields will be present about such transducers. Where such stray magnetic fields are objectionable as in the above cited instances, the present invention may be embodied in the alternative form shown in Figs. 14 to 16 which retains the general form and size of the transducers of Figs. 10 and 13, but is so constructed and arranged that stray magnetic fields are avoided. Thus the transducer 70*a* of Figs. 14 to 16 has a generally cup-shaped housing 71*a* which is flanged at 74*a* at its outer end and is formed with sockets 130*a* and 131*a* so as to be adapted for mounting in clip assemblies of different sizes or designs in the same manner as the transducers of Figs. 10 and 13.

In this alternative form of the invention the housing 71*a* serves as a path for conducting the magnetic flux to the annular magnetic gap of the transducer, but in this form of the invention this function of the housing 71*a* is accomplished in such a manner that the housing acts as a shield rather than as a primary part of the magnetic circuit, and means is provided within the housing 71*a* to afford a primary magnetic circuit. To this end a magnetic yoke 140 is formed from a relatively heavy strip of soft iron or other magnetically permeable material to afford a bottom member 141, two side members 142 disposed at right angles to the bottom member 141, and a top member 143 which is provided by bending the ends of the side members 142 inwardly toward each other. These ends may be joined together as by welding, and the two ends joined are punched to afford an opening 81*a* which forms the outer side of the magnetic gap of the transducer, and hence the member 143 constitutes the outer pole piece in this embodiment of the invention. On its inner face the top member 143 has a locating member 105*a* made from non-magnetic material and held in place by rivets at 104*a*. Thus a permanent magnet 97*a* of cylindrical form may be extended through the locating member 105*a* and into contact with the bottom member 141 of the magnetic yoke 140, and a screw 98*a* extended through an axial bore 99*a* in the magnet is threaded into the bottom member 141 to hold the magnet 97*a* in position.

The magnetic yoke 140 is supported in position within the housing 71*a* by a mounting plate 79*a* which has a central opening therein somewhat larger than the opening 81*a* so that the central portion of the plate 79*a* may be secured to the outer face of the top member 143 in a central relation to the opening 81*a*, and such a connection is in the present instance afforded by the rivets 104*a*. The mounting plate 79*a* is dished inwardly so that when its outer flange or edge portion 79*b* is placed against the outer face of the flange 74*a*, the magnetic gap afforded by the opening 81*a* will be disposed a substantial distance inwardly of the open end of the housing

71*a*. A diaphragm 82*a* of a generally cone-shaped form has a voice coil structure 96*a* supported thereon in such position that it may be centered within the magnetic gap afforded between the opening 81*a* and the magnet 97*a*. The outer edge of the diaphragm 82*a* is disposed in abutment with the outer face of the mounting flange 79*b*, and a magnetic shield in the form of a metal plate 85*a* has its peripheral edge 85*b* disposed against the outer mounting flange portion of the diaphragm 82*a*. The plate 85*a*, the diaphragm 82*a* and the mounting plate 79*a* are held in position on the flange 74*a* of the housing by a plurality of rivets 80*a* which are extended through the several flanges, and in the present instance a fibre gasket 145 is also secured in place on the rear face of the flange 74*a* by means of the rivets 80*a*. After the shield or plate 85*a* has been secured in position as just described the outer cap plate 83*a* may be placed in position over the plate 85*a*, suitable interlocking means being provided so that openings 90*a* in the cap plate 83*a* may be accurately aligned with corresponding openings 90*b* in the shield plate 85*a*. After the cap plate 83*a* has been placed in position, it is secured in this position by an annular clamping ring 93*a*. In the present instance the shield plate 85*a* is offset in its central portion as indicated at 147, and a sheet of fabric 148 is secured as by adhesive to the plate 85*a* in the space afforded by the offset 147. Through this arrangement the reproduction characteristics of the present transducer may be governed to produce the desired frequency response characteristics.

The transducer of Figs. 14 to 16 has a terminal block 115*a* which is substantially similar to the terminal block shown in Fig. 10 and which is secured in position by means such as a rivet 118*a*. In connecting the terminals 121*a* of the terminal block to the coil of the voice coil structure 96, a transformer 125*a* is utilized in substantially the same manner as in the embodiment shown in Fig. 10, and wires 129*a* are extended from the respective terminals 121*a* to the opposite terminals of the primary of the transformer 125*a*. The transformer 125*a* is supported on the plate 79*a* by means including rivets 127*a*. Wires 128*a* are extended from the secondary of the transformer to rivets 149 which are mounted by means of insulating sleeves 150 in the mounting plate 79*a* as shown in Fig. 14, and wires 110*a* are extended from the rivets 149 through the diaphragm 82*a* and to the opposite ends of the voice coil in the same manner as in Fig. 12.

It will be observed that the bottom member 141 of the magnetic yoke 140 is supported out of contact with the wall 72*a* of the housing, and a similar spaced relation is afforded between the side members 142 and the side walls of the housing. Since the sockets 130*a* are formed in the offset portions of the side wall, clearance slots 152 are formed in the members 142 so that the inwardly projecting bosses, formed in the wall 73*a* when the sockets 73*a* are stamped, do not contact the side members 142. Thus it will be clear that any stray magnetic fields about the magnetic yoke 140 will pass to the walls 72*a* or 73*a* of the housing 71*a* and will be conducted to the mounting plate 79*a* and thence to the member 143 which constitutes the outer pole piece and defines the outer side of the magnetic gap. Hence the casing 71*a* in this embodiment of the invention serves as a path for magnetic flux, but since the primary magnetic path afforded by the

yoke 140 provides the best and most effective path to the magnetic gap, the flux density in the housing 71*a* is maintained relatively small at all times, such flux density in the housing 71*a* being so small that objectionable stray fields outside the housing are avoided. Where the walls of the housing are relatively thin as in this embodiment of the invention, the bottom wall 72*a* may be strengthened by the formation of an embossed panel 72*b* therein.

In securing the desired frequency response in the transducer the back loading of the diaphragm 82*a* is preferably reduced through the provision of a plurality of openings 79*c* in the mounting plate 79*a*, this arrangement being such as to enable substantially the entire interior of the housing to function as a back chamber. Further improvement of the frequency response is also attained by forming the diaphragm 82*a* with an annular bead or corrugation 82*b* in the outermost portion of the free area of the diaphragm, and with this bead it is found that the flexing of the diaphragm is relatively free under all conditions. The mounting of the textile member 148 between the cap plate and the shield 85*a* also contributes to the attainment of the desired frequency response, for by selection of the fabric it is possible to eliminate or reduce undesirable components of the voice energy.

It will be evident that the embodiments of this invention illustrated in Figs. 7 to 16, as thus described, are waterproof in character since the diaphragms are of waterproof construction and are arranged to cooperate with the housing in excluding water from the internal electrical elements, and in furtherance of this purpose a suitable lacquer may be applied within the housing about the terminal block and at other points where leakage might occur. When, however, the transducers are employed for some uses, as for example, in aviation work, it is desirable to provide for equalization of the pressure in the back chamber, and where this is desirable and where absolute protection against moisture is not vital, this may be accomplished by providing relatively small pin holes in the diaphragm adjacent to the edge thereof.

Under other circumstances, where the waterproof character of the transducer is to be preserved, the present invention enables the desired equalization of the pressure in the back chamber to be attained through means which prevents entry of water. While such means might be afforded in any of the embodiments shown in Figs. 7 to 16, it is shown only in Fig. 14 where an opening 154 is formed in the panel 72*b* of the housing and a resilient sheet or membrane 155 of rubber or the like is secured on the inner face of the bottom wall 72*a* so as to span the recess afforded by the panel. The sheet 155 is secured to the bottom wall 72*a* by adhesive so as to exclude water from the electrical elements within the housing, and yet when the pressure within the housing exceeds that outside the housing, the resilient sheet 155 may be stretched into the recess afforded by the panel 72*b*, thereby to reduce the pressure in the back chamber to correspond with the external air pressure which is applied to the sheet 155 through the opening 154.

Where the back chamber is thus completely closed or sealed, the air confined within the back chamber is of course compressed as an incident to the operation of the diaphragm, and because of the elastic properties of such air an undesirable variation in the frequency response of the transducer may result at some frequencies, but in accordance with this invention, such an undesired variation is avoided by the provision of means operable to dissipate the energy of the air which is thus compressed within the back chamber. As shown in Fig. 14, such means are afforded by providing a fibrous filler material in a substantial portion of the back chamber, and while this construction may be employed in any of the illustrated embodiments, it is herein shown in but one of such embodiments. Thus, as shown in Fig. 14, the rear portion of the housing is filled with a fibrous material 160 such as kapok or wood fiber. The fibrous material 160 is preferably compressed into blocks of the shape required to fit about the elements of the magnetic circuit and the transformer so that the preformed block of fibrous material may be readily placed in position, but if desired the material 160 may be packed in place bit by bit while the mounting plate 79*b* is held in a slightly separated relation to the open end of the housing. Where the material is thus put in place bit by bit it has been found desirable to place a protective shield of textile fabric across the openings 79*c*, Fig. 16, or the openings 111, Fig. 11, for by such an expedient the filler material 160 is maintained out of contact with the diaphragm at all times. It will be understood that for clarity of disclosure, the fibrous filler material 160 is shown in but a small portion of the back chamber in Fig. 14, but in practice the filler material is placed in position in all or a substantial portion of the back chamber, and is compressed or packed relatively firmly so as to place a high resistive load on the back of the diaphragm and have an efficient dissipating action with respect to the energy of the air as such air is compressed. When the back chamber has been filled to a relatively great extent with wood fiber it has been found that the present transducers of Figs. 7 to 16 have a frequency response which conforms more closely to the desired flat response curve than any prior transducer, and such close conformity has been found to extend through the range of frequencies from below one hundred cycles to above four thousand cycles. Moreover, it has been found that with the transducers of this invention, the variation from the normal frequency response which is usually experienced at high altitudes is reduced to a substantial extent, thereby to produce highly improved operation in high altitude aviation uses. Thus these transducers of Figs. 7 to 16 insure maximum intelligibility of transmission under all noise conditions, and such intelligibility materially exceeds that attained by prior transducers.

From the foregoing description it will be evident that the present invention enables dynamic transducers to attain the desired transducing capacity while maintaining the size and weight thereof at the minimum, and hence the transducers of this invention may be utilized where such considerations are vital factors in determining what type of transducer is to be selected. The use of a cup-shaped housing which also functions as a magnetic yoke contributes in a large measure to the attainment of this desirable result, and it will be observed in this connection that the cup-shaped housing affords a magnetic path of large cross sectional area so as to increase the effectiveness of the magnet in producing maximum flux density in the magnetic gap. Moreover, the use of a cylindrical magnet extending into the outer pole piece and serving as

the inner pole piece enables the maximum of magnetic force to be supplied in a transducer of a given size. These novel features, of course, enable maximum magnetic flux to be attained at the magnetic gap to thereby contribute to the efficiency of the transducer as a whole, and particularly it has been found that the high flux density attained in the magnetic gap of the transducers of this invention enables the voice coil to be reduced radically in size and resistance to thereby correspondingly contribute to the desirable characteristics of the transducers of this invention. The cup-shaped yoke and housing employed in the present transducers is so related to the form and location of the outer pole piece or pole plate that the yoke may also function as the primary supporting means for the diaphragm, and hence the transducers are simplified as to construction and assembly.

When the present invention is embodied in a speaker or earphone the arrangement is such that the cup-shaped housing provides means for mounting the earphone on headbands having different sizes of clip assemblies, and hence the usefulness of the earphones is greatly increased. In this embodiment of the invention the efficiency of the cup-shaped magnetic yoke is such that the magnet may be relatively small, and hence the location of the coupling transformer within the housing of the earphone is attained in accordance with this invention without sacrifice of compactness in the structure as a whole.

In the illustrated embodiments of the invention it will be evident that unusual simplicity of structure and assembly has been attained so that the transducers may be produced with great economy of time and material. Moreover, it will be seen that the construction and arrangement of the diaphragm and voice coil assembly contributes materially to the economy of the present construction, particularly in the mounting of the diaphragm button on the diaphragm in the form shown in Fig. 10, for it will be clear that the diaphragm button may be quickly located in its final position merely by insertion of the flange of the button into the voice coil form until it strikes the internal shoulder of the form.

Hence, while I have illustrated and described preferred embodiments of my invention, it is to be understood that these are capable of variation and modification and I therefore do not wish to be limited to the precise details set forth, but desire to avail myself of such changes and alterations as fall within the purview of the following claims.

I claim:

1. In a transducer, means including a permanent magnet and an outer pole piece of magnetically permeable material arranged to cooperate to define an annular magnetic gap adjacent to one end of the magnet, a diaphragm having a voice coil structure disposed in said magnetic gap, a cup-like housing formed from magnetically permeable material and disposed about said magnet in such a relation that said annular magnetic gap is located inwardly of the open end of said cup-like housing, said pole piece being secured to said cup-like housing to afford a magnetic path between the pole piece and the housing, and means completing a magnetic circuit from the other end of said magnet to said outer pole piece to enable at least a portion of the magnetic flux to flow through said housing to said pole piece.

2. In a transducer, a cup-like housing formed from magnetically permeable material and having a bottom wall and a generally annular side wall, a mounting plate extended across the open end of said housing and secured to the side wall of said housing to provide a magnetic path from said mounting plate to said side wall, a magnetic yoke formed from magnetically permeable material to provide a bottom member, side members and a top member apertured to constitute said top member as an outer pole piece, said outer pole piece being permanently secured to said mounting member to support said magnetic yoke within said housing with said bottom member and side members thereof in spaced relation to said bottom wall and side wall respectively of said housing, a permanent magnet mounted on said magnetic yoke with one end of the magnet in flux transmitting contact with said bottom member of the yoke and with the other end disposed within said aperture in said pole piece to define an annular magnetic gap, and a diaphragm having a voice coil structure disposed within said annular magnetic gap and having the outer edges of the diaphragm mounted on the outer edges of said mounting plate.

3. In a transducer, a magnetic yoke formed from magnetically permeable material to afford a bottom member, two side member and a top member having a central aperture therein, a permanent magnet secured to said bottom member and extended into said aperture in said top member to afford an annular magnetic gap, a mounting plate formed from magnetically permeable material and secured to said top member, a cup-like housing formed from magnetically permeable material and having said mounting plate secured across the open end thereof to support said magnetic yoke within said housing in spaced relation to the walls thereof, said mounting plate being secured to said housing at the open end thereof to afford a magnetic path between said plate and said housing whereby stray magnetic flux passing from said yoke to said housing is transmitted through said mounting plate to said top member of said magnetic yoke.

4. In a transducer, a cup-like housing formed from magnetically permeable material and having a bottom wall and a generally annular side wall, a mounting plate extended across the open end of said housing and secured to the side wall of said housing to provide a magnetic path from said mounting plate to said side wall, a magnetic yoke formed from magnetically permeable material to provide a bottom member, side members and a top member apertured to constitute said top member as an outer pole piece, said outer pole piece being permanently secured to said mounting member to support said magnetic yoke within said housing with said bottom member and side members thereof in spaced relation to said bottom wall and side walls of said housing, a permanent magnet mounted on said magnetic yoke with one end of the magnet in flux transmitting contact with said bottom member of the yoke and with the other end disposed within said aperture in said pole piece to define an annular magnetic gap, a diaphragm having a voice coil structure disposed within said annular magnetic gap and having the outer edges of the diaphragm mounted on the outer edges of said mounting plate, a shield plate of magnetically permeable material positioned across and in spaced relation to the movable parts of said diaphragm, a cap plate of insulating material positioned against the outer face of said shield plate, said cap plate and said shield plate having a plurality of cor-

respondingly positioned perforations therein through which voice energy may pass into contact with said diaphragm,means for locating said cap plate and said shield plate in such a relation that said perforations are in registry, and means for holding said cap plate and said shield plate in position on said housing.

5. In a transducer, a magnetic yoke formed from magnetically permeable material to afford a bottom member, two side members and a top member having a central aperture therein, a permanent magnet secured to said bottom member and extended into said aperture in said top member to afford an annular magnetic gap, a mounting plate formed from magnetically permeable material and secured to said top member, a cup-like housing formed from magnetically permeable material and having said mounting plate secured across the open end thereof to support said magnetic yoke within said housing in spaced relation to the walls thereof, said mounting plate being secured to said housing at the open end thereof to afford a magnetic path between said plate and said housing whereby stray magnetic flux passing from said yoke to said housing is transmitted through said mounting plate to said top member of said magnetic yoke, a diaphragm having a voice coil structure disposed within said annular magnetic gap and having the outer edges of the diaphragm mounted on the outer edges of said mounting plate, a shield plate of magnetically permeable material positioned across said diaphragm, a cap plate of insulating material positioned against the outer face of said shield plate, said cap plate and said shield plate having a plurality of correspondingly positioned perforations therein through which voice energy may pass into contact with said diaphragm, means for

locating said cap plate and said shield plate in such a relation that said perforations are in registry, a sheet of fabric disposed between said shield plate and said cap plate, and means for holding said cap plate and said shield plate in position on said housing.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
966,247	Schwarz	Aug. 2, 1912
1,115,519	Edwards	Nov. 3, 1914
1,546,567	Childress	July 21, 1925
1,586,391	Timmons	May 25, 1926
1,702,434	Hanna	Feb. 19, 1929
1,792,300	Hanna	Feb. 10, 1931
1,901,898	Clarke	Mar. 29, 1933
1,960,449	Midgley	May 29, 1934
1,961,665	Holly	June 5, 1934
1,987,413	Olson	Jan. 8, 1935
2,010,537	Emmert	Aug. 6, 1935
2,020,211	Quam	Nov. 5, 1935
2,029,282	Serge	Jan. 28, 1936
2,037,185	Thuras	Apr. 14, 1936
2,058,555	Betts, et al.	Oct. 27, 1936
2,085,721	Warnke	June 29, 1937
2,119,272	Engholm	May 31, 1938
2,155,474	Creager	Apr. 25, 1939
2,162,270	Mott	June 13, 1939
2,180,615	Serge	Nov. 21, 1939
2,202,886	Abrahams	June 4, 1940
2,216,961	Samial	Oct. 8, 1940
2,293,078	Proctor	Aug. 18, 1942