March 14, 1944. R. W. CARLISLE ET AL 2,344,023

EARPHONE

Filed Sept. 25, 1942 2 Sheets-Sheet 1

Fig. 1

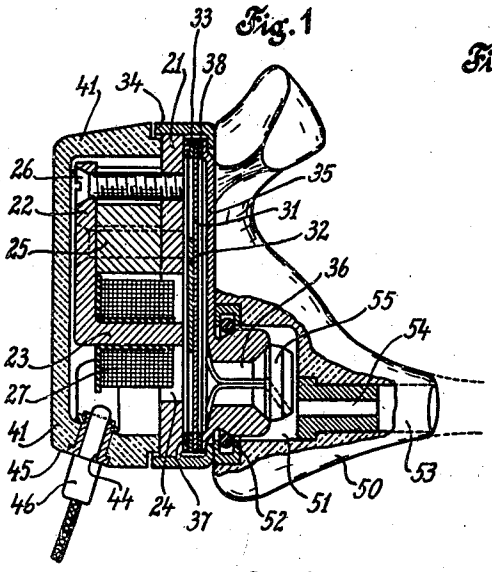


Fig. 2

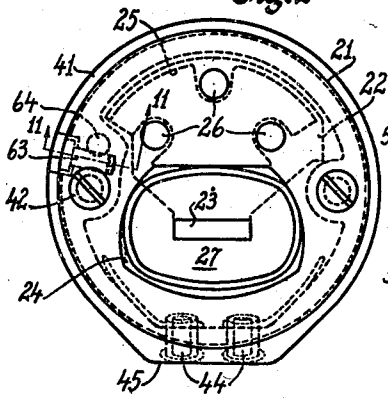


Fig. 4

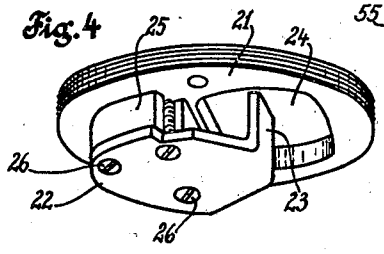


Fig. 7



Fig. 5

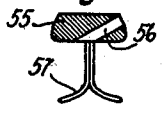


Fig. 8

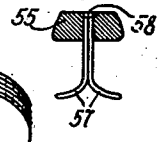


Fig. 6

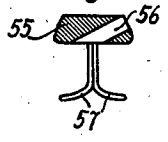
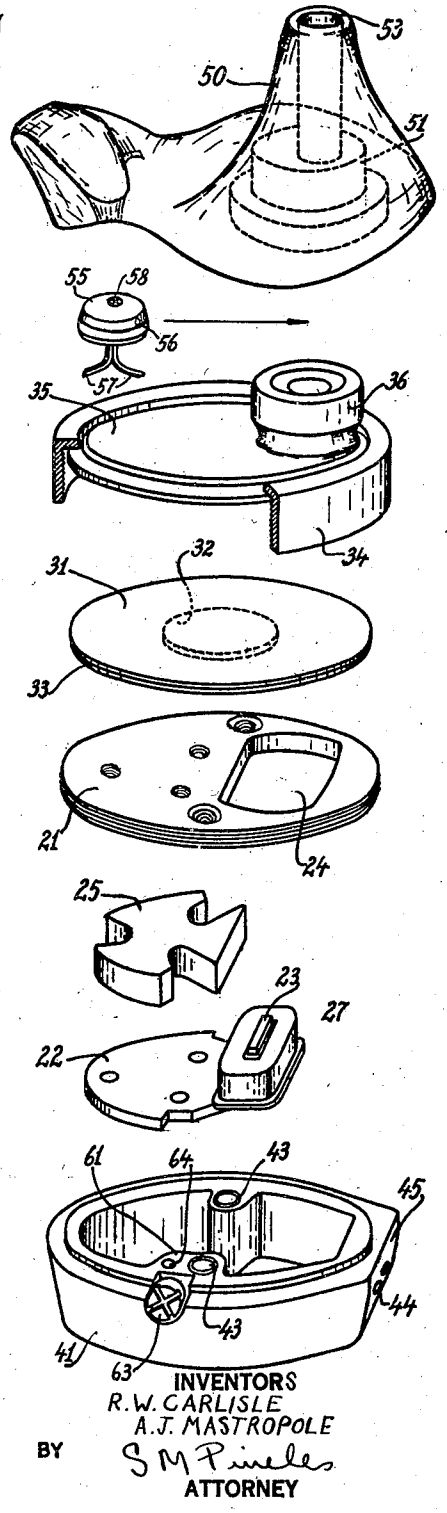


Fig. 3



INVENTORS
R. W. CARLISLE
A. J. MASTROPOLE
BY S M Pinckes
ATTORNEY

March 14, 1944. R. W. CARLISLE ET AL 2,344,023

EARPHONE

Filed Sept. 25, 1942 2 Sheets-Sheet 2

Fig. 9.

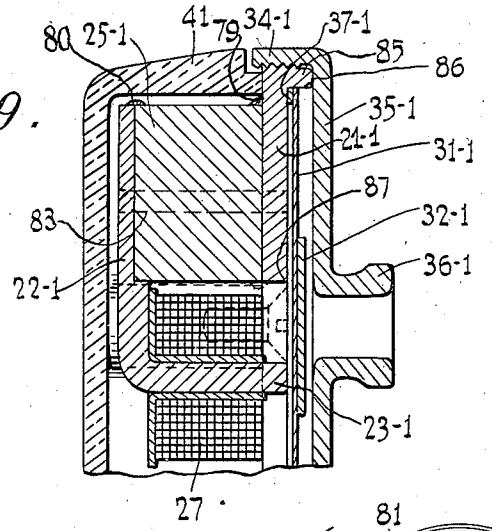


Fig. 10.

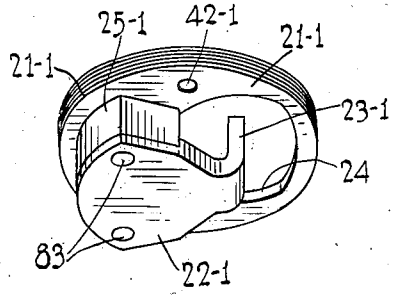
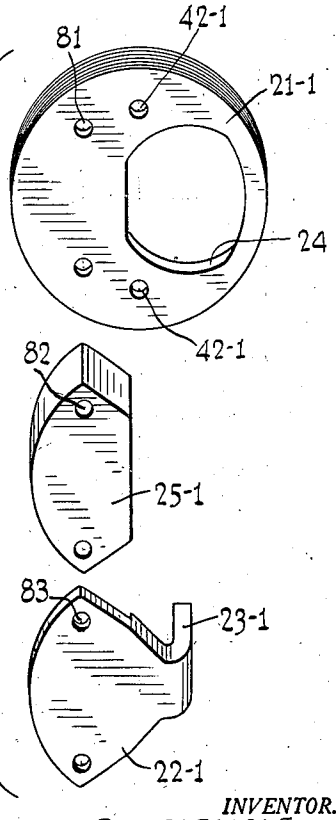


Fig. 11.



INVENTORS
R. W. CARLISLE
A. J. MASTROPOLE
BY S. Michael Pinales
ATTORNEY

Patented Mar. 14, 1944

2,344,023

UNITED STATES PATENT OFFICE

2,344,023

EARPHONE

Richard W. Carlisle, Elmsford, and Alfred J. Mastropole, New York, N. Y., assignors to Sonotone Corporation, Elmsford, N. Y., a corporation of New York

Application September 25, 1942, Serial No. 459,648

6 Claims. (Cl. 179—107)

This application is a continuation-in-part of our application Serial No. 334,678, filed May 11, 1940.

This invention relates to earphones, and particularly to midget size earphones of the type used by deafened persons, small enough to be worn and held within the ear of the user.

Among the objects of the invention is an improved midget earphone combining within an extremely small structure various features which simplify its manufacture, assembly and accurate adjustment in an efficient operating condition essential for producing with such small unit the relatively large volume of relatively high quality output required from a satisfactory hearing aid; and improved methods and arrangements for selectively controlling and adjusting the output characteristics of such earphone so as to fit best the needs of the user.

The foregoing and other objects of the invention will be best understood from the following description of examplifications thereof, reference being had to the accompanying drawings in which

Fig. 1 is a vertical cross-sectional view through a midget earphone illustrating one form of the invention as it is held within the ear of the user;

Fig. 2 is an elevational view of the receiver without its cap;

Fig. 3 is an exploded view of the principal elements of the earphone;

Fig. 4 is a perspective view of the assembled elements of the magnetic driving structure of the earphone;

Figs. 5 and 6 are cross-sectional views along line 5—6 of Fig. 7 of two interchangeable tone control units for the earphone;

Fig. 7 is a top view of the tone control unit;

Fig. 8 is a cross-sectional view along line 8—8 of Fig. 7 of a similar interchangeable control element;

Fig. 9 is a vertical cross-sectional view of another form of midget earphone construction exemplifying the invention;

Fig. 10 is a perspective view of the assembled elements of the magnetic driving structure of the earphone without the coil; and

Fig. 11 is an exploded view of the elements of the magnetic driving structure of Fig. 19.

Most of the deafened are very sensitive and seek to conceal their hearing impairment. Accordingly, a satisfactory hearing aid device for supplying the deafened person with the sound energy required to overcome his handicap must be suitable for comfortable and inconspicuous wear and simple and foolproof in operation so as to free the user from physical as well as mental strains. All the elements of the device must not only be small and light in weight, but must be able to respond at high efficiency to all important speech frequencies and they must operate satisfactorily under all conditions of use, without special attention and frequent reconditioning.

Many efforts have been made in the past to make the hearing aid midget earphones worn in the ear of the user as small, as comfortable and as efficient as possible so as to meet the foregoing requirements.

It was also long known that the hearing deficiencies of different individuals vary over the range of audible sound frequencies, and that it is very important to make it possible to selectively control the frequency response of earphones in accordance with the individual needs of each user.

The earphone of the invention is of much simpler construction than similar prior earphones, and embodies various desirable novel features which make it possible to more accurately manufacture, assemble and adjust such earphone, and to reduce its overall size without decreasing its output and quality.

The invention also provides novel methods and arrangements for selectively controlling the frequency characteristics of the earphone output so that it fits best the needs of the user.

The various features of the invention will be more readily understood from the description of the electromagnetic midget earphone receiver shown in Figs. 1 to 4 which is designed to serve as a part of a hearing aid in which the receiver winding may be traversed by a D. C. current component in addition to the speech frequency current oscillations used for its operation.

The earphone comprises an electromagnetic driving structure formed of a circular outer pole plate 21 constituting an aligning member holding aligned on its inward side an eccentrically located permanent magnet block member 25 and a parallel inner pole plate 22 having an angularly bent pole-piece arm 23 projecting into the opening 24 of the pole plate 21, the three elements being secured to each other as by three screws 26 extending therethrough.

The permanent magnet block 25 has flat parallel walls against which the two parallel pole plates 21, 22 are clamped and is made of good-quality permanently-magnetizable material. Permanent magnetic blocks made of powdered Alnico material, which is sintered in the molded shape shown in the drawings, are used in the practical

construction of such earphones. On the pole arm 23 of the pole plate 22 is mounted the actuating-winding coil 27 of the electromagnetic driving structure.

The hole 24 of the outer pole plate 21 is made large enough to enable the insertion of the coil 27 into its place on the pole arm 23 after the assembly of the magnetic driving structure shown in Fig. 4 has been completed. This is important in the manufacture of such midget earphones because it makes it possible to sand off or grind to an even flat aligned surface level the pole face of the pole arm 23 and the adjacent face of the outer pole plate 21, and to blow out the chips caused by this operation before the coil is inserted. In addition, coils may be easily exchanged and replaced without disturbing the aligned magnetic driving structure.

The flat peripheral portion of the outer surface of the pole plate 21 serves as an aligning support for the vibratory diaphragm 31. The diaphragm 31 is formed of a flat spring metal plate to which is secured, as by soldering, a flat central magnetic armature portion 32 and a flat peripheral stiffening ring 33, which are so arranged that by aligning the peripheral of the diaphragm 31 on the facing peripheral portion of the outer pole plate 21 the pole face of the armature 32 will be symmetrically aligned parallel and opposite to the pole faces at the end of the pole arm 23 and the adjacent portion of the pole plate 21 and will enable accurate adjustment of the magnetic gap between the pole faces of the vibrating diaphragm so formed. As shown in Fig. 1, the intermediate armature portion 32 of the diaphragm 31 bridges the magnetic path between the pole faces of the pole arm 23 and the aligned adjacent portion of the pole plate 21, which are spaced from the parallel pole face of the armature 32 by an accurately adjusted gap.

The aligning member forced by the outer pole plate 21 serves also as the clamping junction for clamping the armature diaphragm 31 in its accurately spaced and aligned position opposite the electromagnetic driving structure. To this end, the pole plate 21 has a threaded cylindrical periphery which is engaged by an inwardly threaded cylindrical clamping rim 34 of the cap plate 35 so as to clamp the periphery of the diaphragm 31 in its aligned position and provide between its exterior surface and the cap wall 35 an acoustic chamber of the desired acoustic characteristics. The cap plate 35 has a projecting knob or tip 36 forming a sound outlet passage to the exterior. The cap 35 and its clamping ring 34 may be made of one piece, or, as shown, of two parts so as to make it possible to adjust the angular position of the cap plate 35. The armature is accurately spaced by a spacer ring 37 of the required thickness.

A spring ring 38 transversely bent into a wavy shape is shown clamped between the rim of the cover plate 35 and the rim of the armature diaphragm 31 so as to hold all operating parts clamped in their adjusted position.

In the earphone receiver assembly described above, the pole plate 21, which, as shown is a very solid rigid part, serves thus as an aligning member which makes it easy to align on its opposite sides the elements of the electromagnetic vibrating system and the acoustic chamber, and to maintain with a minimum of effort and care the accurate magnetic gap spacing and efficient operating conditions essential for producing with a tiny unit fitting within the ear of the person the relatively large sound output of good quality that is required from a satisfactory hearing aid earphone.

The earphone has also a casing shell member 41 which, in distinction from prior earphone designs, does not perform any functions, except to serve as enclosure for the parts of the magnetic structure mounted on the inner side of the aligning pole plate 21. The casing is held clamped to the pole plate 21 of the driving magnetic structure by flat head screws 42 engaging inwardly threaded bushings 43 of the casing 41, the screws constituting the sole supporting connection between the driving structure and the casing and being confined within the periphery of the driving structure plate member 21 and within the interior of the casing.

This arrangement makes it possible to mold the casing shell 41 of a relatively cheap synthetic resin material. Since the casing shell 41 connected to the peripheral part of the driving structure is not used as a reference element for aligning the various parts of the vibrating system and the acoustic chamber, inaccuracies in molding or warpage will not in any way affect the accurate adjustment of the operating elements of the earphone.

The winding ends of the actuating coil 27 are connected to two terminal bushings 44 which extend through a slanted side wall portion 45 of the casing shell 41 at an angle to the generally flat parallel main walls of the earphone structure, so that when the cord plugs 46 of the connecting cord are inserted in the terminal bushing 44, the outwardly projecting plug portions shall not interfere with the insertion of the earphone into the space within the outer ear.

By mounting all the elements of the earphone, which cooperate in translating the electric oscillations delivered to the earphone into sound energy delivered to the ear of the user, on the opposite sides of a flat solid aligning plate, all operating parts may be made of simple shape and easily machined to accurate dimensions, thereby enabling easy assembly and accurate adjustment of all parts in their efficient operating positions.

The aligning plate 21 which is used as a common level for all operating parts, serves also as the support of the housing shell 41 which is so secured thereto that warpage or any inaccuracies in its dimensions cannot affect the adjustment of the operating parts.

The midget earphone construction described above in connection with Figs. 1 to 4 is thus characterized by a number of important features. Its relatively massive electromagnetic driving structure is formed of only three simple elements, namely, a substantially rigid generally flat aligning member having a generally cylindrical peripheral aligning surface and serving as an aligning support for an inwardly extending permanent magnet body, and the single pole piece member projecting from the inner region of the permanent magnet body into the eccentrically located opening confined within the periphery of the aligning member, the several elements being so arranged that the single permanent magnet member induces a concentrated unidirectional flux in a limited space region between the pole surface end of the pole piece and the limited immediately adjacent pole surface portion of the magnetic structure.

The aligning member has also an outwardly facing peripheral aligning surface extending in a predetermined fixed angular relation to its peripheral surface and serving as a support for

the circular peripheral portion of the vibratory diaphragm so as to hold its intermediate magnetic armature portion in the region of the concentrated unidirectional and oscillatory magnetic fluxes induced in the magnetic core structure by the permanent magnet body and the energizing coil mounted on the projecting pole piece.

In addition to holding aligned, in their most efficient operating condition, across a predetermined small gap, the intermediate magnetic vibratory diaphragm portion and the facing pole surface portions of the single pole piece and the adjacent magnetic core structure, the aligning member serves also to clampingly engage, with its cylindrical peripheral surface, the rim of the cap wall and for holding it together with its sound outlet duct in a predetermined aligned position in which it forms in conjunction with the facing diaphragm an acoustic chamber of the predetermined desired acoustic characteristics.

The aligning member serves thus as a common reference level for all structural elements determining the electromechanical and acoustic operating characteristics of the earphone.

The casing serves merely to enclose the parts of the magnetic structure mounted on the side opposite the diaphragm, and the securing elements, which constitute the sole supporting junction connecting the casing to the driving structure, are all confined within the interior of the casing and within the peripheral aligning surface of the driving structure, without exerting any forces on the peripheral region of the aligning member.

The eccentric mounting of the permanent magnet core structure in one portion of the casing interior makes it also possible to provide the side wall portion of the casing bordering the other portion of its interior, in which the pole projection and its coil are located, with terminal elements confined within the tiny space of the casing, which may be readily connected to the coil, and which provide exterior terminal connections to the operating circuit. The construction of the terminal elements used in the earphone constitutes the subject matter of our copending applications Serial No. 346,112, filed July 18, 1940, and Serial No. 443,278, filed May 16, 1942.

As shown in the drawings, the sound outlet knob **36** projecting from the cover plate **35** is offset from the center and is shaped to clamp the earphone to an ear tip **50** molded to fit the outer ear of the user. The ear tip **50** has a cavity **51** for receiving the outlet knob **36** of the earphone which is held clamped therein by a snap fastener ring **52** retained in a collar insert embedded in the molded body of the ear tip **50**. A sound passage **53** extending through the projecting portion of the ear tip registers with and fits into the mouth of the ear canal so that the sound generated in the acoustic chamber of the ear phone will be transmitted through the knob passage **36** and the ear tip passage **53** to the ear canal of the user.

In the drawings is shown an ear tip **50** molded to fit a very small size ear and, as shown, the diameter of the earphone is confined within the circumference of the flat ear tip surface facing it.

The size of such midget earphones presents the following problem: Deafened persons are very anxious that the earphone shall be as small as possible and that it should not be noticeable. In order to meet these requirements, the diameter of the earphone must be kept down if possible so that it should fit within the lobe of a very small ear of a young person. In addition, it is desirable that the earphone should lie as flush within the lobe of the ear as feasible. This in turn requires that it should not be thicker than about $\frac{3}{16}$ of an inch.

The receiver of the invention meets these requirements. Its outer diameter is only .7 of an inch. As shown in the drawings, the midget earphone is thicker than the coil principally by the thickness of the inner pole plate **22** and the armature **32**. Accordingly, the thickness of the midget cannot be substantially reduced without reducing the size of the coil.

Since, as explained hereinabove, the earphone shown in the drawings is designed for use in hearing aids which send a D. C. current component through the earphone coil **27**, a considerable heat is evolved in the coil and the coil of the dimensions shown is just about adequate to take care of such heating effect.

The midget earphones of the invention of the type shown in the drawings may be made considerably thinner if they are designed for use only in hearing aids which do not send a direct current component through the receiver coil **27**. The thickness of a receiver designed for such use could be reduced by at least $\frac{1}{16}$ of an inch so that its overall thickness would be $\frac{1}{16}$ of an inch less than that shown.

By making the permanent magnet block with notches, it is automatically positioned in its proper place between the pole plates **21**, **22** and the shanks of their clamping screws **26** when assembled. In addition, this arrangement provides a large cross-sectional area for the magnetic path between the two pole plates having a sufficiently low magnetic reluctance to assure efficient operation of the receiver without necessitating special magnetic shunt paths for the alternating magnetic flux.

The coercive magnetic force of the permanent magnetic material used in the earphone is large enough to supply the required permanent magnet flux if its total thickness or its effective length between the pole plates is made as little as $\frac{1}{16}$ of an inch. Such construction would require a very short magnetic air gap of less than three thousandths of an inch between the armature and the core structure. If it is desired to operate such receivers with a larger air gap of the order of three to five thousandths of an inch, it is better to use a permanent magnet block **25** having an effective length or thickness of $\frac{1}{8}$ of an inch between the pole plates **21**, **22**.

The design features of the earphone described above eliminate disturbing effects of temperature changes on the adjustment of its cooperating elements that are otherwise encountered in such earphones. The response of the earphones may be regulated by using armature diaphragm structures of different resonant frequencies.

Thus, an earphone shown in the drawing having an armature **32** approximately .030 inch thick will resonate around 1100 cycles; one having an armature approximately .022 inch thick will resonate around 1500 cycles; and one having an armature approximately .015 inch will resonate around 1800 cycles.

Midget receivers operating with such resonant

frequencies have a frequency range extending substantially 50% higher than the resonant frequency. By using a somewhat stiffer diaphragm 31 and an armature 0.12 thick, the resonant frequency may be raised to approximately 25000 cycles and higher, at a slight loss of sensitivity.

The same result may be accomplished by magnetizing the permanent magnet 25 less strongly. Where an increase in low frequency output is desired, the permanent magnet 25 is magnetized to less than full value. If it is desired to damp the mechanical resonance of the armature diaphragm and to extend the high frequency range, the thickness of the acoustic cavity between the armature diaphragm 31 and the cap plate 35 should be kept down to approximately .012 to .015 inch. In some cases, additional damping may be provided by placing a piece of cotton in the cavity 51 of the ear tip 50 in order to attenuate the resonance peaks, or to adjust the output on high signals to a critical level that will not be uncomfortable to the user.

Because of its acoustic propagation characteristics, the air in the knob outlet passage 36 acts as an inertance and has the effect of slightly attenuating frequencies above about 4000 cycles. This effect is desirable since the frequency band above 4000 cycles contains more noise than useful signals. If the acoustic cavity between the diaphragm 31 and the cap 35 is made too large, the air therein acts as a compliance which accentuates the effects of the inertance of the knob outlet passage and increases the attenuation of the high frequencies.

If the audiometric measurement of the user indicates that the diminution of the high frequency output is desirable, or if the user is particularly sensitive to distortion in the high frequency range, it is desirable to control the attenuation of the high frequency output. As shown in Figs. 1 to 3, such control of the high frequency output may be supplied by attaching to the outer end of the knob outlet passage 36 a washer-like plug member 55 provided with a relatively elongated hole 56 of small cross section.

As shown in Figs. 5 to 8, the tone control washer 55 is made very flat so as to occupy only a portion of the cavity 51 of the ear tip 50. The hole 56 is arranged to extend diagonally through the flat body of the washer 55 so that its inertance effect is increased, and to assure that the outlet end of the hole 56 opening into the cavity 51 of the ear tip shall not be clogged by a piece of cotton placed therein. Such acoustic control plug 55 having a hole about .020 in diameter will reduce the output by about six decibels at 4000 cycles and will hardly have any effect at 1000 cycles and below.

The earphones of the type shown may be used either in hearing aids in which its actuating coil is traversed by a direct-current component, or in which the coil is traversed only by alternating current. Because of the small size of the earphone, maintenance of the gap spacing betweeen the armature and adjacent pole faces in a critically adjusted position is of controlling importance. In some cases, it may be very important to maintain the acoustic cavity in between the diaphragm and the cap critically adjusted. The magnetic gap may be critically adjusted by placing a spring washer, such as spring washer 38, between the diaphragm 31 and the pole plate 21, and one or more thin flat washers, such as washer 37, of the predetermined desired thickness between the cap wall 35 and the diaphragm 31 of the acoustic chamber. Thereupon, the cap rim 34 is turned against the pressure of the spring washer until the gap is adjusted in the operating position in which it meets best the needs of the user. If critical adjustment of the acoustic cavity is desired, the spring washer is placed between the diaphragm and the cap wall, while one or more thin washers of predetermined thickness are placed between the pole plate 21 and the diaphragm 31, and the cap rim 34 is turned to critically adjust the acoustic cavity.

In order to assure that the earphone remains in the critically adjusted position, it is provided with an arrangement for locking it in the adjusted position.

As shown in Figs. 2 and 3, the side wall of the casing 41 is provided with an inward protrusion 61 having an inwardly threaded hole in which is mounted a locking screw 63, the head of which is located and arranged to engage the inwardly facing edge portion of the clamping collar 34 of the earphone cap 35. The cap collar 34 may be locked in the adjusted position of the cap by turning the locking screw 63 outwardly until it engages and clamps the cap collar or rim 34 against rotation. By turning the locking screw 63 inwardly, the cap collar 34 is released from its locking engagement, whereupon it may be turned to adjust either the gap or the acoustic chamber, whereupon it is again locked in the adjusted position by turning the locking screw 63 outwardly. The head of the locking screw 63 is provided with cross grooves to permit its being turned by a screw driver and its outer surface is slightly curved to facilitate its locking engagement with the inner edge of the cap rim 34.

A firm anchorage of the adjusting screw within the thin wall of the casing 41 is provided by forming the wall protrusion 61 as an extension of the molded protrusion of the bushing insert 43, and embedding in the protrusion 61 a metal pin insert 64 close to the bushing insert 43.

Figs. 9 to 11 illustrate another type of electromagnetic earphone construction based on the principles of the invention described in connection with Fig. 1. Its electromagnetic driving structure comprises a substantially rigid, circular, plate-like aligning member 21—1 provided with an inwardly-projecting, eccentrically arranged permanent magnet member 25—1 and a pole member 22—1 having an eccentrically arranged pole piece 23—1 projecting into an opening 24—1 of the aligning member so as to concentrate a strong permanent magnet flux in the central space region between the end of the pole piece 23—1 and the adjacent portion of the aligning member provided with the permanent magnet block 25—1.

Instead of securing the several elements to each other by screws, they are held together by soldering. The soldering may be accomplished by applying suitable layers of solder 79 to the exterior peripheral regions 79, 80 along which the upper and lower exterior edges of the permanent magnet block 25—1 adjoin the outward and inward pole plates 21—1 and 22—1 respectively, and heating the solder while the elements are held properly assembled in a suitable jig, and removing them from the jig after the solder has been cooled.

The outer pole plate member 21—1, the permanent magnet block 25—1 and the inner pole plate 22—1, respectively, may be provided with suitable aligning holes 83 arranged to receive suitable

aligning pins, and keep them properly aligned during the soldering operation.

The aligning pins may be formed of a solder composition, or of magnetic cores having on their exterior a layer of solder composition, and thus serve as junction parts of the finished structure.

In the earphone construction shown in Figs. 9 to 11, the circular aligning member 21—1 is provided with a peripheral flange 85 and the cylindrical exterior of the flange is provided with a threaded surface for clamping thereto the internally threaded rim 34—1 of an integrally formed cap member 35—1 having a centrally located sound outlet duct 36—1.

The peripheral surface of the aligning member 21—1 surrounded by its flange 85 serves as an aligning surface for holding aligned thereon the periphery of the circular vibratory diaphragm 31—1 so that its central portion which is provided with a magnetic armature 32—1 shall be spaced from the facing end portion of the pole piece 23—1 and the adjacent pole face portion 87 of the aligning member 21—1 by a predetermined small magnetic gap traversed by the concentrated strong permanent magnet flux induced therein by the permanent magnet block 25—1.

In the arrangement illustrated, the diaphragm 31—1 is formed of magnetic material and the armature 32—1, instead of being secured to its inner side, is shown secured to its outer side facing the cap 35—1. The required magnetic gap spacing is maintained by a circular spacer element 37—1 which may be made either as an integral portion of the aligning member structure 21—1 or as an interchangeably removable washer-like spacer ring. Notwithstanding its small size, a permanent magnetic block 25—1 of Alnico material, having dimensions given in connection with Figs. 1 to 4, will produce in the gap a permanent magnetic flux strong enough to hold, by itself, the vibratory diaphragm 31—1 in its proper operating position, without the necessity for clamping its circular peripheral region against its circular support 37—1.

The size of the acoustic chamber may be adjusted by placing a spacer washer between the end surface 86 of the circular flange 85 and the cap 35—1 clamped thereto. If all earphones are to be constructed with an acoustic chamber of fixed dimensions and fixed gap spacing, the gap spacing element 37—1 is made as an integral part of the aligning member 21—1, and its outward surface which serves to hold in alignment the peripheral region of the diaphragm, and the end surface 86 of the flange 85 against which the cap 35—1 is clamped as well as the surface portion of the pole piece 23—1 and the adjacent pole piece region 87 of the aligning member, are ground to predetermined dimensions by a single tool, thus assuring proper alignment of all the structural elements determining the electromechanical and the acoustic operating characteristics of the earphone.

In other respects, the construction of the earphone of Figs. 9 to 11 is similar to that of Figs. 1 to 4.

It will be apparent to those skilled in the art that the novel principles of the invention disclosed herein in connection with specific exemplifications thereof will suggest various other modifications and applications of the same. It is accordingly desired that in construing the breadth of the appended claims they shall not be limited to the specific exemplifications of the invention described herein.

We claim:

1. In an earphone designed to be small enough for carrying substantially in the ear of the user: a casing having an open side; a relatively massive driving structure comprising a substantially rigid generally-circular aligning member extending along the open side of the casing and an inwardly extending magnetic core structure enclosed by said casing; said aligning member having a generally cylindrical peripheral surface and an eccentrically located opening confined within its periphery; said aligning member having an outwardly facing peripheral aligning surface extending in predetermined fixed angular relation to said cylindrical peripheral surface; said core structure having a single pole piece projecting from the interior end of said core structure into the region of said opening and an eccentrically located permanent magnet body extending from the region of the inner end of said pole piece toward the region of its outward end for inducing a concentrated unidirectional flux in a confined space region extending between the outward end of said pole piece and the adjacent portion of said magnetic structure; a vibratory diaphragm having a circular peripheral portion supported in a predeterminedly aligned position by the outward aligning surface of said aligning member and an intermediate magnetic armature portion held in the region of said concentrated flux so as to be traversed thereby; a coil surrounding said pole piece for inducing with electric oscillations of the principal audiofrequency range corresponding vibratory magnetic forces in the region of said concentrated flux; said aligning member holding said magnetic core structure in a predeterminedly aligned position so that the induced vibratory forces impart a vibratory motion to the intermediate diaphragm portion at a predetermined small gap space from the outward portion of said pole projection and the adjacent outward portion of said magnetic core structure; a cap structure having a cap wall including a sound outlet duct overlying said diaphragm and a cap rim clampingly engaging the peripheral surface of said aligning member in a predetermined aligned position in which said cap wall forms with said diaphragm an acoustic chamber of predetermined acoustic characteristics; and securing means constituting the sole supporting junction connecting said casing to said driving structure and being confined within the interior of said casing and within the peripheral aligning surface of said driving structure.

2. In an earphone designed to be small enough for carrying substantially in the ear of the user: a casing having an open side; a relatively massive driving structure comprising a substantially rigid generally-circular aligning member extending along the open side of the casing and an inwardly extending magnetic core structure enclosed by said casing; said aligning member having a generally cylindrical peripheral surface and an eccentrically located opening confined within its periphery; said aligning member having an outwardly facing peripheral aligning surface extending in predetermined fixed angular relation to said cylindrical peripheral surface; said core structure having a single pole piece projecting from the interior end of said core structure into the region of said opening and an eccentrically located permanent magnet body extending from the region of the inner end of said pole piece toward the region of its outward end for inducing a

concentrated unidirectional flux in a confined space region extending between the outward end of said pole piece and the adjacent portion of said magnetic structure; a vibratory diaphragm having a circular peripheral portion supported in a predeterminedly aligned position by the outward aligning surface of said aligning member and an intermediate magnetic armature portion held in the region of said concentrated flux so as to be traversed thereby; a coil surrounding said pole piece for inducing with electric oscillations of the principal audiofrequency range corresponding vibratory magnetic forces in the region of said concentrated flux; said aligning member holding said magnetic core structure in a predeterminedly aligned position so that the induced vibratory forces impart a vibratory motion to the intermediate diaphragm portion at a predetermined small gap space from the outward portion of said pole projection and the adjacent outward portion of said magnetic core structure; a cap structure having a cap wall including a sound outlet duct overlying said diaphragm and a cap rim clampingly engaging the peripheral surface of said aligning member in a predetermined aligned position in which said cap wall forms with said diaphragm an acoustic chamber of predetermined acoustic characteristics; terminal elements connected to the coil and held by a side wall portion of the casing bordering the portion of its interior through which the pole piece projects; and securing means constituting the sole supporting junction connecting said casing to said driving structure and being confined within the interior of said casing and within the peripheral aligning surface of said driving structure.

3. In an earphone designed to be small enough for carrying in the ear of the user: a relatively massive driving structure comprising a substantially rigid plate-like aligning member having a generally cylindrical peripheral surface and an opening confined within its periphery; one side of said aligning member having an aligning surface extending adjacent to and in predetermined fixed angular relation to said cylindrical peripheral surface; a magnetic core structure extending along the other side of said aligning member in a predetermined aligned position relatively to said aligning surface and having a pole projection extending into the region of said opening, and windings interlinked with said core structure for inducing with electric oscillations of the principal audio-frequency range corresponding magnetic vibratory forces in said core structure; a vibratory diaphragm having a peripheral portion supported in a predeterminedly aligned position by the aligning surface of said aligning member and a magnetic portion held in a vibratory condition at a predetermined small gap opposite said pole projection so as to be driven by magnetic forces acting across said gap; and a cap structure having a cap wall including a sound outlet duct overlying said diaphragm, and a cap rim arranged to be guided in detachable interlocking engagement and in a predetermined aligned condition by the peripheral surface of said aligning member to a position in which it holds said diaphragm and said cap wall secured in a predetermined aligned position along said aligning surface so as to form an acoustic chamber of predetermined acoustic characteristics between the diaphragm and the cap wall; and a casing portion affixed to said driving structure and held in a position in which it is free from direct clamping engagement with said cap rim and forms with said cap structure an enclosure around said core structure and said diaphragm.

4. In an earphone designed to be small enough for carrying in the ear of the user: a relatively massive driving structure comprising a substantially rigid plate-like aligning member having a generally cylindrical peripheral surface and an opening confined within its periphery; one side of said aligning member having an aligning surface extending adjacent to and in predetermined fixed angular relation to said cylindrical peripheral surface; a magnetic core structure including an additional rigid plate-like magnetic member and a flat permanent magnet block affixed to the other side of said aligning member in a predetermined aligned position relatively to said aligning surface; said additional plate-like member having a pole projection extending into the region of said opening, and windings interlinked with said core structure for inducing with electric oscillations of the principal audio-frequency range corresponding magnetic vibratory forces in said core structure; a vibratory diaphragm having a peripheral portion supported in a predeterminedly aligned position by the aligning surface of said aligning member and a magnetic portion held in a vibratory condition at a predetermined small gap opposite said pole projection so as to be driven by magnetic forces acting across said gap; and a cap structure having a cap wall including a sound outlet duct overlying said diaphragm, and a cap rim arranged to be guided in detachable interlocking engagement and in a predetermined aligned condition by the peripheral surface of said aligning member to a position in which it holds said diaphragm and said cap wall secured in a predetermined aligned position along said aligning surface so as to form an acoustic chamber of predetermined acoustic characteristics between the diaphragm and the cap wall; and a casing portion affixed to said driving structure and held in a position in which it is free from direct clamping engagement with said cap rim and forms with said cap structure an enclosure around said core structure and said diaphragm.

5. In an earphone designed to be small enough for carrying in the ear of the user: a relatively massive driving structure comprising a substantially rigid plate-like aligning member of magnetic material having a generally cylindrical peripheral surface and an opening confined within its periphery; one side of said aligning member having an aligning surface extending adjacent to and in predetermined fixed angular relation to said cylindrical peripheral surface; a magnetic core structure including an additional rigid plate-like magnetic member and a flat permanent magnet block affixed to the other side of said aligning member in a predetermined aligned position relatively to said aligning surface; said additional plate-like member having a single pole projection extending into the region of said opening, and windings interlinked with said core structure for inducing with electric oscillations of the principal audio-frequency range corresponding magnetic vibratory forces in said core structure; a vibratory diaphragm having a peripheral portion supported in a predeterminedly aligned position by the aligning surface of said aligning member and a magnetic armature portion held in a vibratory condition at a predetermined small gap opposite said pole projection and an adja-

cent portion of said aligning member so as to form an electromagnetic path therebetween and be driven by magnetic forces acting across said gap; and a cap structure having a cap wall including a sound outlet duct overlying said diaphragm, and a cap rim arranged to be guided in detachable interlocking engagement and in a predetermined aligned condition by the peripheral surface of said aligning member to a position in which it holds said diaphragm and said cap wall secured in a predetermined aligned position along said aligning surface so as to form an acoustic chamber of predetermined acoustic characteristics between the diaphragm and the cap wall; and a casing portion affixed to said driving structure and held in a position in which it is free from direct clamping engagement with said cap rim and forms with said cap structure an enclosure around said core structure and said diaphragm.

6. In an earphone designed to be small enough for carrying substantially in the ear of the user: a casing having an open side; a relatively massive driving structure comprising a substantially rigid generally-circular aligning member extending along the open side of the casing and an inwardly extending magnetic core structure enclosed by said casing; said aligning member having a generally cylindrical peripheral surface and an opening confined within its periphery; said aligning member having an outwardly facing peripheral aligning surface extending in predetermined fixed angular relation to said cylindrical peripheral surface; said core structure having a pole piece projecting from the interior portion of said core structure through one section of the casing into the region of said opening located eccentrically with respect to the center of said circular aligning member; a permanent magnet body forming part of said core structure and located in the other section of said casing eccentrically with respect to the center of said circular aligning member and interposed between the inner end of said pole piece and the outward region of the magnetic structure for inducing a concentrated unidirectional flux in a confined space region of the central part of said aligning member extending between the outward end of said pole piece and the adjacent portion of said magnetic structure; a vibratory diaphragm having a circular peripheral portion supported in a predeterminedly aligned position by the outward aligning surface of said aligning member and an intermediate magnetic armature portion held in the region of said concentrated flux so as to be traversed thereby; a coil surrounding said pole piece for inducing with electric oscillations of the principal audiofrequency range correspondingly varying magnetic forces in the region of said concentrated flux; said pole piece and the surrounding coil occupying the major part of the section of the casing through which it extends and said permanent magnet occupying the major part of the section of the casing through which it extends; said aligning member holding said magnetic core structure in a predeterminedly aligned position so that the induced vibratory forces impart a vibratory motion to the intermediate diaphragm portion at a predetermined small gap space from the outward portion of said pole projection and the adjacent outward portion of said magnetic core structure; a cap structure having a cap wall including a sound outlet duct overlying said diaphragm and a cap rim clampingly engaging the peripheral surface of said aligning member in a predetermined aligned position in which said cap wall forms with said diaphragm an acoustic chamber of predetermined acoustic characteristics; and securing means constituting the sole supporting juncture connecting said casing to said driving structure and being confined within the interior of said casing and within the peripheral aligning surface of said driving structure.

RICHARD W. CARLISLE.
ALFRED J. MASTROPOLE.