Nov. 10, 1959 H. S. KNOWLES ET AL **2,912,523**

ELECTRO-ACOUSTIC TRANSDUCER

Filed Oct. 26, 1955 2 Sheets-Sheet 1

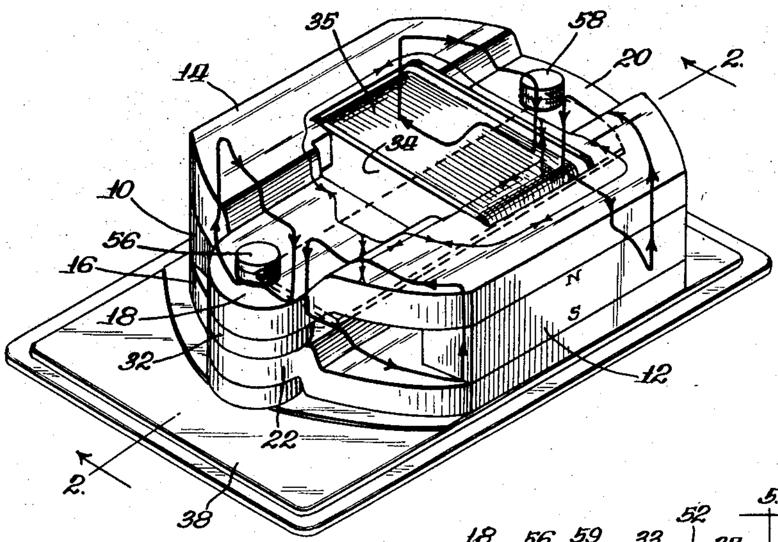
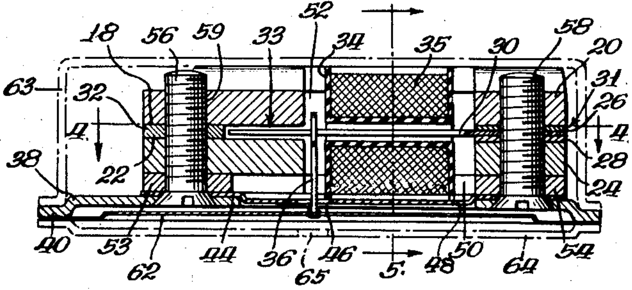


Fig. 1.

Fig. 2.



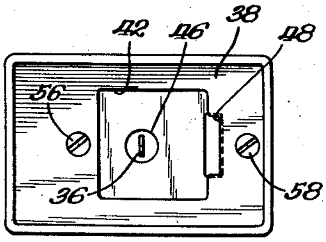


Fig. 3.

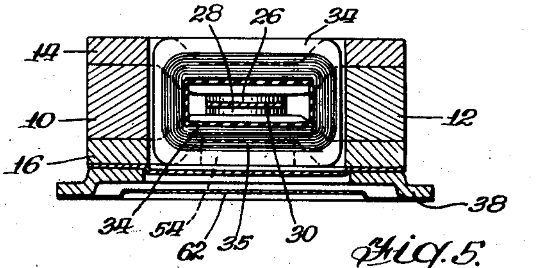


Fig. 5.

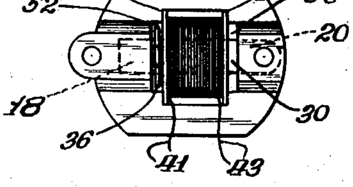


Fig. 6.

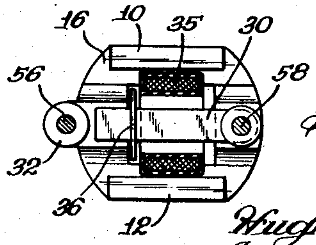


Fig. 4.

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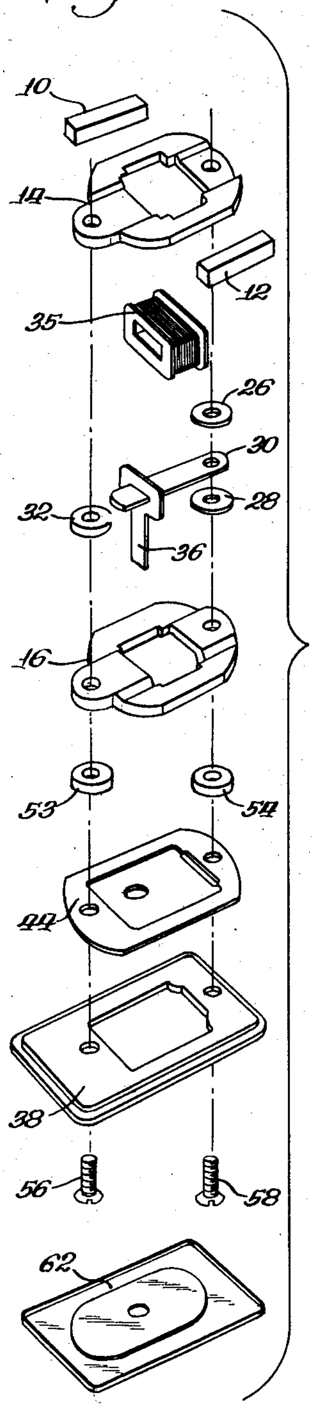
Fig. 7



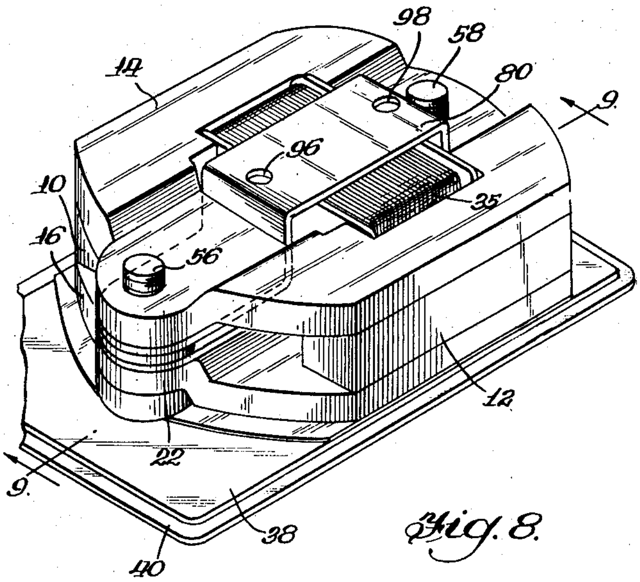
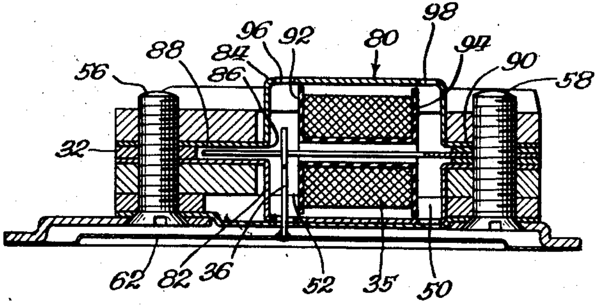


Fig. 8

Fig. 9



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2,912,523

ELECTRO-ACOUSTIC TRANSDUCER

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Application October 26, 1955, Serial No. 542,805

12 Claims. (Cl. 179—108)

This invention relates to a transducer and particularly to an electro-acoustic transducer of a size that may be used in hearing aids. For another electro-acoustic transducer see copending United States patent application Serial No. 436,416, filed June 14, 1954 by the present applicant Knowles and another.

The transducer which is the subject of this invention is of that type wherein a vibratable armature is disposed between two gaps, one in each of two flux conductors connected in parallel in a flux circuit. Under circumstances where the armature is magnetically entered in each gap, there will be no net flux flow through the armature and the transducer is in magnetic balance. By applying a variable current to a coil around the armature, or by mechanically moving the armature, for example by a diaphragm, this balance is upset, and the resulting flow of flux through the armature produces an energy in the alternative form to that introduced to the transducer, i.e., if the energy introduced is a variable electric current in the coil, the resulting mechanical movement of the armature vibrates the diaphragm; but if the energy introduced comes from vibrations of the diaphragm, the resulting flow of flux through the armature induces an electric current into the coil.

The principal object of the present invention is to provide an electro-acoustic transducer which not only is shielded from external magnetic fields, but which does not itself generate such fields. Applicants' transducer is used principally as a microphone and as a receiver in a hearing aid, and so long as the microphone and the receiver were physically spaced from each other, as for example, the receiver in the ear and the microphone on the chest, the generation by the transducer of magnetic flux fields extending beyond its physical boundaries was not too important. Applicants directed their attention toward shielding the armature and coil of the transducer from external stray fields, and the acoustic transducer described in the above-identified copending application was developed.

This object of sealing in magnetic fields and shielding from external fields has become acute because hearing aid designers wish to mount the microphone and the receiver close to each other in a single case. The hearing aid people wish to use accepted articles of headwear such as eyeglasses or earrings, in the case of women, to house both microphone and receiver. This juxtapositioning of the electric working parts results in serious feedback and oscillation, particularly since the electrical power in the receiver is between 105 and 108 times the electrical power in the microphone in modern hearing aids. Since the sensitivity of these acoustic transducers depends upon the efficiency of the translation of energy from mechanical to electrical or electrical to mechanical forms, it is important that the energy within the transducer be not added to or decreased by outside apparatus.

One of the features of the present invention is the positioning of the armature, or reed, in the center of what may be described as a cage of flux conductors. Any magnetic fields generated in the air by the armature or coil of the transducer are held within the limits of the transducer because expanding they encounter flux conductors which capture and confine them. On the other hand, these same flux conductors act as shields for absorbing any stray fields entering from outside. These flux conductors are the pole pieces and the magnets which are sufficiently extensive so that they form a sort of tubular wall in the axis of which lies the armature. They establish such perfect flux paths, i.e., so devoid of air gaps, that there is little likelihood of flux leaving the system so as to constitute stray fields which interfere with other apparatus. The relative size of the outside surfaces of the magnets and pole pieces to air gaps leading to the armature is of the utmost importance.

Another object of this invention is to prevent stray fields from adversely affecting normal flux flow or flux fields in the transducer. When a stray field encounters a flux conductor in a transducer, the stray flux will either add to or subtract from the flux flowing through the conductor. One of the features of this invention is the positioning of flux conductors with reference to both the coil and the reed so that a single stray field entering the transducer will tend to produce equal and opposite flux flows in the flux conductors and will cancel itself out.

Another object of this invention is to increase the strength of the transducer for a given volume. A feature of the present invention is the positioning of two spaced magnets between the long sides of two pole pieces disposed in spaced, parallel, registered relationship. As will be seen in the disclosure, the resulting structure is a sort of a tube closed at both ends, except for a through, transverse opening in which the coil is positioned in certain embodiments. The flux circuits are very compact and with the armature positioned in the axis of this tube, the flux from the two magnets can be brought to the working gaps very effectively.

A second embodiment of the invention is similar to the first, but shows the use of two shunt bars made of high flux permeable material, the basic idea disclosed in the above mentioned copending application. The shunt bars enclose the coil and act as an additional shield from external stray fields.

These advantages have been attained in both embodiments without sacrificing simplicity of assembly and without impairing the opening extending to air from both sides of the armature adjacent that portion in the fixed gap whereby a pin may be inserted from either side so as to adjust the free end of the armature in the other gap to produce magnetic equilibrium between the two gaps even though the mechanical parts are not in mechanical symmetry.

These and such other objects as may hereinafter appear are attained in the embodiments of the invention shown in the accompanying drawings, wherein:

Figure 1 is a perspective view of a preferred form of applicants' twin magnet transducer;

Figure 2 is a longitudinal sectional view taken on the line 2—2 of Figure 1;

Figure 3 is a plan view from the diaphragm side of the transducer with the diaphragm removed;

Figure 4 is a sectional view taken on the line 4—4 of Figure 2;

Figure 5 is a sectional view taken on the line 5—5 of Figure 2;

Figure 6 is a plan top view of the generator portion of the transducer;

Figure 7 is an exploded view of the parts of the transducer of Figures 1 to 5 in vertical alignment for assembly;

Figure 8 is a perspective view of the transducer shown in Figure 1 with shunt bars in position; and,

Figure 9 is a sectional view taken on the line **9—9** of Figure 8.

Continuing to refer to the drawings, particularly Figures 1 to 5, applicants' transducer consists of two permanent magnets **10** and **12**. While these magnets are elongated, the lines of flux do not run parallel to the length but transversely as the "N" and "S" symbols indicate. The magnetic strengths of these two magnets are substantially equal. This is attained by selecting for each transducer similar magnets, assembling them into the transducer, and then demagnetizing or further magnetizing until the total magnetism reaches an optimum value. Flux connecting the two north poles of the magnets **10** and **12** is an O-shaped pole piece **14** and flux connecting the two south poles is an O-shaped pole piece **16**. Each pole piece has two inwardly directed offsets **18** and **20**, and **22** and **24**, which will be called gap faces. Between the faces **20** and **24** are two spacers **26** and **28** which have permeabilities of the order of magnitude of that of air between which is mounted one end of a flux-conductive armature or reed **30**. These together constitute the fixed flux gap **31**. Between the faces **18** and **22** is mounted a non-magnetic spacer **32** whose thickness preferably equals the combined thickness of the spacers **26** and **28** and the reed **30**. Inwardly of the spacer **32** is the variable flux gap **33**. It is to be understood that the distance between the faces **18** and **22** need not equal the distance between the faces **20** and **24**, nor does the area of these faces need to be equal, as long as the ends of the reed **30** are disposed in equal magnetic potential regions in the two gaps **31** and **33**, without excitation.

Positioned around the reed **30** is a coil **35** wound on a flux non-conductive frame **34**, which is press fitted into the opening between the O-shaped pole pieces **14** and **16**. Referring to Figure 6, the pole piece **14** has coil frame seats **23** and **25** which are narrower than the shortest distance between the faces **18** and **20**, thereby providing through passageways **50** and **52**. Leads **41** and **43** may be brought out from the coil in whatever direction is required by the transducer housing to be used. As can be seen in Figure 2, the opening through the coil substantially exceeds the cross-sectional dimensions of the reed **30** so that the reed **30** is free to vibrate therein. Mounted on the free end of the reed in the passageway **52** is a diaphragm link **36**.

The transducer is adjusted according to the application it is to have. If a substantial direct current is to flow through the coil **35** under operating conditions, as is required of a receiver, the reed **30** is adjusted to have its ends in equipotential magnetic regions with this current flowing through the coil. Likewise, the reed **30** is positioned in equi-magnetic potential regions if no substantial direct current flows through the coil **35**, as when used as a microphone.

The alloy composition of these two pole pieces provides the maximum incremental permeability attainable with the unidirectional flux density required. These pole pieces carry the sustained uni-directional field established by the magnets **10** and **12** as indicated by the heavy solid line with the single direction arrows in Figure 1. In this structure by using two symmetrically disposed magnets, only half of the uni-directional flux carried by gaps **31** and **33** is carried by each arm of the pole pieces. This lowered uni-directional flux permits the selection of a magnetic alloy having higher permeability. This higher permeability also improves the shielding effect of the pole pieces. As will be noted from the flux lines in Figure 1, the symmetrical structure also provides two parallel paths for the alternating flux, thereby doubling the permeance, or the ease in conducting this alternating flux. Alloys containing 45–50% nickel, the balance iron, provide a good compromise between incremental permeability and saturation density in this application.

It is to be noted that the transducer constitutes a vibration detector without the link **36** and diaphragm **62**. A vibrational force applied parallel to the plane of vibration of the reed **30** will set the reed into motion.

In like manner, the transducer described above may be used as a recording head for a phonograph by replacing the link **36** and diaphragm **62** with a stylus **37**.

These basic elements of applicants' transducer are assembled on a rectangular mounting plate **44**. This plate **44** is made of flux non-conductive material and it or equivalent may constitute the sole base plate for the transducer. Where the transducer is to be used as a microphone or receiver as herein shown, the mounting plate **44** is assembled with a heavier plate **38**, also of flux non-conductive material, whose rectangular perimeter carries an outwardly directed flange **40** which forms an open-sided rectangular sound chamber over the face of which is positioned a diaphragm **62** by any suitable means. The plate **38** has a large rectangular opening **42**, see Figure 3, in which seats an offset portion in the plate **44**. The plate **44** has an opening **46** through which extends the link **36**, whose lower end is fastened to the diaphragm **62**. The plate **44** also has an opening **48** in alignment with the passageway **50**. A pair of spacers **53** and **54** are positioned above the plate **44**.

In devices of this type, thousandths of an inch are important. Referring to Figure 2, the offset portion of the plate **44** forms an inwardly directed recess into which the coil **35** extends, thereby reducing the gross thickness of the transducer by 1/32 of an inch.

All of the parts thus far described are held in assembled relationship by two threaded bolts **56** and **58**, the under side of whose heads engage the diaphragm receptacle side of the mounting plate **38**. Their shanks pass through aligned holes in the various parts as shown in Figures 2 and 4, being drawn tight in threaded holes, such as **59** in the upper pole piece **14**.

In order that the flux circuits will be confined to the two magnets, the reed and the pole pieces, all other parts are made of flux non-conductive material. These parts, namely, the mounting plate **38**, plate **44**, spacers **53**, **54**, **26**, **28**, **32**, screws **56** and **58**, and link **36**, are made of copper, brass or aluminum.

In a device as sensitive as applicants' transducer, even small imperfections such as metal shavings that may drop onto the parts during assembly, or burrs left by the stamping tools, or slight irregularities in spacing of the parts, will effect a flow of flux down the reed even though the field around the coil is static and the link **36** is motionless. Applicants make no attempt to correct these errors by attaining very close mechanical symmetry. Instead, applicants utilize the passageways **50** and **52**, see Figures 2 and 3, as a means for inserting a pin from above to deflect the reed downwardly and from below to deflect it upwardly so as to magnetically center the free end of the reed **30** in the gap **33** and attain an equal flow of flux through the gaps **31** and **33** even though the parts are not in exact mechanical symmetry.

As illustrated in Figure 2, the transducer is in the form of a microphone, and has a generally rectangular imperforate case **63** with an open end sealed to the mounting plate **38**. The case **63**, shown by broken lines, prevents interference from the back wave from the diaphragm **62** with the incident sound waves on the face of the diaphragm **62**. The frequency response of the microphone is further adjusted to the range for hearing aids by the plate **44** with its aperture **46**, and a cover **64**, also shown by broken lines, which is secured to the mounting plate **38** adjacent to the diaphragm **62** and provided with an orifice **65** confronting the central portion of the diaphragm **62**. Both the case **63** and cover **64** are constructed of non-magnetic materials, such as aluminum.

In Figures 8 and 9, applicants show the twin magnet transducer of Figures 1 and 2 equipped, however, with shunt bars **80** and **82**. The transducer of these figures is identical with the first form and hence the parts are not numbered in order that the positioning of the shunt bars and the flux circuit lines may be seen with less confusing indicia around them. Referring to Figure 8, the shunt bar **80** will be seen to be a flat strip of material having two reverse bends such as **84** and **86** at each end. The shunt bar **80** is identical with the shunt bar **82**, but they are inverted with respect to each other so that the coil **32** will be clear. The shunt bars are in physical contact with flux-conductive metal only on the faces **88** and **90**; otherwise, they are spaced from all other bodies although they may be in physical contact with the end walls **92** and **94** of the coil frame, these end walls being made of flux-nonconductive material, i.e., a fibrous material or molded nylon. In order to accommodate the diaphragm link **36** in the passageway **52** and to maintain the passageway **50** of a size so that the adjusting pins may be inserted, while nevertheless retaining the same dimensions for the other elements of the transducer, the width of the coil **32** and its frame have been slightly reduced.

The two ends of each shunt bar are not symmetrical, the left-hand end as viewed in Figures 7 and 8 being longer so as to permit clamping by means of the spacer washer **32**. Transverse passageways **96** and **98** permit passage of the adjusting pins when they are on the fixed gap side of the transducer and provide a passageway for the diaphragm link **36** on the other side of the transducer.

In the embodiment, the O-shaped pole pieces **14** and **16** need not be a compromise for handling variable flux and unidirectional flux at the same time, and hence may be made of rather "hard" magnetic metal. The shunt bars **80** and **82** should be made of very "soft" or high permeability metal. Applicants use "Permalloy" which has a composition of 79% nickel, 4% molybdenum, and 17% iron for shunt bars **80** and **82**.

In both embodiments of applicants' invention, there is little flux leakage through air. The sectional view of Figure 5 is substantially the same for both embodiments of the invention, neglecting the shunt bars in the embodiment of Figures 8 and 9, and it is evident that the easiest path for the flux is always through metallic conductors with the exception of the two gaps, and since it is the purpose of the transducer to concentrate flux at these two gaps, the maximum strength attainable from the two permanent magnets is obtained. In the copending application, the permanent magnet circuit has a tendency to push unidirectional flux into the shunt bars establishing two spaced flux-conductive bodies. Leakage through the air between these two bodies, i.e., shunt bars, occurred and the advantages of the shunt bars were in part lost.

The amount of flux at the pole face of each of the two gaps **31** and **33** is obtained substantially equally from the two magnets. The surface area of each magnet in engagement with the associated pole piece is somewhat greater than the cross section of both of the arms of the pole piece leading to the two faces. All of the flux that each magnet can introduce into the pole piece must flow through these two small cross sections. In the copending design, the relationship of this surface area between the magnet and the pole piece and the cross section of the arms leading to the gaps was closer to 4 or 5 to 1, whereas in the present design, it is only 2 to 1. By using two smaller magnets and four cross-sectional feeds into the part of the gap faces, applicants are able to force more flux to the gaps, or better, are able to relate the sizes of the magnets to the cross section of the pole piece arms so that substantially all of the flux that the magnets can produce will reach the gaps.

Referring to Figures 6 and 7, the opening through one of applicants' O-shaped pole pieces has the general shape of a Greek cross. By this arrangement, the coil frame can be made with substantially the same outside diameter as the inside length of one dimension of the opening and then squeeze-fitted into position. It is important that the coil remain in fixed position with respect to the armature. The side walls of the opening of one arm of the cross holds the coil frame. Referring to Figure 5, the coil is entirely inside the outside plane surfaces of the upper and lower pole pieces. This reduces the chance of accidental displacement.

The ends of the transverse portion of the Greek cross opening provide the narrow passageways **50** and **52** on either side which accommodate the diaphragm link in one passageway and permit insertion of pins in the other passageway to mechanically adjust the armature.

The transducer may be considered as an oblong cage whose top and bottom walls are formed by the pole pieces and whose side walls are formed by the magnets with the end of the tube closed by non-magnetic members, such as **32**, **26** and **28**. Vertically through this cage is an opening in which sits the coil. In the long axis of this cage is disposed the armature or reed. The armature itself is completely shielded from the outside excepting for comparatively small passageways. A stray field approaching from the outside must first encounter a flux conductor, i.e., pole piece, magnet, or shunt bar. Applicants have measured the electrical power induced by a stray field in one of these transducers used as a microphone (Fig. 2) and found it to be reduced by a factor of from 4 to 10 depending on orientation compared to the structure described in the above referenced application, and by a factor of from 9 to 120 compared to a device known to the art of generally similar sensitivity and acoustic response. Since the field produced by a receiver is reduced by the same factor for weak signals, and only slightly less for strong signals due to non-linear magnetic properties, the power induced by one of applicants' devices used as a receiver into another used as a microphone is reduced by an average factor of approximately 49 compared to devices described in patent application Serial No. 436,416, and by an average factor of approximately 4165 compared to prior art devices described above. These figures result from the fact that the external field generated by the device is reduced by a factor "*a*" and the undesired signal induced into the second similar device is reduced by the same factor, thus reducing the electrical coupling between the devices by a^2. As a result, the power amplification of a hearing aid can be increased by these respective factors for a given amount of feedback.

This decrease in electrical coupling between the microphone and receiver makes it possible to juxtapose the microphone and receiver. Further, due to the small size in which applicants' transducers can be constructed, one particular construction being over-all $\frac{1}{4}$ inch by $\frac{11}{16}$ inch by $\frac{15}{32}$ inch, a receiver and microphone may be positioned at distances between centers less than 2 inches and as close as $\frac{3}{4}$ inch between centers, the power in the receiver exceeding the power in the microphone by a factor of at least 10^5, without producing excessive feedback.

In the embodiment shown in Figure 8, the highly permeable shunt bars will have additional shielding effect, protecting not only the armature but the coil.

It is also to be noted that the present invention is applicable to all transducers of the balanced armature type, whether one end of the armature is clamped or the armature is merely pivoted.

Having thus described their invention, what applicants claim is:

1. A transducer comprising two generally flat pole pieces, said pole pieces being laterally spaced from each other in transverse alignment and generally parallel relationship, two magnets positioned between the pole pieces and along opposite edges of the pole pieces, like poles of the magnets contacting the same pole piece, means associated with the inside wall of one pole piece between the magnets and forming two gap faces so that flux leaves the pole piece through its side wall, said pole

faces forming with the other pole piece two gaps of low conductivity, an armature positioned in both gaps and vibratable in one, a coil around the armature, a diaphragm, means mechanically connecting the diaphragm and the armature, and means for holding the foregoing elements in assembled relationship.

2. A transducer comprising a pair of flux-conductive O-shaped pole pieces laterally spaced from and generally parallel to each other, two magnets disposed in flux-conductive relationship between the pole pieces and disposed between opposite edges of the pole pieces so as to form two flux gaps between the exposed inner side surfaces of the pole pieces, said magnets having like poles touching the same pole piece, a flux-conductive armature having one portion fixed in one gap and another portion vibratable in the other gap, and a coil disposed around and spaced from the armature.

3. An electro-acoustic transducer comprising a pair of pole pieces of generally flat configuration positioned in spaced relationship with their surfaces substantially parallel, two magnets, one positioned between the pole pieces along one side and the other positioned between the pole pieces along the other side, the polarity of the magnets touching the same pole piece being identical, there being a central opening through each pole piece, a coil positioned in said opening, an armature positioned in said coil and freely movable therein and extending parallel to the sides of the pole pieces containing the magnets and projecting beyond the coil so that the ends of the armature are between the inwardly directed side surfaces of the pole pieces, and means for fixing one end of the armature between the two pole pieces.

4. The transducer of claim 2 wherein the opening in each pole piece exceeds the length of the coil and the coil is centered in the openings of the pole pieces thereby providing a passageway between each end of the coil and the adjacent wall of the pole piece.

5. An electro-acoustic transducer comprising a pair of flat pole pieces positioned in lateral spaced relationship with their facing surfaces substantially parallel, two magnets positioned between the pole pieces and spaced from each other with the north pole of both magnets engaging one pole piece and the south poles the other pole piece, there being an opening of Greek cross configuration through each pole piece between the magnets so as to establish a passageway through the assembly, an armature fixedly mounted by one portion between the pole pieces so as to extend between the magnets across the passageway where a free end of the armature is vibratable between the inwardly directed side surfaces of the pole pieces, and a tubular frame carrying a coil press fitted into the walls of the pole pieces forming one arm of the cross and disposed around the armature.

6. A transducer comprising a pair of plate shaped flux-conductive pole pieces laterally spaced from and parallel to each other, two permanent magnets disposed in flux-conductive relationships between the pole pieces and disposed along opposite edges of the pole pieces so as to form two flux gaps between the inwardly directed exposed surfaces of the pole pieces, said magnets having like poles touching the same pole piece, a flux-conductive armature having one portion fixed in one gap and another portion vibratable in the other gap, and a coil disposed around and spaced from the armature, said coil being entirely disposed between the pole pieces.

7. The transducer of claim 1 wherein the pole faces are inwardly offset portions of the side surfaces of the pole piece.

8. The transducer of claim 1 wherein the two portions of one of the pole pieces whose inner surfaces constitute one side of the two gaps has been inwardly offset so as to narrow the gap.

9. A transducer comprising two generally flat O-shaped pole pieces, said pole pieces being laterally spaced from each other with the openings therein in transverse alignment and their surfaces in generally parallel relationship, two magnets positioned between the pole pieces and along opposite edges of the pole pieces, like poles of the magnets contacting the same pole pieces, means associated with the inside wall of those two portions of one pole piece that connect the magnets forming two gap faces so that flux leaves the pole piece through its side wall, said pole faces forming with the other pole piece two gaps of low flux conductivity, an armature positioned in both gaps and vibratable in one, a coil around the armature, a diaphragm, a drive pin connecting the diaphragm and the armature, and means for holding the foregoing elements in assembled relationship.

10. The transducer of claim 9 wherein the surface area of each pole face forming a gap is substantially greater than the cross section of the pole piece carrying flux from one magnet to said gap.

11. The transducer of claim 9 wherein the means for holding the elements in assembled relationship is a pin through both pole pieces and the armature which clamps the armature in fixed position at one gap.

12. The transducer of claim 9 wherein each O-shaped pole piece has an outwardly directed extension through which registering holes are positioned and which holes carry the pins for holding the elements in assembled relationship.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,912,523 November 10, 1959

Hugh S. Knowles et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 25, for "entered" read -- centered --.

Signed and sealed this 9th day of August 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents

UNITED STATES PATENT OFFICE

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