July 21, 1970 H. S. KNOWLES 3,521,208

RELUCTANCE ADJUSTMENT IN ELECTROMAGNETIC DEVICES

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Fig. 2.

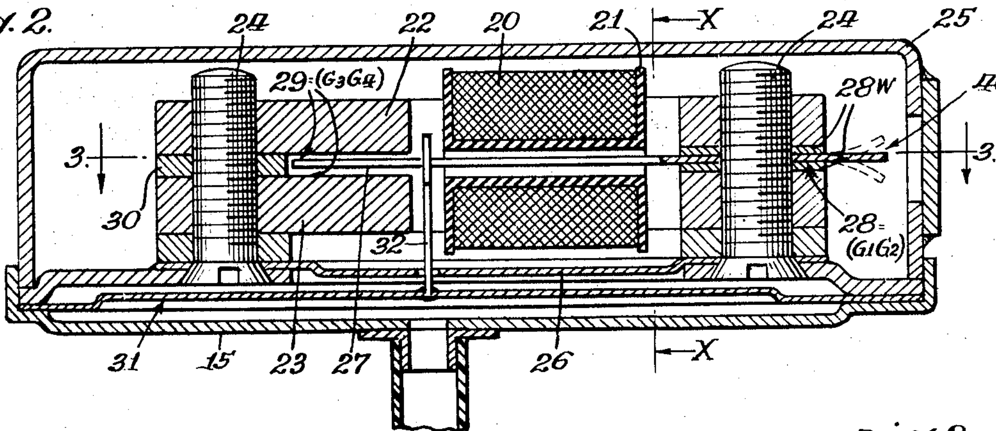


Fig. 1.

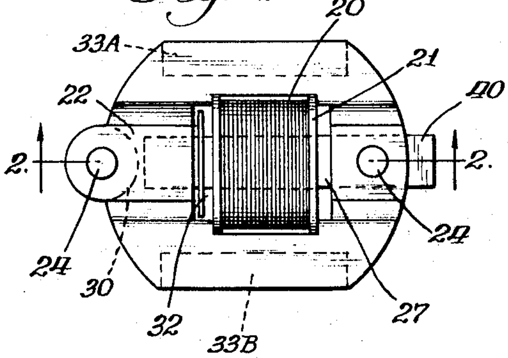


Fig. 3.

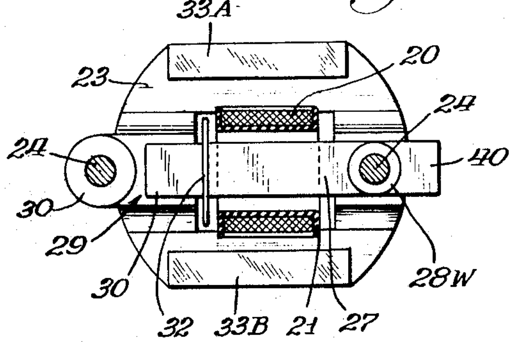
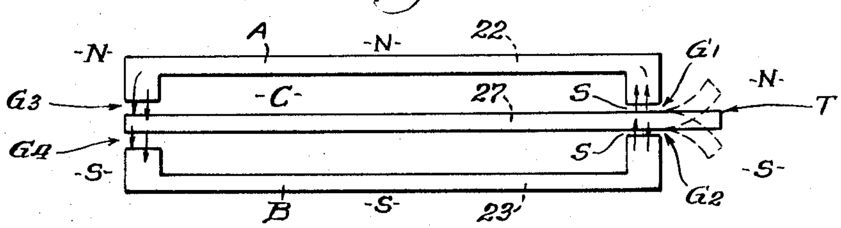


Fig. 4.



For Single Tab: $R_1 : R_2 = R_3 : R_4 \equiv$ Reed Balance

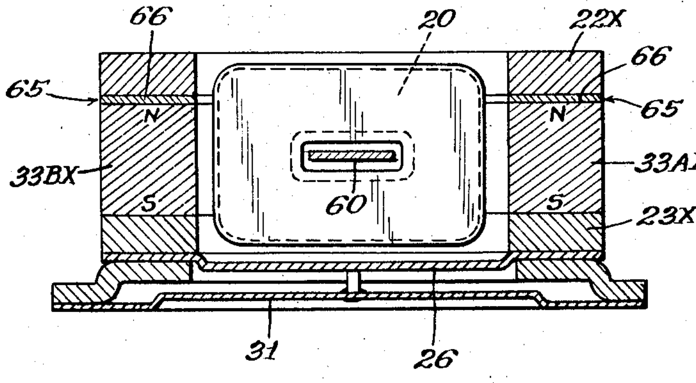


Fig. 5.

INVENTOR.

Hugh S. Knowles

BY

Atty.

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Fig. 6.

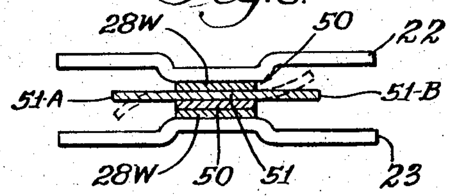


Fig. 6A.

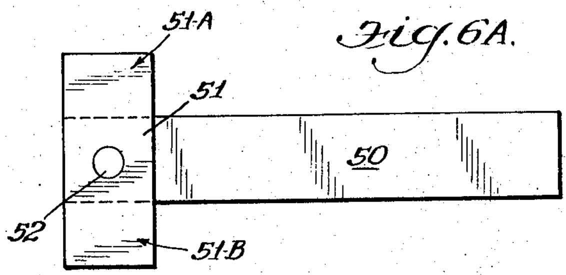


Fig. 7.

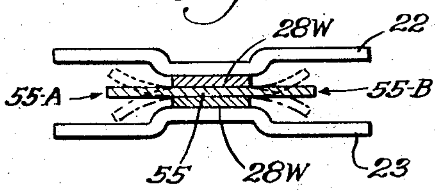
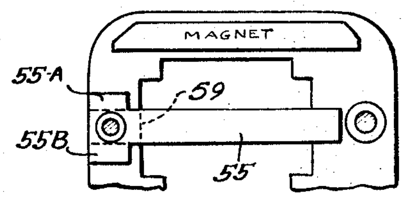


Fig. 7a



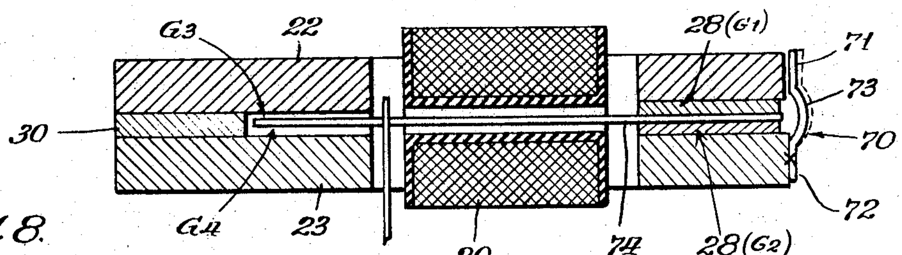


Fig. 9.

Fig. 8.

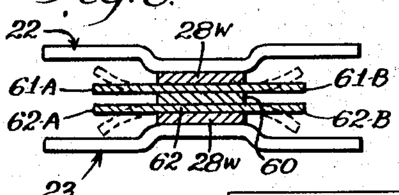


Fig. 10.

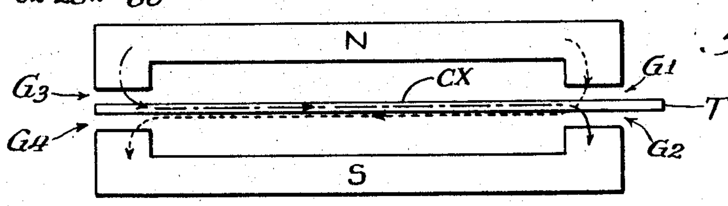
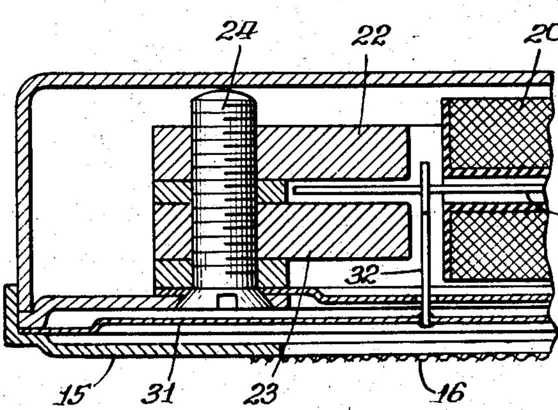


Fig. 11.



INVENTOR.
Hugh S. Knowles
BY Wm. S. Stone
Atty.

United States Patent Office

3,521,208

Patented July 21, 1970

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3,521,208

RELUCTANCE ADJUSTMENT IN ELECTRO-MAGNETIC DEVICES

Hugh S. Knowles, Glen Ellyn, Ill.
(9400 Belmont Ave., Franklin Park, Ill. 60131)

Filed Apr. 22, 1958, Ser. No. 730,082
Int. Cl. H01f 7/08
U.S. Cl. 335—231 6 Claims

ABSTRACT OF THE DISCLOSURE

An electro-magnetic transducer comprising a magnet, a pole piece flux-conductively engaging each pole of the magnet, an elongated armature, means clamping one end of said armature in spaced relationship to the pole pieces, there being a bending line between the clamped end and the vibratable end of the armature, and a flux-conductive, bendable tab having one end flux-conductively mounted on one pole piece adjacent the clamping means and the other end extending adjacent the other pole piece for varying the reluctance in the air gap between the pole pieces at the fixed end of the armature.

This invention pertains to the provision of improvements in electromagnetic devices such as transducers employing an armature movable relative to polarized pole pieces, and more particularly, but not exclusively, to that class of transducers used as receivers and microphones in heading aids, and the like, in which the armature may be a long thin magnetic reed reacting relative to pole pieces conducting the main polarizing flux.

One of the principal objects of the invention is the provision of a method and means for adjusting the reluctance at certain gaps in the magnetic circuit in such transducers for the purpose of improving the efficiency and response characteristics of such devices by eliminating troublesome magnetic flux acting along the length of the armature reed, and also by adjusting certain imbalances in gross polarizing flux at said gaps.

More particular objects are the provision of simple but highly effective paramagnetic adjusting members especially effective and practical in conjunction with miniaturized equipment and situated relative to certain fixed gap portions of a magnetic circuit for transducers of the class described, and characterized in that these members may be moved, as by bending, relative to pole pieces to produce changes in effective reluctance at fixed and working gaps so that the vibratory armature reed may be freed of unwanted flux conditions.

This disclosed adjusting means may be singular or plural in number; may be part of the reed or detached therefrom; and are located conveniently relative to the fixed gap means for manipulation to correct alone for longitudinal flux through the reed; or to correct for gross flux imbalance at the gaps; or may be utilized in a form capable of correcting both types of imbalance simultaneously by adjustment of a single corrector member located close to the fixed gaps.

Certain other aspects of novelty and utility characterizing the invention relate to details of the construction and operation of the embodiments hereinafter described in view of the annexed drawings, in which:

FIG. 1 is a magnified top plan view of an improved driver or generator unit of a type adapted for use as a heading aid transducer;

FIG. 2 is a greatly enlarged vertical section through a complete transducer, specifically a receiver, as it would appear looking in the direction of lines 2—2 of a driver unit such as shown in FIG. 1;

FIG. 3 is a horizontal section taken to reduced scale along lines 3—3 of FIG. 2;

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FIG. 4 is a schematic diagram illustrating certain magnetic-circuit conditions relating to the devices shown in FIGS. 1 to 3;

FIG. 5 is a transverse section of a modified form of the pole-piece structure shown in FIG. 2 as would be seen at lines X—X of the latter, parts being shown in elevation;

FIG. 6 is a schematic representation of a transverse sectional detail of the clamp gap region of a modified form of magnetic-circuit adjusting means;

FIG. 6A is a schematic longitudinal plan detail of the armature means employed in the arrangement of FIG. 6, i.e., taken on the line 6A—6A of FIG. 6;

FIG. 7 is a schematic representation of a transverse sectional detail of the clamp gap region of another modified form of the invention wherein the tabs are an integral part of the reed;

FIG. 7A is a schematic longitudinal plan detail of the armature means employed in FIG. 7, i.e., taken on the line 7A—7A of FIG. 7, and showing the inside edge of the tab positions spaced from the inside, transverse clamping edge of the fixed gap;

FIG. 8 is a schematic transverse sectional detail depicting the clamp gap region of another modified form of magnetic-circuit structure and adjusting means therefor;

FIG. 9 is a schematic vertical section through parts of a modified transducer motor employing a single corrector for adjusting longitudinal reed and pole piece flux and gross gap flux imbalances simultaneously;

FIG. 10 is a schematic diagram of the magnetic circuit for a construction of the class shown in FIGS. 2 and 4 and serving to illustrate theoretically a circulating or longitudinal flux condition in a reed;

FIG. 11 is a partial sectional detail through a transducer similar to FIG. 2, but showing changes required where the transducer is utilized as a microphone.

In its rudimentary aspects, the transducer depicted in FIGS. 1 and 2 (to greatly enlarged scale) is of a type intended for use as a receiver (or, with slight modification, as a microphone as in FIG. 11) in a hearing aid, and consists essentially of a coil **20** wound solenoid-fashion on a suitable insulating bobbin **21** and secured between juxtaposed pole pieces **22** and **23**, which are joined in assembly by screws **24** in the manner seen in FIG. 2, wherein the unit of FIG. 1 is shown secured within a housing **25** on the inner side of an outwardly-recessed plate member **26** through which said screws are passed, and the recessed portion of which also serves as the basket for a diaphragm mentioned hereafter.

An elongated armature reed **27** is clamped at one end between the pole pieces and non-magnetic spacer means, such as brass washers **28W** to extend freely for vibratile motion (vertically in FIG. 2) through the core of the coil with the free end of the reed movable in an air gap **29** formed between said pole pieces by reason of the presence thereat of a nonmagnetic spacer **30**. Through a single gap where spacer **30** is located, in effect the gap **29**, called the "working gap" becomes two gaps, one on each side of the reed in the region occupied by the free end thereof.

A diaphragm **31** (FIG. 2) is suitably secured for vibration in the basket recess of wall **26**, and is drivingly connected to said armature or reed by means of a lightweight drive link **32** slotted transversely at its upper end to interfit snugly with the reed for vibratory displacement by the latter responsive to signal energy acting in coil **20**, the working flux of which magnetizes the reed correspondingly, the reed in turn reacting in a polarized field existing across the working gap **29** owing to the provision of polarizing means, such as a pair of elongated transversely magnetized, permanent magnets **33A, 33B**, secured between the pole pieces on opposite sides of coil **20** (FIG. 3).

The construction thus far described is fundamentally related to that disclosed in my U.S. patent application Ser. No. 615,406, filed Oct. 11, 1956 and issued as U.S. Letters Pat. No. 2,966,558 on Dec. 27, 1960.

It is emphasized that the scale to which the representations of the devices in FIGS. 1 to 3 are drawn, is greatly enlarged, and that the actual size of these devices is so small (e.g. for the device of FIG. 1—less than 1-cubic centimetre) as to give rise to many troublesome problems of critical character in the successful manufacture and operation thereof, these problems relating to functional and structural aspects of both individual parts and the cooperative assembly thereof.

Among these problems is that of procuring optimum magnetic performance and efficiencies at the very small scale and in the miniaturized configurations required. Closely related to these latter considerations is another problem in effectively, expeditiously, and economically making certain critical adjustments relating to imbalances in the magnetic circuit, both during and subsequent to manufacture.

It is to the provision of highly effective, practical, and ingenuous solutions for certain of these problems that the present disclosures are addressed; and for the purpose of clarifying the nature of one of these problems relating to so-called "circulating" or longitudinal flux through the reed, there is schematically depicted in FIG. 4 a pair of polarized pole pieces A and B, and an armature reed —C— clamped at one end between magnetically inert (e.g. brass) spacers —S— (corresponding to washers **28W**) creating a first pair of air gaps G_1, G_2 (which are called "fixed" or "clamp" gaps, because the reed is clamped therein, and are analogous to the gaps existing at **28** in FIG. 2), the opposite end of said reed being free to vibrate in a working gap which in effect provides a second pair of air gaps G_3, G_4, the latter being analogous to the two working gaps on opposite sides of the free end of the reed as at **29** in FIG. 2.

The reluctance across each of the gaps G_1, G_2, G_3, G_4, has corresponding values designated for purposes of this explanation —R_1, R_2, R_3, R_4; and for optimum performance when little or no direct current flows through the coil **20** it is found that the relationship of these values should be ideally such that $R_1/R_2=R_3/R_4$. When achieved, all longitudinal flux along the armature is, in a manner of speaking, substantially "balanced out," at least for the static or resting condition of the reed —C—.

Thus, for purposes of this disclosure, it may be said simply that, under the aforesaid conditions of equal gap-reluctance ratios in a transmitter or microphone wherein there is a negligible D.C. current present in the coil, the armature reed —C—, while at rest, is magnetically "neutral" relative to the gross polarizing flux present in the circuit and particularly that acting across gaps G_1, G_2, G_3, G_4.

However, when the transducer is used as a miniature telephone receiver, there is normally sufficient Direct Current through the coil **20** to produce flux longitudinally along the reed. In this case the relative values of R_1 and R_2 are purposely modified as by use of non-magnetic shims of appropriate thickness at G_1 or G_2 to produce the desired effect, so that the flux produced by the D.C. coil current is balanced out by a counterflux caused to flow in a reverse direction longitudinally through the reed as a result of the magnetic circuit imbalance produced by altering R_1 and R_2 as aforesaid.

To obtain high efficiency, the permeability of the reed should be high. High permeability is, however, associated with low saturation densities. To obtain distortion-free reproduction in a receiver the flux through the reed must be proportional to the signal current. This requires that the permeability of the reed be substantially constant for all signal currents. When high permeability materials are used it is therefore essential that there be substantially no flux through the reed when there is no signal current. This permits maximum signal-current amplitudes without distortion.

Accordingly, one of the major objects of the present disclosures relates to the provision of a simple and highly effective method and means for adjusting a transducer or like device of the general character described, either during or subsequent to manufacture, to achieve the aforesaid neutral or magnetically balanced condition of the armature reed —C— by making adjustments at the fixed gaps G_1, G_2, calculated to render R_1/R_2 effectively equal to R_3/R_4.

The method in one of its aspects provides for decreasing the reluctance at one or the other of the fixed gaps situated on opposite sides of the reed at its clamped end; the means for effectuating this method being the provision of a paramagnetic member **40**, FIGS. 1 to 3 (or —T—, FIG. 4), which may be an integral part of the reed and which is an extension of the otherwise normal length thereof beyond the pole pieces at the physical margins of the clamping gaps in a position of access to be bent out of the plane of the reed toward one or the other of the pole pieces, as indicated by the dotted-line positions of part **40** shown in FIGS. 2 and 4.

Mere mechanical centering of the reed —C— relative to the air gaps will not necessarily produce the required conditions of reluctance to balance out the flux through the reed, although mechanical centering (and balance) of the reed, is generally desirable for other reasons. In this connection it may be observed that skillfully applying certain permanent deflections to the reed by "knifing" or bending adjustments, and by producing certain strains in the reed, can also effect desirable adjustments having a bearing upon the performance of such devices; however, the present disclosures are not concerned with adjustments of this latter type (the same being in part the subject matter of a co-pending application Ser. No. 719,958, filed Mar. 7, 1958 and issued as U.S. Letters Patent No. 3,002,058 on Sept. 26, 1961, and it should be noted that the reluctance-adjusting methods and means herein disclosed are assumed to be described in relation to a reed which is preferably set in manufacture to a position such that the free end thereof is within about .0005 in. of its required spacing from either pole face in the working gap, by which is meant the gap at **29**, the gaps at **28** at the opposite or fixed end of the reed being called for convenience the "fixed" or sometimes the "clamp" gaps. Moreover, the reluctance-adjusting means and methods described herein are not designed nor intended to impart any substantial corrective strain to the reed beyond the clamp gap.

The effect of the various reluctance adjusting means described herein may be more clearly understood by considering the definition of reluctance. The reluctance $R=l/ua$ where l is the length of the flux path, a is the area perpendicular to the lines of uux through which the flux passes and u is the permeability of the material along the length l. Ercept as otherwise noted herein, the assumption is made that ferromagnetic portions of the magnetic circuits such as pole pieces and the armature reed are operated at flux densities for which their permeability is very high and approximately constant, compared to the permeability of air. The permeability of air and of what are herein described as non-magnetic metals, such as brass, copper and the like is unity. The reluctance of gaps, or portions of the magnetic circuit in which air or non-magnetic metals are the materials through which the flux flows, is l/a since u is unity. Since u is unity and independent of the number of lines of flux it follows that the reluctance of the gaps is independent of the number of lines of flux. When the reluctance of a gap between adjacent ferromagnetic surfaces which are not uniformly spaced is evaluated one must consider small enough elements of area so the flux path length, l, between them can be considered uniform. The sum of the reciprocals of the reluctance, a/l, for all such elements of area in the gap region is equal to the reciprocal of the total gap reluctance.

The effect of lengthening the armature reed **27** by adding the extension or tab **40** thereto can therefore be seen to reduce the reluctance of gaps G_1 and G_2 by adding to and extending the normal clamp gap area. If the tab is in the plane of the reed as shown in the cross hatched section in FIG. 2, this reduction is small because the flux path length from the reed to the pole pieces is long compared to length of the gap at the clamp surfaces. The latter gap length in the direction of the flux lines is determined by the thickness of a washer **28W**. As the tab is bent toward one pole piece, the reluctance between the tab and pole piece decreases slowly at first and then rapidly as the gap length approaches zero. The reluctance from the tab to the other piece from which it is receding increases only slightly. The tab is most effective when it is close to a pole piece.

The beneficial results flowing from the foregoing reluctance-balance method and means are of especially great significance in the case of miniaturized equipment. But there are other adjustments of related character which also should be made, and the present disclosures provide further modifications to this end.

It has been pointed out that the tab **40** can produce only a decrease in effective reluctance across the fixed gaps G_1, G_2 (FIG. 4); and corollary to this is the fact that tab **40** primarily effects only the elimination of longitudinal flux in the reed —C—. Longitudinal flux is sometimes arbitrarily referred to as "circulating" flux, although strictly it does not circulate in the ordinary sense of the word; but this expression when used in connection with a magnetic circuit of the type described is intended to connote the flux which acts longitudinally along the reed due to imbalance from the causes described. This condition is portrayed in the analogous magnetic-circuit diagram of FIG. 10 wherein one flux path is represented by dotted line arrows as acting from gap —G_1—, into and along the reed and thence out of the reed again into gap G_4, the latter gap in this sense being complementary to gap G_1. In the reverse direction, the dash-dot arrow lines show the "longitudinal" or "circulating" flux as acting from gap G_3 down into and along the reed in the opposite direction, thence out of the reed down into the complementary lower gap G_2.

There is still another condition of magnetic imbalance which is quite troublesome in such devices, particularly the miniaturized embodiments thereof, the same being in the nature of an unequal flux density across the several gaps arising from a number of causes including such things as variations in dimension, configuration, and metallurgical and physical properties of the materials in the permanent magnets, pole pieces, and armatures, all of which can cause unequal densities in the gross flux at any of the several gaps G_1, G_2, G_3, G_4 or their counterparts at **28, 29.** This type of imbalance of gross gap flux cannot be effectively corrected by any manipulation of the single-tab form of corrector or adjusting means **40** described in view of FIGS. 1 to 4.

However, the modified tab construction depicted in FIGS. 6 and 6A is capable of manipulation for effecting correction of both kinds of imbalance. In this construction the armature reed **50** has no longitudinal extension but is of normal length, that is, it has no tab **40** of a type projecting longitudinally of the reed beyond the geometric margins of the clamp gaps. Instead, there is provided a thin magnetic shim **51** of preferably rectangular shape and pierced centrally, as at **52**, to pass one of the mounting screws **24** for assembly with the reed at the clamp gap.

The shim **51**, in the assembled condition shown schematically in FIG. 6, is clamped with the reed between a pair of non-magnetic spacers **28W** which in turn are disposed between the upper and lower pole pieces **22, 23** in substantially the same fashion as described for the construction of FIGS. 1 to 3, the shim **51** having opposite sidewise or laterally-projecting tabs **51A, 51B**, which can be bent upwardly or downwardly into various positions of adjustment, such as indicated by dotted lines in FIG. 6.

As in the actual embodiment of FIG. 2, or the schematic diagram of FIG. 4, the so-called *fixed gaps* at **28** of G_1, G_2, are respectively influenced by bending the tabs **51A, 51B** toward the appertaining pole piece (i.e. G_1 upwardly—G_2 downwardly).

The total number of lines of flux the permanent magnets supply the magnetic structure depends on the reluctance of the structure "viewed" from the permanent magnet surfaces. As the reluctance of the structure is raised, the total number of lines of flux supplied by the magnets decreases. This decrease is less than would occur if the magnet had no internal reluctance. This internal magnet reluctance makes it possible to slightly alter the amount of flux through all four gaps, G_1, G_2, G_3, and G_4 even though the reluctance of only one is changed. To be useful in practice this effect needs to be augmented by introducing gaps between the magnets and the structure (**65** in FIG. 5) as hereinafter described. When one or more tabs or the corrector hereinafter described are moved, the reluctance of the total structure viewed from the magnet changes slightly. Since the total structure reluctance and the magnet air gap reluctance are additive, the effect of introducing the latter, which is a fixed quantity, is to minimize the effect of variations in the former. This results in the magnet more nearly supplying a constant number of lines of flux.

In the constructions shown in FIGS. 6 through 8 it will be seen that by properly adjusting the tabs the gross flux through the gaps at both the clamp and working gap ends of the reed can be adjusted. If tab **51B** in FIG. 6 is bent into the dotted position the reluctance R_1 of G_1 is lowered. This increases the flux through the dotted path in FIG. 10 and therefore through G_4. Since the flux available from the pole piece **22** (N in FIG. 10) is limited, this results in diverting some flux from G_3. Bending the tab **51A** downward to the dotted position in FIG. 6 reduces the reluctance of G_2 and increases the flux through G_2. This will tend to increase the flux through G_3. Since the total flux available from the pole piece **22** is limited, the flux through G_1 and G_4 will decrease. By proper adjustment, however, the reluctance relationship

$$R_1/R_2=R_3/R_4$$

can still be met so there is no longitudinal flow of flux through the reed. Flux has, however, been diverted from G_3 and G_4 to G_1 and G_2. This is beneficial when it is desirable to reduce the flux density in the arms of the pole piece near the working gap to avoid magnetic saturation thereof. This effect is important in receivers where the alternating signal flux in the pole pieces becomes an appreciable portion of the steady polarizing flux.

Thus, in FIG. 4, if the tab —T— is bent upwardly, the upper gap G_1 is decreased in reluctance and the flux through it increased and an inverse effect is produced at the complementary working gap—that is, the flux through the gap G_4 at **29** has its flux decreased for the reason that the lowering of the reluctance at upper fixed gap G_1 diverts flux from the reed so that there is then less flux leaving the reed at the other end into the complementary lower working gap G_4. The reluctance is directly proportional to the gap length and inversely proportional to the gap area and the permeability of the material in the gap. If the latter is air the permeability (in the common system of units) is unity. The permeability of non-magnetic materials like brass, copper, aluminum, etc. is also unity. The *reluctance* of a gap is however *independent* of the amount of flux through it. In like manner (referring still to FIG. 4) similar results follow the bending of the tab **40** *downwardly*, that is to say, the reluctance of the lower fixed gap G_2 would be decreased and the flux through it increased, while the apparent reluctance of the complementary upper working gap G_3 would be in effect *increased*, since less flux can traverse the reed longitudinally from gap G_3 toward gap G_2.

Accordingly, as respects longitudinal flux in the reed in a magnetic circuit of the type portrayed in FIG. 4, a modification in the flux in one gap will be reflected in effect in the opposite sense at the complementary gap.

The same principles apply to the laterally-projecting multiple or dual tabs **51A**, **51B** and the appertaining gaps in the shim-type corrector means shown in FIG. 6, with the important difference that, whereas the single tab **40** of FIG. 2 can only be positioned to effect primarily one or the other of the fixed gaps at any given time, the device of FIG. 6 is not so limited but can affect to a marked degree either gap alone or both gaps at the same time. When both tabs **51A**, **51B** are bent in the same direction (i.e. both up or both down) primarily one fixed gap will be affected; but if the two tabs are bent oppositely in the manner indicated in FIG. 6, then both fixed gaps will be affected, and consequently, in accordance with the principles latterly explained, flux in *both* working gaps would likewise be affected, from which it will now be understood that the dual-tab type of reluctance-correcting or adjusting means can be manipulated to affect the flux in all four gaps, by reason of which an imbalance in gross gap flux, as well as longitudinal flux along the armature reed, can be easily and quickly corrected.

In general, it may be observed that the actual armatures or reeds **27** and **50** are preferably fabricated from thin ferromagnetic stock of high permeability and relatively low saturation density (e.g. about 7,000 to 8,000 li./cm.^{2}) in order to have an optimum sensitivity to weak signals; whereas, the metal from which the pole pieces are formed is of lower permeability having, for example, a saturation density of the order of about 14 to 18 thousand li./cm.^{2} for conduction of the relatively strong polarizing flux supplied by magnets **33A**, **33B** and adequate conduction of the weak signal flux.

In view of these latter considerations, the effective control range for a corrector tab which is an integral part of the reed, such as tab **40**, is somewhat limited by the permeability of the stock from which the reed is made, and while this does not detract from the practical utility of this form of adjusting means in a microphone, saturation of the tab limits the adjustment and has been found to introduce distortion in the higher amplitude signals in a receiver. The dual, lateral-tab shim construction of FIGS. 6 and 6A is not subject to such a limitation since the shim **50** can readily be made from different stock having a much higher saturation density and of different thickness and cross-sectional and superficial areas than the reed, with a consequently greater flux-carrying capacity and a correspondingly greater control effect, which is augmented by its previously-mentioned capability of controlling both gross and circulating types of flux imbalance. By making the tab thinner than the reed, it may be more readily bent and will leave no residual strains in the reed to produce subsequent material flow or reed drift. The tabs are preferably made of high-saturation density material so that even if thinner than the reed they can conduct more flux and provide a greater effective control range.

If desired, however, the dual lateral-tab type of corrector **51** may be embodied as an integral part of the reed **50**, in which case the resulting construction would be substantially identical in appearance to the combination shim and reed structure **50–51** depicted in FIG. 6A, assuming the dotted-line representation to be erased.

The mounting of such an integral reed and dual-tab corrector structure is illustrated schematically in FIGS. 7 and 7A wherein it will be observed that this embodiment requires only the use of a pair of non-magnetic spacers **28W** between the reed **55** and the two pole pieces **22**, **23**, the lateral corrector tabs **55A**, **55B** being selectively movable to biased positions, both up or both down, or one up and one down, as required, and as indicated by dotted and dash-dot lines in FIG. 7. In FIG. 7A, the reed **55** is shown in plan view. The bending line of the reed in the fixed gap is along the dotted line **59** and movement of the tabs **55A** and **55B** does not have any appreciable effect on the vibratable end of the reed.

In order to procure the fullest benefit from the shim type of corrector shown in FIG. 7, it is desirable to have one of the two gaps at **28** (corresponding either to G_1 or G_2) initially of somewhat lower reluctance than the other so that the maximum correction or lowering of reluctance at the remaining gap can be effected by bending both tabs **55A**, **55B** in the *same* direction away from the gap of lower reluctance. However, the necessity for this provision may be avoided, and the adjusting capacity of the correction means may be greatly extended, by employing two shims arranged in spaced superposed relation in the manner shown in FIG. 8 wherein a reed **60** of normal length (having no integral adjustment tab or extension) is flanked above and below by magnetic shims **61** and **62** in superposed relation and which are respectively spaced from the adjoining pole pieces **22**, **23** by non-magnetic spacers **28W**.

This arrangement affords such possibilities of adjustment as having all tabs **61A**, **61B**, and **62A**, **62B** bent in the same direction, all up or all down; or having tabs **61A** and **61B** bent toward each other and the remaining tabs otherwise, or having tab **61A** bent upwardly, **62A** downwardly, with **61B** bent upwardly and **62B** bent downwardly, and so-on.

The effectiveness of the versatile adjustments afforded by the use of multiple shims, as in FIG. 8, is quite marked, and in miniaturized constructions of the general class described, the overall performance of the transducers employing the same can be still further improved by making the total flux supplied by the magnets as nearly constant as possible under the limitations imposed by the small size of these units. This is done by decreasing the "length" of the magnets **33A**, **33B** (along their magnetic axes) as illustrated in FIG. 5, wherein each of the magnets **33AX** and **33BX** is shown spaced from the upper pole piece by a shallow air gap **65**. This gap is preferably created by grinding the upper pole faces of each of the two magnets (bearing in mind that the latter are magnetized transversely) to produce a gap the "length" of which desirably may be approximately 5 percent of the "length" of the magnets. To stabilize the assembly mechanically, these gaps **65** are preferably each filled-in by a non-magnetic spacer **66** of brass or the like.

The reluctance introduced by the gaps **65** increases the total reluctance into which the permanent magnets work, and the effect of the foregoing reluctance changes at the gaps, resulting from the adjusting and balancing methods recited, consequently produces little change in the total available flux provided by these magnets.

In FIG. 9 there is shown a further modification of the flux-balancing means in the form of an external magnetic corrector member **70** of high permeability and of approximately Omega-shape in that it has two substantially flat end portions **71**, **72** joined by curved bight or arcuate portion **73**.

This shunt member is adapted to be mounted at the clamp-gap end of the transducer with the concavity of the bight **73** opposite the fixed end of reed **74** of normal (i.e. non-extended) length. Attachment of the member **70** may be effected by spot-welding one of its legs to one of the pole pieces. The stock of which it is made should be thin enough to permit bending and of high permeability.

The operation of the device of FIG. 9 is such that the single corrector **70** will serve to adjust both kinds of gap imbalance at one setting assuming, for example, that gaps G_1 and G_2 or G_3 and G_4 are not identical; that is, by bending the shunt **70** toward or away from the clamp gaps and reed-end, as may be required, both gross flux imbalance at all gaps, and flux traversing the reed longitudinally, will be brought to balance in the sense heretofore explained because, according to this method, the corrector **70** is "external" in that it by-passes flux wholly around (rather than partially through) the clamped end of the reed, and directly from one pole piece **22** to the other pole piece **23**, so that diversion of this flux depends on there being a "drop" along "N" or "S." As in the case of previously-described embodiments, the source of flux in the construction of FIG. 9 is regarded as substantially constant, and for this purpose the special gap means **65** is desirably utilized to assure this condition.

The expressions "bending" and "bendable," as used herein in connection with deflecting relative to a pole piece, are intended to refer to bending by reasonable manual force, with or without the aid of a tool such as the so-called "knifing" tool commonly used for deflecting relay springs, switch blades, and the like.

It is futrher pointed out that the foregoing description, for purposes of brevity and clarity, has preferentially employed the term "reluctance" in most instances where the reciprocal term "permeance" might have been used with equal propriety and due regard to the mathematically reciprocal character of these expressions; and accordingly, no especial limitation is intended by adoption of the term "reluctance" where the term "permeance" can appropriately be substituted; and, moreover, while specific forms of construction have been shown and described in compliance with the patent statutes, the invention is not intended to be limited or restricted thereby except as contemplated by the appended claims.

As pointed out previously, the single integral type of corrector means **40** is limited as to permeability by the required moderate permeability in the reed, although its reluctance-modifying effect can be augmented somewhat by enlargement of its superfical area and any special configuration of shape which changes in size or construction of the transducer might permit. But such a corrector is intended to modify primarily the condition of longitudinal or "circulating" flux imbalance.

The multiple-tab type of correctors, however, being effective to adjust both longitudinal and gross-gap imbalances and being subject to a much higher permeability rating than the reed, may require the provision of a constant-flux means such as the flux-source gaps **65**, it being understood that the latter may be employed if desired in all forms of transducer, whether a receiver, such as illustrated in FIG. 2, or a microphone, such as shown in part of FIG. 11, it being understood that the only difference between these two devices resides in the fact that generally a lower value of D.C. current will be present in the coil **20** in a microphone, and the diaphragm cover plate **15** for the microphone may have a large opening covered by grill fabric **16**, whereas the receiver of FIG. 2 may have a smaller opening fitted into a so-called Thuras tube adapted to fit into the ear.

The foregoing embodiments as specifically described are intended to illustrate, as required by statute, what is presently believed to be the best known method and construction for carrying out the invention, but the invention is not intended to be limited by anything hereinbefore set forth except as may be contemplated by the appended claims, in which:

The invention claimed is:

1. An electromagnetic transducer comprising a magnet, a pole piece flux-conductively engaging each pole of the magnet, said pole pieces extending laterally of the magnet to form a non-magnetic gap therebetween, an elongated, flux-conductive, elastic armature, means clamping one end of said armature in non-magnetic, spaced relationship to the pole pieces in fixed position in said gap so that the other end of said armature may vibrate in another portion of said gap, there being a bending line between the clamped end and the vibratable end of the armature, and a flux-conductive, bendable tab having one end flux-conductively mounted on one pole piece adjacent the clamping means and the other end extending adjacent the other pole piece far varying the reluctance in the air gap between the pole pieces at the fixed end of the armature.

2. An electromagnetic transducer comprising a magnet, a pole piece flux-conductively engaging each pole of the magnet, said pole pieces extending laterally of the magnet to form a non-magnetic gap therebetween, an elongated, flux-conductive, elastic armature, means clamping one end of said armature in non-magnetic, spaced relationship to the pole pieces in fixed position in said gap so that the other end of said armature may vibrate in another portion of said gap, there being a bending line between the clamped end and the vibratable end of the armature, and a bendable tab having a permeability higher than the armature and having one end flux-conductively associated with the armature in the clamping means and the other end extending laterally into said gap for varying the reluctance in the air gap between the pole pieces at the fixed end of the armature.

3. An electromagnetic transducer comprising a magnet, a pole piece flux-conductively engaging each pole of the magnet, said pole pieces extending laterally of the magnet to form a non-magnetic gap therebetween, an elongated, flux-conductive, elastic armature, means clamping one end of said armature in non-magnetic, spaced relationship to the pole pieces in fixed position in said gap so that the other end of said armature may vibrate in another portion of said gap, there being a bending line between the clamped end and the vibratable end of the armature, and an armature projecting beyond its clamp portion on the side opposite to the vibratable end into space adjacent the gap for varying the reluctance in the air gap between the pole pieces at the fixed end of the armature.

4. An electromagnetic transducer comprising a magnet, a pole piece flux-conductively engaging each pole of the magnet, said pole pieces extending laterally of the magnet to form a non-magnetic gap therebetween, an elongated, flux-conductive armature positioned in said gap, a flux-conductive leaf mounted on each side of the same end of the armature with each end of each leaf projecting laterally of the armature into the adjacent portions of the gap, a non-magnetic spacer positioned on each leaf, said spacers, leaves and armature being in a stack clamped between said pole pieces so that the other end of the armature may vibrate in another portion of said gap.

5. The electromagnetic transducer of claim **4** wherein the material of the leaves is not only flux-conductive but readily bendable.

6. The electromagnetic transdacer of claim **4** wherein the material of the leaves has a higher permeability than the material of the armature.

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GEORGE HARRIS, Primary Examiner

U.S. Cl. X.R.

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