Oct. 22, 1929. C. L. FARRAND 1,732,644

TELEPHONIC LOUD SPEAKER

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Fig. 1.

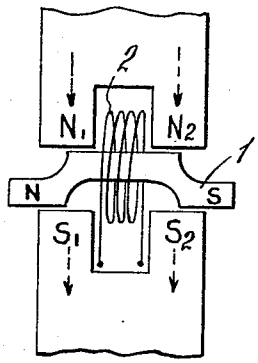


Fig. 2.

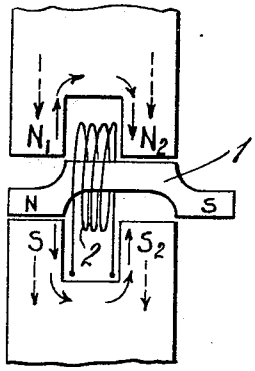


Fig. 3.

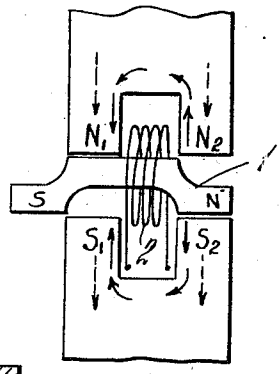


Fig. 4.

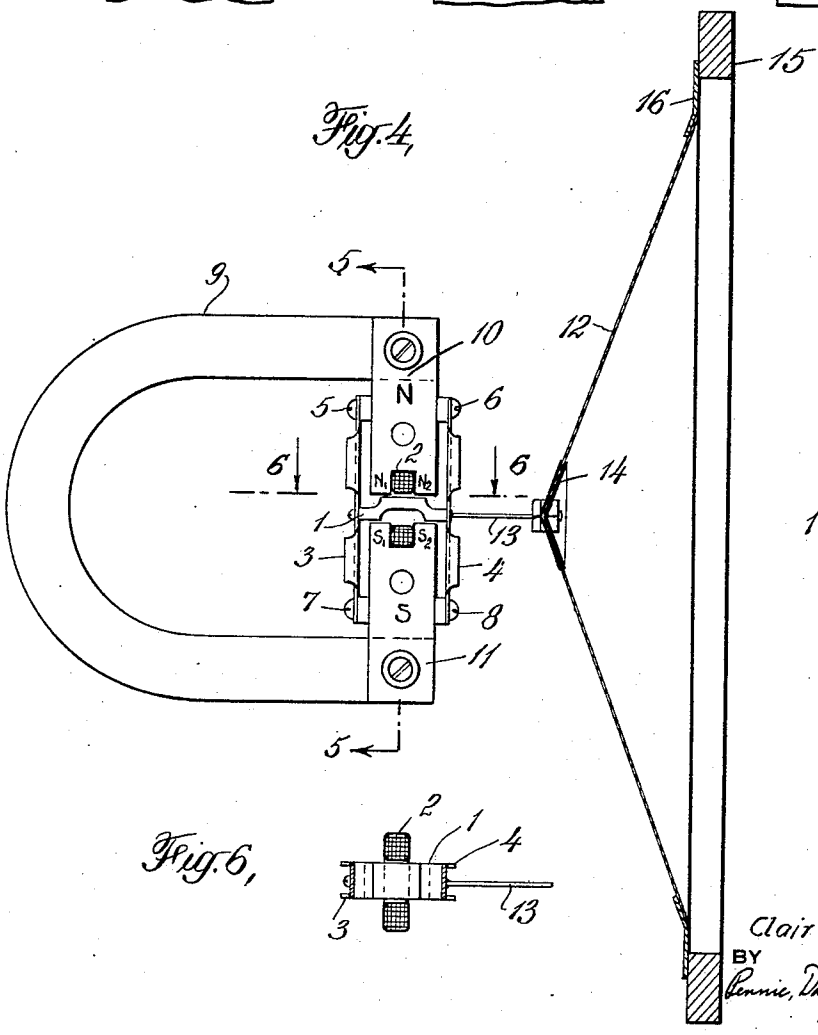


Fig. 5.

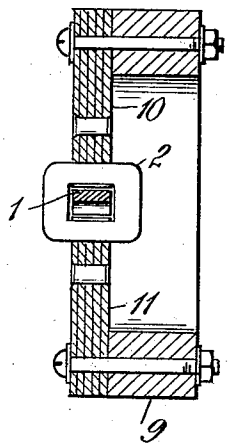


Fig. 6.

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Fig. 8,

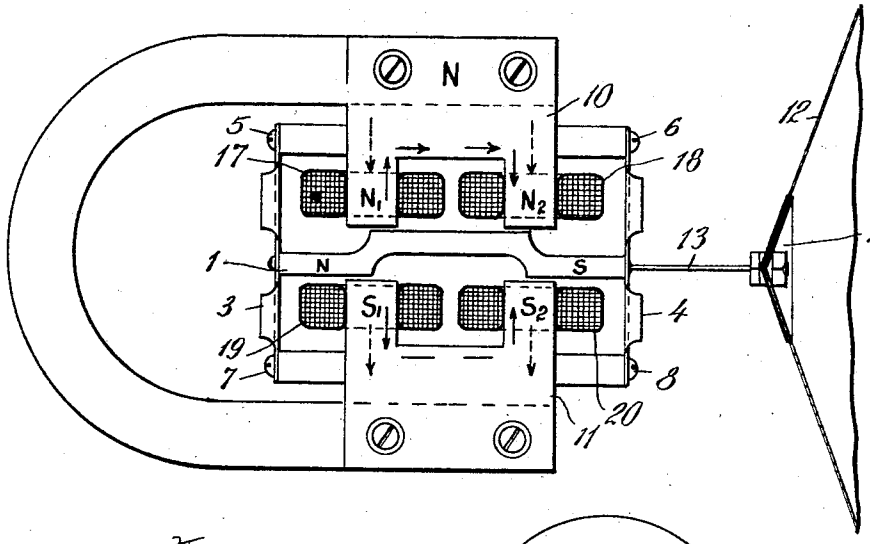


Fig. 7,

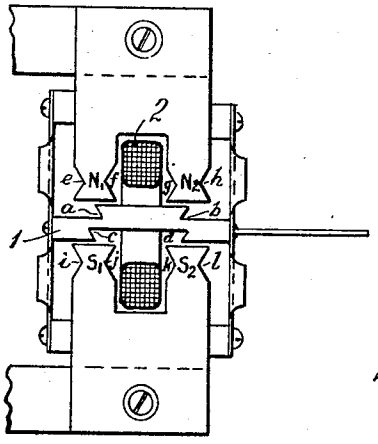
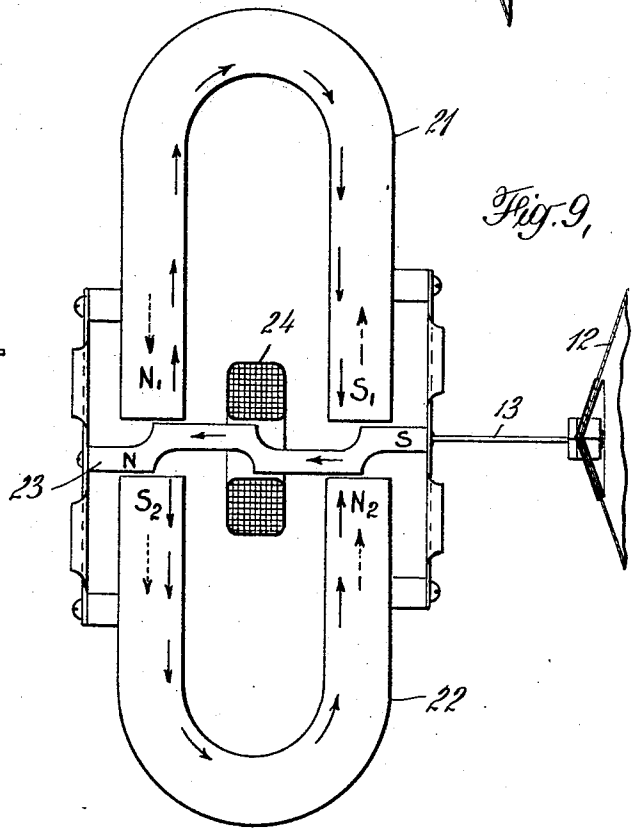


Fig. 9,



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Fig. 10.

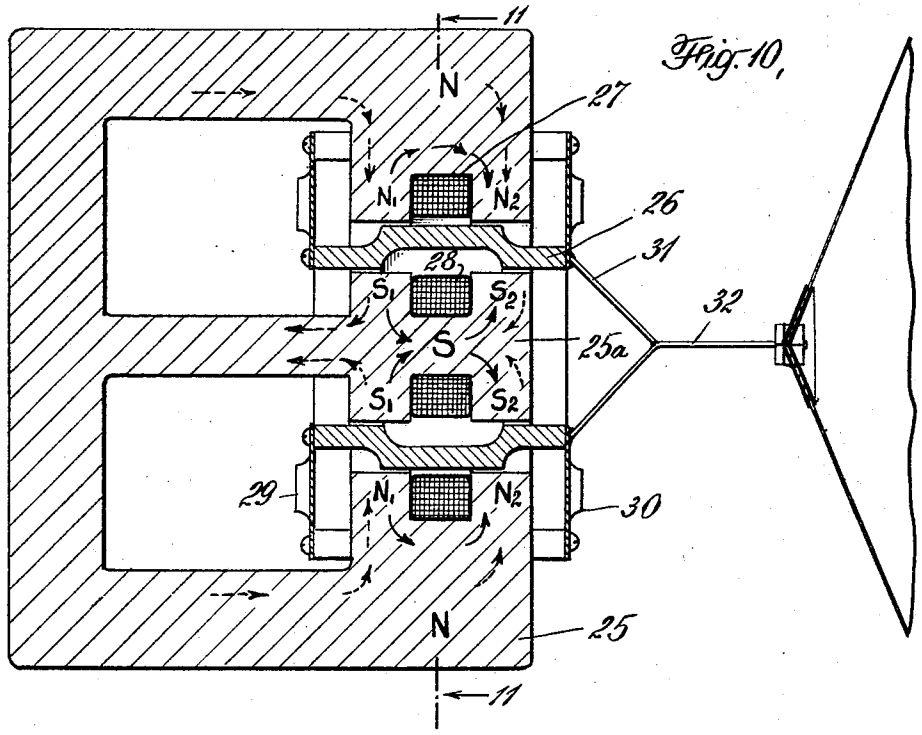
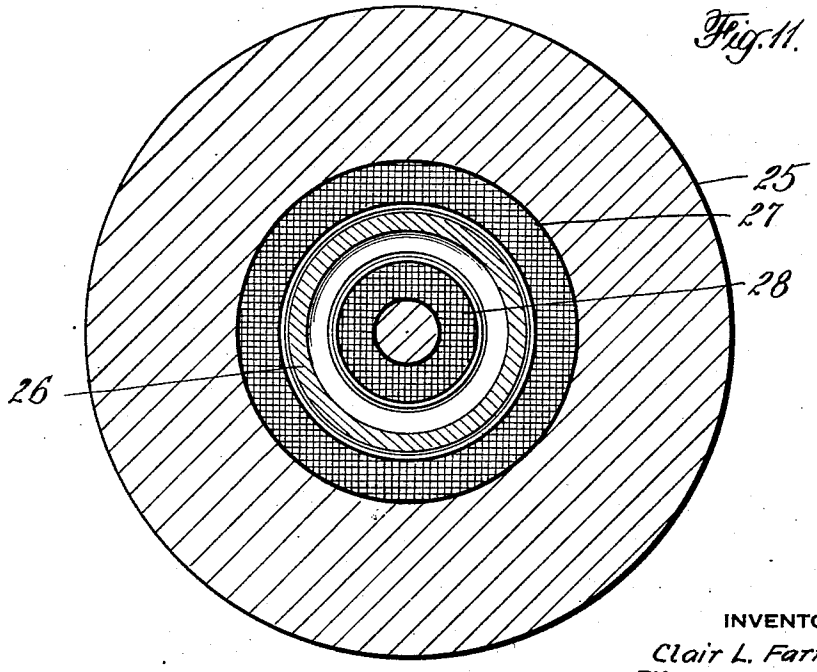


Fig. 11.



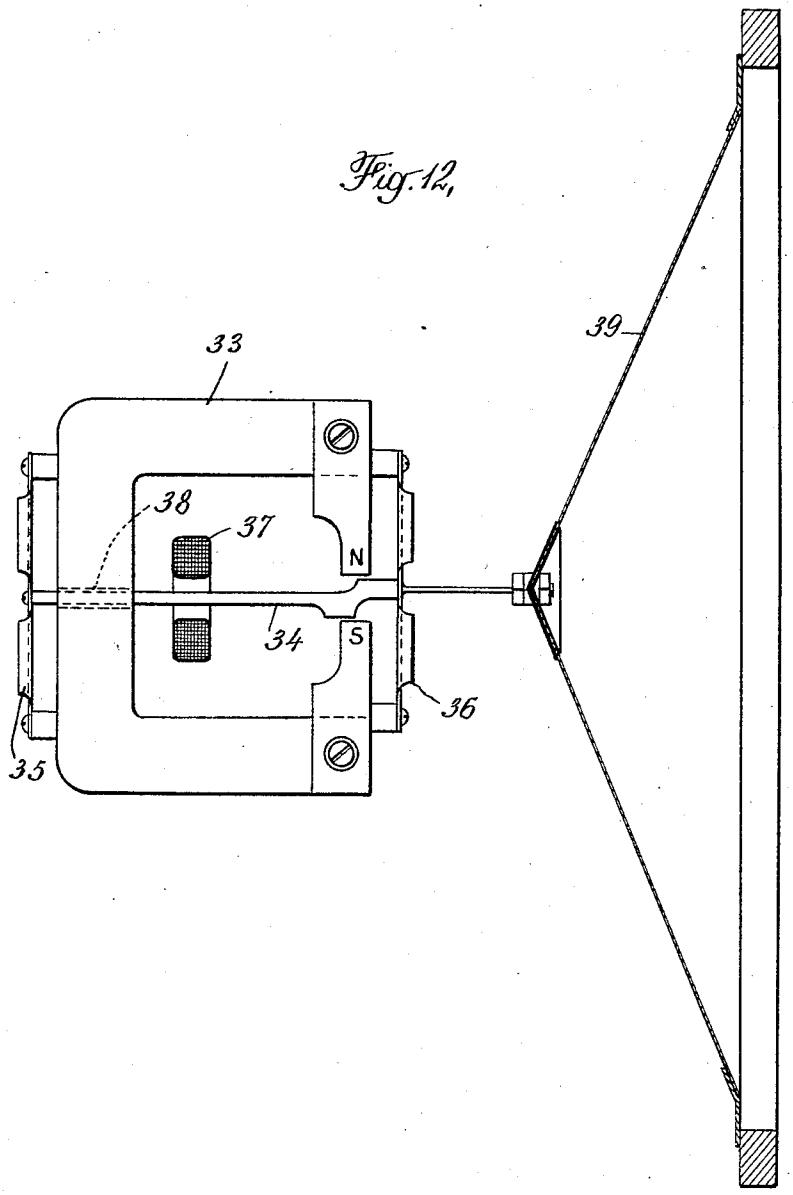
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Fig. 12.



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UNITED STATES PATENT OFFICE

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TELEPHONIC LOUD-SPEAKER

Application filed July 9, 1928. Serial No. 291,234.

This invention relates to loud speaking telephone actuating motors, its objects being to improve the quality of tone reproduction while at the same time attaining high operating efficiency and a structural design susceptible of production at moderate or relatively low cost.

For the purpose of the following discourse, loud speaker actuating motors (considering only those which have met with commercial recognition) may conveniently be classified in two generic categories, namely: those having magnetic armatures adapted to be actuated toward and away from the magnetic pole pieces; and secondly, those in which the actuable element corresponding in function to the aforementioned armature is a movable coil more or less freely suspended in a magnetic field. In the first mentioned class there are two types: First, those in which the vibratory diaphragms are of magnetic material and arranged to be actuated directly as, for example, in the ordinary telephone receiver; and secondly, those in which the diaphragms are indirectly actuated through the media of magnetic armatures pivotally mounted in the magnetic fields and arranged to move toward and away from the magnetic poles. The best known and probably most satisfactory species of the latter type motor is that commonly identified by the appellation "balanced armature type", in which the armature is pivoted at its center and held in mid-position between the magnetic field pole-pieces by means of a centering spring.

Loud speaker actuating motors of the second class, which is to say, those in which the armature comprises a moving coil, are generally denoted as of the "dynamic type."

The foregoing nomenclature will be employed hereinafter to designate the respective types of actuating motors.

In the design of commercial loud speakers there are in general these three cardinal desiderata: tone fidelity, high operating efficiency and structural simplicity. In addition it is not infrequently a prime requisite that the device be very compact—especially when it is to be enclosed, for example, in a radio cabinet or other limited quarters. Moreover, it is often the case that the attainable quality of reproduction in a commercial loud speaker is inexorably restricted by competitive selling prices. These last mentioned factors must be considered as more or less inimical to a realization of the utmost in quality of reproduction; but they are seemingly unavoidable.

To achieve a high degree of tone fidelity a number of controlling factors must be considered. Among these one of the most important is freedom of motion of the moving elements. Otherwise expressed, one of the essential prerequisites to fine tonal quality and a close approach to fidelity of reproduction is that the movable elements including the diaphragm and armature be able to function with a minimum of physical restraint. This means, in the vernacular of those engaged in the development of loud speakers, that inertia and "stiffness" must be minimized. Inertia is due, of course, to the mass of the moving parts and its minimization may be accomplished only by restricting the mass of those parts. "Stiffness" is that quality which results, for example, from the use of a spring for centering the armature or otherwise restraining it or restoring it to its normal position. The use of such a spring is essential in actuating motors of the balanced armature type and the spring used is unavoidably quite vigorous because it must function successfully to keep the armature from striking the pole pieces. Another source of stiffness may consist in the diaphragm not being freely movable.

Irrespective of the underlying origin of physical restraint or impedance operating against the freedom of the movable elements—that is to say whether it is due to inertia or "stiffness" or both—the resultant effect is much the same in that the quality of reproduction is injured—the injury usually being somewhat proportional to the degree to which the movable elements are restrained.

In a balanced armature type motor the armature is pivoted at its center and so arranged that its two end portions oscillate toward and away from the magnetic pole pieces. To prevent the armature striking the pole

pieces and, normally, to keep it properly centered therebetween, it is essential that a rather vigorous restraining spring be employed. This necessarily involves "stiffness" and invariably gives rise to proportionately defective reproduction—especially at the lower frequencies—and in addition a loss of efficiency arising from the necessity of expending energy in working against the spring action.

It is not the purpose of this explanation to disparage motors of the balanced armature type; nor is it intended to imply that the quality of reproduction attainable with a motor of that type is necessarily poor. As a matter of fact, it is possible to attain very pleasing reproduction with a motor of the balanced armature type notwithstanding a very considerable departure from absolute tone fidelity. Furthermore, it is possible under favorable conditions to attain a high degree of operating efficiency with a motor of that type. But quality and efficiency, as applied to loud speaker performance, are relative characteristics; and that which may veritably be said to be good may still be a long way from the attainable height of perfection.

The balanced armature type motor is not only deficient on the score of tone fidelity and relatively inefficient mechanically because of the necessity of employing a stiff centering spring, but is furthermore subject to a very serious practical limitation due to its variable air gap. To realize anything like an approach to high operating efficiency in an electromagnetic device having an armature and air gap, it is essential that the gap be as narrow as practical considerations will permit. On the other hand, to attain satisfactory output volume at the lower audible frequencies it is necessary that the loud speaker diaphragm have imparted to it a very substantial amplitude of vibration at those frequencies. Particularly is this the case with relatively small diaphragms—since the output volume is a function of the air displaced. To attain satisfactory amplitude at the diaphragm with a balanced armature type motor two alternative expedients are available: either the magnetic air gap or gaps may be made relatively wide with a concomitant sacrifice of efficiency; or there may be provided a link and lever mechanism of one form or another for stepping up the amplitude of vibrations in such a way as to impart to the diaphragm a larger amplitude than that of the armature. The latter expedient is most commonly resorted to but is objectionable. This is mainly because of the resonance effects due to the vibratory periods of the links and levers, but also because of the increased complexity of design and cost of production.

From the standpoint of tone fidelity the deficiencies of the balanced armature type motor can be avoided through the use of a motor of the dynamic type in which low inherent "stiffness" and low inertia can be readily attained. With the latter type of motor a very superior quality of reproduction can be realized. But dynamic motors are relatively costly and electrically quite inefficient. It is seemingly essential in a dynamic motor to provide an electrically energized magnetic field because a permanent magnet of tolerable size will not supply sufficient magnetic flux density. This is due to the fact that the size of the movable coil together with the necessary clearances involves a relatively wide gap between the poles of the magnetic field structure and this, in turn, necessitates a large magnetizing force in order to produce adequate operating flux density. It is usually most expedient to arrange for energizing the field of a dynamic type motor from an alternating current source and since the field energizing current must be uni-directional it is necessary to provide a rectifier. These factors obviously result in a comparatively high cost of production, not to mention the added cost of operation due to the field current requirements.

The superior reproduction attainable with dynamic type motors is due largely, if not entirely, to their inherent freedom of motion or what amounts to the same thing—lack of "stiffness" and low mass of moving parts and consequent ability to follow closely the fluctuations of the energizing current.

The present invention provides a loud speaker motor in which the actuated element is an armature of magnetic material yieldably suspended in such a way that it is freely movable substantially in a straight line transversely of the magnetic field air-gaps, the arrangement being such that stiffness is largely avoided while at the same time the armature is adequately restrained against lateral movements. Since the direction of movement of the armature is transverse of the magnetic field air gaps and therefore parallel to the pole faces, the air gap separation between the armature and pole faces is constant or substantially so and may for that reason be as narrow as other practical considerations will permit. The air gap losses are consequently very small by virtue of which fact it is ordinarily unnecessary to provide a powerful field magnet—a permanent magnet of moderate size usually being sufficient.

In the preferred embodiments of the invention there are four magnetic field pole-projections co-operating with the armature; and these are so oriented and the armature so formed that a very high conversion efficiency is realized. By this is meant that the electrical and magnetic forms of energy are

converted efficiently into mechanical motion. Hence, a high ratio of output volume to input energy can be realized, together with very faithful reproduction at all frequencies within the useful audible range—the latter characteristic being due in part to the high conversion efficiency and in part to the very low stiffness and low inertia of which the preferred structures are capable.

Other characteristic features of the invention will be adduced in conjunction with the detailed description of the various embodiments and modifications illustrated in the accompanying drawings, in which:

Figs. 1, 2 and 3 are fragmentary elevational views illustrating the fundamental principles of operation by consecutive steps,

Fig. 4 is an elevational view, partly in section, of one of the preferred embodiments of the invention,

Fig. 5 is a sectional view taken along the line 5—5 of Fig. 4,

Fig. 6 is a sectional view taken along the line 6—6 of Fig. 4,

Fig. 7 illustrates a modification applicable to the structure of Figs. 4, 5 and 6,

Fig. 8 is an elevational view of an alternative form of structure,

Fig. 9 illustrates another alternative structure,

Fig. 10 is a sectional view of an actuating motion having a cylindrical field structure and cylindrical armature,

Fig. 11 is a cross-sectional view along the line 11—11 of Fig. 10, and

Fig. 12 is an elevational view of still another embodiment of the invention.

Figs. 1, 2 and 3 are fragmentary representations of one of the preferred embodiments of the invention, depicting the movements of the armature in three consecutive steps and serving to facilitate the explanation to follow concerning the principles of operation of the invention.

In Fig. 1, the armature 1 is shown in its normal non-actuated position wherein it is yieldably held in suspension (the suspension springs having been omitted in these figures) between the polarized pole-projections marked N_1, N_2, S_1 and S_2—the letter "N" designating the north magnetic pole and "S" the south magnetic pole. The armature 1 is so formed, proportioned and located (as shown) that in its normal non-actuated position it overlaps about one-half the face area of each pole-projection through narrow air gaps. The other surfaces of the armature are offset so as to increase as much as possible the air gap distances between them and the faces of the pole projections. The offset surfaces of the armature are not to be considered when reference is made hereinafter in this specification and the subjoined claims to the over-lap of the armature with respect to the pole projections. It so happens that in the example illustrated, the armature over-laps adjacent face areas of the north pole projections and non-adjacent face areas of the south pole projections but if the polarities were reversed the arrangement would work equally well and in precisely the same manner; so it may be said that it is immaterial which side of the armature is adjacent the north pole projections and which is adjacent the south pole projections.

The armature is made of magnetic material, such as soft iron or silicon steel, and is suspended in such a way (to be described later) that it is free to move bodily in two opposite directions only from its normal non-actuated position (Fig. 1). The two extreme actuated positions of the armature are represented in Figs. 2 and 3, respectively. In the former figure, the armature is shown in its extreme right-hand position as there viewed, while in the latter figure it is shown in its extreme left-hand position. The "maximum amplitude" of the armature—which term may be used hereinafter—is the distance the armature is capable of moving under magnetic actuation from its normal position as shown in Fig. 1 to either side thereof, as illustrated in Figs. 2 and 3, respectively. The "total maximum distance" which the armature may traverse under magnetic actuation is therefore twice its amplitude. The armature is shown surrounded by a coil or winding 2 about its mid-portion, the function of which is to actuate the armature in accordance with sound waves to be reproduced. Fluctuating currents corresponding to the sound waves to be reproduced are impressed upon coil 2 and the armature is magnetized in alternate directions in conformity to the direction, intensity and frequency of the impressed voltages.

In each of the Figures 1, 2 and 3, there is represented by dotted arrows an uni-directional magnetic flux having its origin in any suitable source, such as a permanent field magnet or electro-magnet—depending usually upon the intensity of magnetization required and other practical considerations of no immediate moment.

In Fig. 2, there are represented the magnetic changes and concomitant armature displacement resulting from an energization of coil 2 in such a direction as to set up a magnetic flux rendering the left-hand end of the armature of north polarity as indicated by the letter "N" on the armature. The paths of the flux engendered by coil 2 are indicated by full line arrows. It will be seen that there is superinduced in pole projections N_1 and S_2 magnetic lines of force in opposition to the normal magnetic lines of force represented by the dotted arrows, whereas in pole projections N_2 and S_2, there are similarly superinduced magnetic lines of force having the same direction as the normal magnetic lines of force therein. It is therefore manifest that the flux

density in pole projections N_2 and S_1 is momentarily increased, whereas it is concurrently decreased in pole projections N_1 and S_2. As a result of this magnetic force variation, the armature moves towards the position indicated in Fig. 2; and the amplitude of its movement depends upon the intensity and duration of the applied force as will be readily apparent. This movement of the armature results in a decrease of reluctance of the flux path through the armature from pole projection N_2 to pole projection S_1, which pole projections are of opposite polarity and non-contraposed in their space relation. The reluctances of the paths through the armature between pole-projections of like polarity remain constant or substantially so irrespective of the position of the armature. Likewise the magnetic paths transversely of the armature between contraposed pole-projections of unlike polarity are of constant or substantially constant reluctance. This is because the sum of the air gap areas included in each of the respective magnetic paths is a constant or substantially constant quantity. These are characterizations which warrant particular notice because they constitute important and generic distinctions which are utilized to define the invention in the subjoined claims.

Another characterization which it is thought worth while to call special attention to at this point is that the poles N_2 and S_1 in Fig. 2 are diagonally opposite. For the purpose of this specification the expression "diagonally opposite" as applied to the orientation of the pole projections is to be considered as a species of the more generic expression "non-contraposed". The reason for this distinction will become more apparent as the description progresses.

The magnetic phenomenon occurring when the coil 2 is energized by current of opposite direction as compared to the assumed current direction of Fig. 2 is indicated in Fig. 3. From what has already been said with respect to Figs. 1 and 2, the magnetic changes depicted in Fig. 3 should be clear without further discussion. Likewise, the reason for the movement of the armature to the left-hand position, as indicated in Fig. 3, should be equally evident.

It is to be noted in passing that whenever the actuating coil 2 is being energized, there is an increasing diagonal flux path through the armature between one pair of diagonally opposite pole-projections of opposite polarity and at the same time a decreasing diagonal flux path between the remaining two diagonally opposite pole-projections. By the expression "diagonal" it is the intent to convey the idea of the flux traveling from a pole projection at one side of the armature, thence lengthwise of the armature to a pole projection at the other side thereof. The essential factor is that the flux travels lengthwise of the armature, which is to say in the direction of its movement and, while in the preferred embodiments of the invention it also travels diagonally as described, it will be shown in conjunction with the description of Fig. 9 hereinafter that the latter characteristic is not an unexceptionable requisite.

Having explained the principles of operation as applied to a form of structure representative in a general way of the preferred embodiment of the invention, there will now be described a more complete loud speaker assemblage incorporating those principles, after which some modified forms of structure will be described and their several relationships pointed out in such a way as to make it clear that all the arrangements described are generically similar and within the scope of the one inventive idea.

Figs. 4, 5 and 6 depict a loud speaker structure of practicable form characterized by simplicity of design, economy of manufacture and the ability to operate efficiently and reproduce with a high degree of fidelity. This structure does not include certain refinements which are not regarded as strictly essential and which will be described later in conjunction with Fig. 7 of the drawings; but otherwise it may be said to represent the preferred embodiment of the invention.

In Figs. 4, 5 and 6, the armature is designated by reference numeral 1, and the actuating coil by numeral 2, as in the preceding figures.

In Fig. 4 the actuating coil 2 is shown in cross-section in order to more clearly expose the armature. A cross-section of the armature and longitudinal section of the pole pieces are shown in Fig. 5. A plan view of the armature and cross-section of the suspension springs 3 and 4 are shown in Fig. 6, together with a cross-sectional view of the actuating coil.

The armature is shown in its normal non-actuated position held in suspension between the pole projections by a pair of leaf springs 3 and 4, secured at their ends by means of screws 5, 6, 7 and 8. Springs 3 and 4 are preferably formed as shown, with stiffening flanges which are cut away at the ends and mid-portions to permit the springs to flex freely. The purpose of the flanges is to prevent the springs vibrating independently and audibly. They can be damped in other known ways. These springs are made of quite thin metal—preferably duralumin—and while serving adequately to restrain the armature against lateral movement they nevertheless offer little impedance or stiffness to movements of the armature in the directions in which it is intended to move, that is, lengthwise. It is evident on its face that these springs would not permit of a large

amplitude of movement but within the limits of the amplitude requirements for ordinary loud speaker purposes, they offer very little restraint to the action of the armature. The attainable amplitude without the imposition of undue restraint upon the movements of the armature is manifestly a function of the length of the springs.

The magnetic field structure in this example comprises a permanent magnet 9 of the "horse-shoe" type and laminated pole pieces 10 and 11, respectively. The contraposed ends of the pole pieces are each bifurcated thereby forming the pole projections N_1, N_2 and S_1, S_2—the actuating coil 2 being seated in the recesses formed in bifurcating the pole pieces.

A vibratory diaphragm 12 of the floating conical type is directly connected to the armature through the medium of a connecting pin 13,—there being a metal fitting 14 attached to the apex of the cone to facilitate the connection. The diaphragm is shown mounted on a baffle board 15 through the medium of a flexible rim 16 preferably of kid-skin.

In any telephonic reproducer, the output volume is a function of the area and amplitude of the diaphragm, or in other words, of the volume of air displaced. Conversely, the predetermined maximum amplitude of vibration in designing a loud speaker is a quantity which is dependent upon the area of the diaphragm and the desired volume at the lowest audible frequencies. Experience has indicated that with a conical diaphragm of moderate size, say 8 inches diameter, a maximum amplitude of .030 inch will produce satisfactory output volume for all ordinary purposes. For smaller diaphragms and equal output volume the amplitude must, of course, be greater; and with larger diaphragms it may be smaller. An amplitude of .030 inch means that the armature moves a total maximum distance of .060 inch in traveling from one extreme position to the other.

It should now be quite evident that the width of the pole projections in the direction of the movement of the armature is a matter of importance. They should be about equal in width to the maximum stroke of the armature, that is, twice the maximum amplitude. Any excess width of pole projection tends to produce superfluous amplitude and magnetic losses while insufficient width reduces the amplitude of armature movement. The theoretically correct pole projection width is a dimension equal to twice the calculated maximum amplitude of vibration which, for the amplitude postulated above, would be .060 inch. This dimension is equal, approximately, to one-sixteenth inch—the latter being regarded as a convenient and satisfactory dimension for the width of the pole projections.

In Fig. 7 there is illustrated a modification applicable to the structure of Figs. 4, 5 and 6. This figure is a fragmentary elevational view corresponding in part to Fig. 4. The armature 1 as well as the pole-projections (Fig. 7) are shown angularly relieved at certain critical points for the purpose of reducing magnetic fringe losses. Any magnetic flux passing between a pole-projection and the armature without producing a proportional component of force tending to move the armature in the proper direction represents, quite obviously, a loss. Therefore it is desirable to restrict as much as possible the flux leakage from the sides of the pole-projections and likewise to and from those surfaces of the armature which are not intended to be acted upon by the attraction and repulsion of the pole-projections. The armature accordingly is shown relieved at the points *a*, *b*, *c* and *d*, while the pole-projections are correspondingly relieved at the points *e*, *f*, *g*, *h*, *i*, *j*, *k* and *l*. By so doing the magnetic paths extraneous to the narrow air gaps may be substantially attenuated and the losses proportionately reduced.

It is preferable in building the structure of Figs. 4, 5 and 6 to incorporate the modification of Fig. 7 and it is believed that the advantage accruing fully justifies any slight added cost that may be involved in the arrangement of Fig. 7 as compared to that of Figs. 4, 5 and 6.

Fig. 8 is an elevational view, partially in cross section, portraying an alternative structure similar in principle to that of Figs. 4, 5 and 6 but differing therefrom in the disposition of the actuating coils. In Fig. 8 there are four actuating coils shown instead of the one in the structure of Figs. 4, 5 and 6. These coils are designated respectively by reference numerals 17, 18, 19 and 20. The latter coils are each wound about one of the pole-projections and are so connected as to superinduce magnetizing forces of the same character as those indicated in Figs. 2 and 3. These superinduced forces operate additively and subtractively in exactly the same way as previously described, and there is apparently no essential distinction in the two structures aside from the number and disposition of the actuating coils and the fact that the armature is slightly more accessible.

Fig. 9 has been included with a view to portraying a variant form of structure which is quite markedly different from the preferred embodiments hereinbefore described but which, nevertheless, comes within the scope and embrace of the inventive idea. In this case the field structure comprises two permament magnets 21 and 22 of the horse-shoe type. The pole pieces are not bifurcated as in the previously described structures, but there are, nevertheless, four pole-projections. These are marked N_1, N_2, S_1 and S_2. It will

be noted first that the two pole-projections adjacent the same side of the armature in each instance are of opposite polarity, whereas in the previously described structures they are of like polarity. On this account it is necessary that the armature be of different form than in either of the previous structures. The armature in its normal non-actuated position, as shown, overlaps through a narrow air-gap the inward half-portion of one pole-projection and the outward half-portion of the other pole-projection adjacent to each side of the armature. Now there will be noted a point in common between the structure of Fig. 9 and that of Fig. 4, which is that the armature overlaps corresponding fractional face areas of pole-projections of like polarity. More concretely expressed, the armature in this case overlaps the inward half of the face area of each of the two north-pole projections and the outward half of the face areas of the two south-pole projections. The same is true of the structure of Fig. 4.

In operation there is a close analogy or similarity between the structure of Fig. 9 and that of Fig. 4. It is to be assumed that the actuating coil 24 surrounding the armature 23 is momentarily energized in such a direction as to magnetize the armature so as to render it of north polarity at the left-hand end—this being indicated by the letter "N" inscribed on the armature. The dotted line arrows indicate the constant uni-directional flux of the permanent magnets, while the full line arrows indicate the momentary flux engendered by the current in the actuating coil. It will be seen that the permanent flux in the pole-projections N_1 and S_1 is opposed by the momentary flux set up by the actuating coil, whereas the permanent flux in the pole-projections S_2 and N_2 is at the same time aided by the momentary flux. Hence there is an increase of magnetic flux passing longitudinally through the armature from pole-projection N_2 to pole-projection S_2, and this increase of flux operates to propel the armature toward the right, causing the overlap of the armature with respect to the pole-projections S_2 and N_2 to increase.

At this point there may be pointed out an important generic distinction characterizing alike the structure of Fig. 9 and that of Fig. 4, which is to the effect that the reluctance of the flux paths between non-contraposed pole-projections increases and decreases in response to movements of the armature. In other words, in Fig. 9 the pole-projections S_2 and N_2 are non-contraposed and of opposite polarity. Likewise the pole-projections N_1 and S_1 are non-contraposed and of opposite polarity. In Fig. 4 the pole-projections N_1 and S_2 are non-contraposed and of opposite polarity. These, however, may be said to be diagonally opposite in space relation. The same is true of the relationship between the pole-projections N_2 and S_1, Fig. 4. It should now be clear that the expression "diagonally opposite pole-projections" is, for the purpose of this specification, a species within the embrace of the more generic expression "non-contraposed pole-projections."

In the structure of Fig. 9 the magnetic paths through the armature between contraposed pole-projections and between pole-projections of like polarity are of constant reluctance or substantially so. These are characteristics common to all the structures described. On the other hand there are these differences to be noted: In the structure of Fig. 9 the paths between diagonally opposite pole-projections are of constant reluctance or substantially so, while the reluctances of the paths between pole-projections at the same side of the armature are variable. In the other structures the opposite holds true. It is quite apparent on its face that the structure of Fig. 9, is in principle, closely akin to the others and may be defined in the same terms.

The structure of Fig. 9 has been included in this application with a view to emphasizing the fact that the invention is susceptible of a considerable range of variation and modification. This structure, while not regarded as one of the preferred embodiments, is, nevertheless, entirely operative and capable of rendering very satisfactory results. It has, however, some deficiencies when compared to the structures previously described. In the first place, it involves two permanent magnets, and secondly, an armature of greater irregularity than those previously described. The magnetic circuit paths of the actuating coil are necessarily longer than in the preceding structures unless the permanent magnets are made very small, which would probably not be desirable. Finally, the arrangement of Fig. 9 is not quite as well adapted to be molded into a compact and simple structure as are the previously described arrangements.

Figs. 10 and 11 are longitudinal sections and end views, respectively, of a rather distinctively different form of structure involving the same principles as previously described but in which the field magnet and armature are cylindrical in form instead of being in the form of bars. The field magnet 25 is cylindrical in form, and has an axial projection 25^a forming one of the pole pieces, while the other pole piece is constituted by the inwardly projecting peripheral portion of the cylindrical field element. Both of the portions which are marked N and S, respectively, are bifurcated, thereby forming angular pole-projections N_1, N_2, S_1 and S_2. The armature 26 is cylindrical in form, being disposed in the air gaps between the pole-projec-

tions, and has a longitudinal section similar to that shown in Fig. 4. The actuating coils 27 and 28 are seated in the recesses between the pole-projections as shown. In Fig. 10 the direction of the permanent flux is indicated by the dotted arrows, while the momentary flux engendered by the actuating coils when the current is flowing one way is indicated by the full line arrows. From a consideration of the essential relative flux directions as indicated by the arrows in Fig. 10, it becomes at once apparent that the actuating coils 27 and 28 must be arranged so that the current therein at any instant flows in opposite directions, otherwise the magnetic fluxes set up by the two coils would tend to cancel each other. That being the case, there would be little or no response. The armature is supported on suitable suspension springs 29 and 30, and is connected through a suitable spider 31 and actuating pin 32 to a diaphragm like that shown in Fig. 4.

Fig. 12 shows another variant form which the invention may take. In this case there are only two pole-projections, "N" and "S" respectively—these being the poles of the permanent field magnet 33. The armature 34 is suspended in the air-gap in leaf springs 35 and 36 and is so formed as to over-lap, in its normal non-actuated position, as shown, one-half the face area of each pole-projection. The armature passes through an aperture 38 in the magnet 33. The arrangement is such that when the coil 37 is energized in one direction the armature is attracted by the pole-projection "N" and repelled by pole-projection "S"—the reverse effect occurring when the coil is energized by current flowing in the opposite direction. The armature is shown connected to a diaphragm 39 as in the preceding structures.

There are numerous additional modifications and variant forms of structure within the embrace of the present inventive idea, but those illustrated and described are sufficiently representative examples to indicate to those skilled in the art the many practicable forms in which the invention may be embodied.

What is claimed is:

1. In a telephonic loud-speaker, an armature of magnetic material yieldably suspended so as to be oscillatorily movable bodily in two opposite directions only from its normal non-actuated position, a magnetic field structure including a source of uni-directional magnetic flux, a plurality of pole-projections forming a part of said field structure, said pole-projections being disposed laterally adjacent to said armature, a winding for actuating said armature in accordance with sound waves to be reproduced, said winding having a magnetic circuit including said armature and said pole-projections, the arrangement being such that when said winding is energized in one direction there is effected an increased flux density in two non-contraposed ones of said pole-projections which phenomenon is accompanied by a movement of said armature toward a position in which the reluctance of the magnetic path between said non-contraposed pole-projections and through said armature is reduced to a minimum, the opposite phenomenon and resultant effect occurring when said winding is energized in the opposite direction, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

2. In a telephonic loud-speaker, an armature of magnetic material yieldably suspended so as to be oscillatorily movable bodily in two opposite directions only from its normal non-actuated position, a magnetic field structure including a source of uni-directional magnetic flux and a plurality of magnetic pole-projections disposed laterally adjacent said armature, a coil structure for actuating said armature in accordance with sound waves to be reproduced, said coil structure having a magnetic circuit including said armature and said pole-projections and so arranged as to cause an increase of flux density in at least two non-contraposed ones of said pole-projections when current flows in a given direction through said coil structure and a decrease of flux density in the remaining pole-projections, said armature being so formed, proportioned and located with respect to said pole-projections that it will be moved in one direction, thereby decreasing the reluctance of the magnetic flux path therethrough between the non-contraposed pole-projections in which the flux density is increased, the opposite phenomenon and effect occurring when said coil structure is energized with current of opposite direction, the movements of said armature being in conformity as to amplitude and frequency with the fluctuating current impressed upon said coil structure, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

3. In a telephonic loud-speaker, an armature of magnetic material yieldably suspended so as to be oscillatorily movable bodily in two opposite directions only from its normal non-actuated position, a magnetic field structure including a source of uni-directional magnetic flux and four pole-projections disposed laterally adjacent to said armature, two of said pole-projections being disposed at one side of said armature and the other two at another side thereof, two of said pole-projections being of one polarity and two of another, said armature being so formed and proportioned that, in its normal non-actuated position, it overlaps fractional face areas of said pole-projections through narrow air-gaps, the arrangement being such that when said armature is moved in one of its two directions of movement the aforementioned over-

lap with respect to two of said pole-projections of opposite polarity will increase, said last-mentioned pole-projections being non-contraposed in their space relation, the overlap with respect to the other two pole-projections decreasing, the reverse effect occurring when said armature is moved in the opposite direction, a coil structure for actuating said armature, said coil structure having a magnetic circuit including said armature and said pole-projections and so arranged that when energized by current flowing in one direction therethrough two of said pole-projections of opposite polarity and non-contraposed in space will have superinduced in them magnetic lines of force of the same direction as those normally therein while the other two pole-projections will have superinduced in them magnetic lines of force in opposition to those normally therein, said armature being attractively propelled by the two pole-projections in which the magnetic forces are additive, whereby the reluctance of the magnetic path between said last-mentioned pole-projections and through said armature is decreased, said magnetic path being diagonal of the oscillatory path of movement of said armature, the reverse effect occurring when said coil structure is energized by current flowing therethrough in the opposite direction, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

4. In a telephonic loud-speaker, an armature of magnetic material yieldably suspended so as to be oscillatorily movable bodily in two opposite directions only from its normal non-actuated position, a magnetic field structure including a source of uni-directional magnetic flux, a plurality of pole-projections forming a part of said field structure two of said pole-projections being of the same magnetic polarity and disposed in spaced-apart relation adjacent to one side of said armature, at least one additional pole-projection of the opposite polarity being disposed laterally adjacent to another side of said armature, said armature, in its normal non-actuated position overlapping corresponding fractional face areas of two of said pole-projections at one side thereof, a winding for magnetically energizing said armature in alternate directions in accordance with sound waves to be reproduced, said winding having a magnetic circuit including said armature and said pole-projections the arrangement being such that when said winding is energized by current flowing through it in one direction there results an increase in magnetic flux in two of said pole-projections of opposite polarity and diagonally opposite in space, said increase in flux passing lengthwise through said armature, said armature being thereupon caused to move lengthwise to a position wherein the reluctance of the flux path between said diagonally opposite pole-projections and through said armature is decreased, the opposite effect occurring when said winding is energized by current flowing therethrough in the opposite direction, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

5. In a telephonic loud-speaker, an armature of magnetic material yieldably suspended so as to be oscillatorily movable bodily in two opposite directions only from its normal non-actuated position, a magnetic field structure including a source of uni-directional magnetic flux and a plurality of magnetic pole-projections disposed laterally adjacent said armature there being at least two of said pole-projections adjacent to each of at least two sides of said armature, a plurality of said pole-projections being of one magnetic polarity and the remaining ones of said pole-projections being of the opposite magnetic polarity, said armature being so formed, proportioned and located that, in its normal non-actuated position it overlaps adjacent fractional face areas of the said pole-projections of one magnetic polarity and non-adjacent fractional face areas of the said pole-projections of the opposite magnetic polarity, an actuating coil structure for magnetically energizing said armature in accordance with sound waves to be reproduced, said coil structure having a magnetic circuit including said armature and said pole-projections the arrangement being such that when said coil structure is energized by current flowing in one direction a magnetic flux is superinduced in said pole-projections and said armature, the flux thus superinduced being at any given instant in opposition to the normal flux in certain of said pole-projections and in aiding relation to the normal flux in the others of said pole-projections so that whenever the current increases in said coil structure there is an increasing magnetic flux passing lengthwise of said armature between non-contraposed ones of said pole-projections whereby said armature is caused to be moved lengthwise to a position wherein the reluctance of the magnetic path between said non-contraposed pole-projections and through said armature is decreased, the opposite effect occurring when said coil structure is energized by current flowing in the opposite direction, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

6. In a telephonic loud-speaker, an armature of magnetic material yieldably suspended so as to be oscillatorily movable bodily in two opposite directions only from its normal non-actuated position, a magnetic field structure including a source of uni-directional magnetic flux and four pole-projections disposed laterally adjacent to said

armature, two of said pole-projections being of like magnetic polarity and disposed in spaced-apart relation at one side of said armature the other two of said pole-projections being of opposite magnetic polarity and disposed at another side of said armature in spaced-apart relation, said armature being so formed, proportioned and located that, in its normal non-actuated position, it overlaps adjacent fractional face areas of the said pole-projections at one side thereof and non-adjacent fractional face areas of the pole-projections at the other side thereof, the arrangement being such that when said armature is moved in one of its two directions of movement from its normal position the aforementioned overlap with respect to two of said pole-projections of opposite polarity will increase said last mentioned pole-projections being non-contraposed in their spaced relation, the overlap with respect to the other two pole-projections concurrently decreasing, the reverse effect occurring when said armature is moved in the opposite direction, a coil structure for actuating said armature, said coil structure having a magnetic circuit including said armature and said pole-projections and so arranged that when energized by current flowing in one direction therethrough two of said pole-projections of opposite polarity and non-contraposed in space will have superinduced in them magnetic lines of force of the same direction as those normally therein while the other two pole-projections will have superinduced in them magnetic lines of force in opposition to those normally therein, said armature being attractively propelled by the two pole-projections in which the magnetic forces are additive, whereby the reluctance of the magnetic path between said last mentioned pole-projections and through said armature is decreased, said magnetic path being diagonal of the oscillatory path of movement of said armature, the reverse effect occurring when said coil structure is energized by current flowing therethrough in the opposite direction, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

7. In a telephonic loud-speaker, an armature of magnetic material yieldably suspended so as to be oscillatorily movable bodily in two opposite directions only from its normal non-actuated position, a magnetic field structure including a source of uni-directional magnetic flux and a pair of bifurcated pole pieces in contraposed relation, said armature being interposed between said pole pieces and movable transversely of the magnetic air gaps therebetween, each of said pole pieces comprising two pole-projections which are formed by virtue of its bifurcation, an actuating coil for said armature seated in the recesses formed by the bifurcation of said pole pieces, said armature being so formed, proportioned and located that, in its normal non-actuated position, it overlaps adjacent fractional face areas of the pole-projections at one side thereof and non-adjacent fractional face areas of the pole-projections at the opposite side thereof, said actuating coil having a magnetic circuit including said armature and said pole-projections the arrangement being such that, in response to electrical energization of said coil in one direction, the magnetic flux in two of said pole-projections of opposite polarity and non-contraposed in space is supplemented, whereupon and whereby said armature is moved to a position wherein it overlaps a larger portion of the face area of each of said last mentioned pole-projections, the reverse effect occurring when said actuating coil is energized by current flowing therethrough in the opposite direction, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

8. In a telephonic loud-speaker, an armature of magnetic material, a magnetic field structure including a source of uni-directional magnetic flux and a pair of bifurcated pole pieces, said armature being interposed between said pole pieces and yieldably suspended so as to be oscillatorily movable bodily in two opposite directions only from its normal non-actuated position and transversely to the air gap between said pole pieces, an actuating coil surrounding said armature and seated in the recesses formed by the bifurcation of said pole pieces, said armature being so formed that its mid-portion only is closely adjacent to the pole-piece faces at one side thereof while its end portions only are closely adjacent to the pole-piece faces at the other side thereof, said armature in its normal non-actuated position, overlapping in a lengthwise direction about one half the width of each pole-projection formed by the bifurcation of said pole-pieces the arrangement being such that when said armature is moved in one direction from its normal position the overlap thereof with respect to two diagonally opposite ones of said pole-projections increases while the overlap thereof with respect to the other two diagonally opposite ones of said pole-projections concurrently decreases, the reverse effect occurring when said armature is moved in the opposite direction from its normal position, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

9. In a telephonic loud-speaker, a magnetic field structure including a source of uni-directional magnetic flux and a system of magnetic pole-projections arranged on either side of an air-gap so that each is contraposed to another of opposite polarity, an armature of magnetic material yieldably suspended in said air-gap and interposed between the faces

of said pole-projections, said armature being oscillatorily movable bodily transversely of said air-gap substantially in a straight line and in two opposite directions only from its normal non-actuated position, said armature being formed with laterally projecting portions having surfaces which overlap fractional face areas of each of said pole-projections when said armature is in its normal non-actuated position, the arrangement being such that, when said armature moves lengthwise in either direction from its normal position, the overlap of the armature with respect to the faces of at least two of said pole-projections of unlike polarity increases while the overlap with respect to the faces of at least two other of said pole-projections of unlike polarity decreases, the arrangement furthermore being such that the reluctances of the magnetic paths between the faces of contraposed pole-projections and through said armature are substantially constant irrespective of the movements of said armature, means for magnetically energizing said armature in accordance with sound waves to be reproduced, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

10. In a telephonic loud-speaker, a magnetic field structure including a source of unidirectional magnetic flux, and a system of magnetic pole-projections arranged on either side of an air-gap so that each is contraposed to another of opposite polarity, an armature of magnetic material yieldably suspended in said air-gap and interposed between the faces of said pole-projections, said armature being oscillatorily movable bodily transversely of said air-gap substantially in a straight line and in two opposite directions only from its normal non-actuated position, said armature having a plurality of surfaces parallel to the direction of movement thereof, said surfaces (when said armature is in its normal non-actuated position) overlapping about one-half the face of each of said pole-projections, at least two of said pole-projection faces being overlapped inwardly and at least two outwardly, the magnetic paths across the air-gap between contraposed pole-projections being of substantially constant reluctance irrespective of the position of said armature, an actuating coil system for magnetically energizing said armature in accordance with sound waves to be reproduced, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

11. In a telephonic loud-speaker, a magnetic field structure including a source of uni-directional magnetic flux, and a system of magnetic pole-projections arrayed on either side of an air-gap so that each is contraposed to another of opposite polarity, an armature of magnetic material yieldably suspended in said air-gap and interposed between the faces of said pole-projections, said armature being oscillatorily movable bodily transversely of said air-gap substantially in a straight line and in two opposite directions only from its normal non-actuated position, the mid-portion of said armature being laterally offset with respect to its end portions, said mid-portion overlapping adjacent fractional face areas of two of said pole-projections, said end-portions overlapping non-adjacent fractional face areas of another two of said pole-projections, an actuating coil system for magnetically energizing said armature in accordance with sound waves to be reproduced and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

12. In a telephonic loud-speaker, a magnetic field structure comprising a permanent magnet and a pair of bifurcated pole-pieces, each including a pair of pole-projections formed as a result of the bifurcation of the pole pieces, each of said pole-projections being contraposed to another of opposite polarity, there being an air-gap interposed between, an armature of magnetic material yieldably suspended in said air-gaps and interposed between the faces of said contraposed pole-projections; said armature being oscillatorily movable bodily transversely of said air-gaps substantially in a straight line and in two opposite directions only from its normal non-actuated position, the mid-portion of said armature being laterally offset with respect to its end portions, said mid-portion overlapping adjacent fractional face areas of two of said pole-projections of like polarity, said end portions overlapping non-adjacent face areas of the pole-projections of opposite polarity, an actuating coil system having a magnetic circuit including said armature and said pole-projections, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

13. In a telephonic loud-speaker, a magnetic field structure including a source of unidirectional magnetic flux, and a pair of poles of opposite polarity, an armature of magnetic material adjacent to both said poles, said armature being formed and arranged so that in its normal non-actuated position it overlaps fractional face areas of both said poles, said armature being yieldably suspended so as to be movable bodily in a plane parallel to the faces of said poles and in two opposite directions only from its normal non-actuated position, said armature, when moved in either direction, increasing its overlap with respect to one of said poles and decreasing its overlap with respect to the other of said poles, an actuating coil system operable to energize said armature in accordance with sound waves to be reproduced, said coil system being so arranged that the portions of said armature adjacent to said pole-projections are always of like polarity

irrespective of the momentary direction of energizing current in said coil system, and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

14. In a telephonic loud speaker, a magnetic field structure including a pair of pole-projections of opposite magnetic polarity and having parallel faces, an armature of magnetic material movable bodily in a plane parallel to the faces of said pole-projections and in two opposite directions only from its normal non-actuated position, one end portion of said armature being operatively associated with both of said pole-projections and arranged to overlap fractional face areas of both said pole-projections in such a way that upon movement of said armature in either of its two directions of movement the overlap thereof with respect to one of said pole-projections increases, while the overlap with respect to the other of said pole-projections simultaneously decreases, the reverse effect occurring when said armature is moved in the opposite direction, a magnetic coil system for variably magnetizing said armature in accordance with sound waves to be reproduced and a vibratory diaphragm connected to said armature and adapted to be actuated thereby.

In testimony whereof I affix my signature.

CLAIR L. FARRAND.