

March 24, 1936.

A. A. THOMAS

2,035,104

TELEPHONE INSTRUMENT

Original Filed July 10, 1925 2 Sheets-Sheet 1

FIG. 1

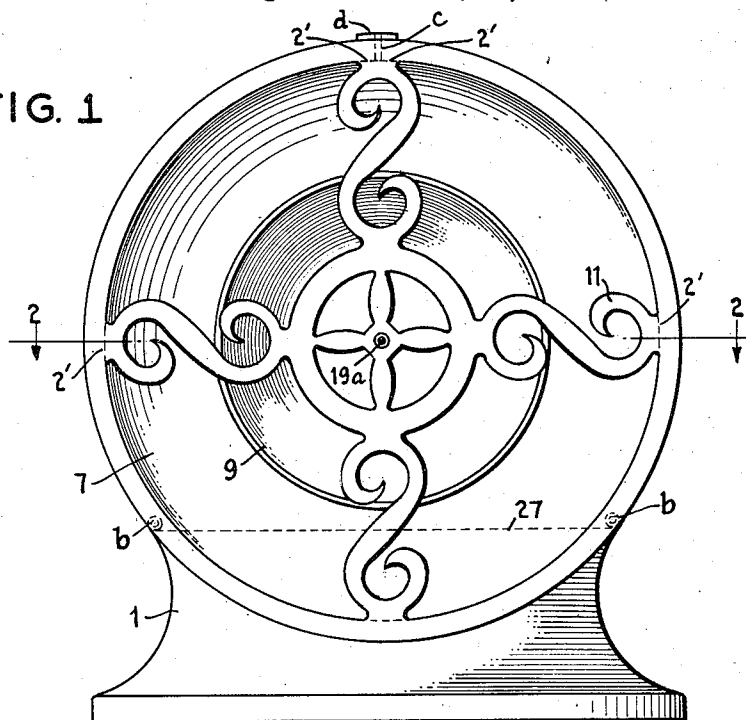


FIG. 2

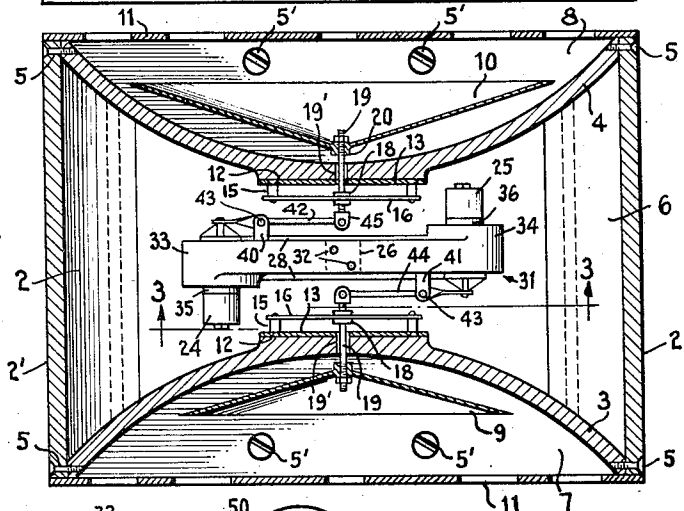
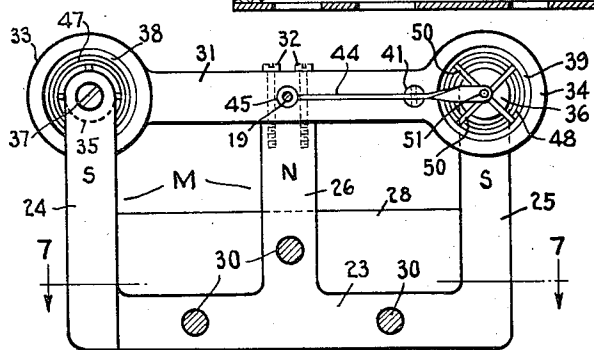


FIG. 3



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FIG. 4



FIG. 7



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UNITED STATES PATENT OFFICE

2,035,104

TELEPHONE INSTRUMENT

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Original application July 10, 1925, Serial No.
42,626. Divided and this application June 24,
1935, Serial No. 28,058

8 Claims. (Cl. 179—115.5)

My invention relates to telephone instruments, and its object is to provide a receiver of the so-called loud-speaking type embodying various features of novelty for improving the acoustic reproduction. The loudspeaker of my invention is particularly useful for radio reception, but it is broadly applicable in any connection where electrical energy is utilized in the reproduction of sound.

This application is directed to the construction of the magnet or driving motor mechanism, the other features being claimed in my copending application filed July 10, 1925, Serial No. 42,626, of which this application is a division.

It is a generally recognized fact that a telephone receiver with only one diaphragm cannot give out high and low notes with an equal degree of fidelity, because the acoustic capacity of a single diaphragm cannot properly extend over the entire musical scale. Thus, a diaphragm having a high natural frequency cannot properly respond to low notes, and a diaphragm that responds best to low notes does not operate satisfactorily on high notes. Then, too, a diaphragm that is held rigidly bound at its circumferential edge will always accentuate frequencies which are at or near the natural frequency of the diaphragm, thereby distorting the reproduction. Also, in prior loudspeakers, all sounds issue out of the same horn or (as in the cone-type speakers) from the same diaphragm, so that, where orchestral or band music is reproduced, the fine notes of the violin and flute come from the same spot as the deep tones of the bass instruments. This is unnatural, for in the actual rendition of such music, the players are so arranged that the high notes and the bass notes reach the hearers from different parts of the room.

In order to overcome the foregoing and other defects and objections in prior loudspeakers, I have provided an instrument employing a plurality of diaphragms (two are usually sufficient) having different acoustic capacities or characteristics so as to encompass the entire musical scale. One diaphragm has a high natural frequency, and the other a low natural frequency, the two together reproducing high notes and low notes with practically equal resonance and naturalness. These diaphragms, although controlled by the same telephone circuit, are mechanically disconnected and therefore free to operate independently of each other, so that each produces its own vibrations without being hampered by the movements of the other. For this purpose, I have devised a novel construction of electromagnetic

mechanism in which a single magnet (preferably of the permanent type) provides two separate cylindrical air gaps. In each air gap operates a coil connected in a circuit of variable currents, and each coil is connected with a diaphragm.

The size and area of the diaphragms are sufficiently large to give a loudspeaking reproduction without the need of horns or other mechanical amplifiers, although such may be added if desired. The diaphragms are preferably cone-shaped and are constructed of any suitable material which gives the diaphragm the proper degree of rigidity. The mounting of the diaphragms, as will later appear, is such that they may be left free at the circumference, so that they vibrate bodily with the same amplitude over their entire area. The practical advantages of this construction will become clear as the description proceeds.

Another feature in my new loudspeaker consists in so mounting the diaphragms that their vibrations are projected in different directions into the free air. This adds to the naturalness of the reproduction, especially in band and orchestral music, for the high notes projected by one diaphragm and the low notes of the other diaphragm seemingly come from different parts of the room. A preferred method of producing this effect is to provide the outer casing of the instrument with a pair of open chambers oppositely arranged, and in each chamber is mounted a diaphragm. As the diaphragms vibrate the high and low notes are projected in opposite directions, and this avoids the "choky" effect so apparent in those loudspeakers where all tones, high and low, issue out of a single opening or from the same diaphragm. The chambers associated with the diaphragms are preferably bowl-shaped and amplify the sound produced by the diaphragms.

The foregoing and other objects and advantages of my invention will be clearly understood from a detailed description of the accompanying drawings, which illustrate a preferred embodiment and also modifications in certain details. In these drawings—

Fig. 1 represents an elevational view of a loudspeaker constructed in accordance with my invention;

Fig. 2 shows a plan view in cross-section on line 2—2 of Fig. 1;

Fig. 3 is a detached view, in elevation, of the electromagnetic system which operates the diaphragms;

Fig. 4 is a fragmentary view in section similar

to Fig. 2 except that the diaphragm is supported by a flexible membrane at its outer periphery;

Fig. 5 shows a face view of the disk and spring arm on which each diaphragm is adjustably supported;

Fig. 6 is an end view of the magnetic structure illustrated in Fig. 3, certain parts being shown in section for clearness;

Fig. 7 is a cross-section on line 7—7 of Fig. 3;

Fig. 8 shows a modified construction of magnetic frame in which two annular air gaps are arranged centrally in axial alignment;

Fig. 9 is an edge view of Fig. 8, and

Fig. 10 is a plan view of Fig. 8, certain parts being shown in section for clearness.

Referring to Figs. 1 and 2, there is an outer casing or frame comprising a base 1, a cylindrical wall or housing 2 which is open at both ends, and a pair of concave disks 3 and 4 securely connected to the housing by any suitable means, as by screw 5 or otherwise. These disks, which act as sound boards or panels, are rigidly held in position by being fastened either to the housing 2, as by screws 5, or to the upright extension of base 1, as by screws 5'. The housing 2 and the disks 3 and 4 form a closed chamber 6, practically dust-proof, containing the electromagnetic mechanism of the instrument. To permit ready assembling and adjusting of the parts in this chamber, the housing 2 may be provided with a removable section hinged on base 1. In Figs. 1 and 2, the housing 2 comprises a pair of sections 2' hinged or otherwise movably connected at b to opposite sides of the base. The top edges of these separable sections meet at c, where they may be locked together by a suitable latch d, or any similar device adapted to be readily opened. When the housing 2 is made of the separable sections 2', the screws 5 are not necessary, since the concave disks 3 and 4 are secured to the base 1 independently of the sections 2', as by the screws 5' or otherwise. When I refer to the members 3 and 4 as disks, I do not mean that they must be circular, for they obviously may be of any other practical design.

The concave or bowl-shaped disks 3 and 4, which may be formed of wood, metal or a suitable composition, constitute bowl-shaped chambers 7 and 8, in which are mounted the acoustic diaphragms 9 and 10, respectively. These diaphragms are preferably cone-shaped, as illustrated, and may be constructed of any material that is sufficiently rigid and light in weight—such as, stiff paper (preferably moisture-proof), fibre, stiffened cloth, bakelite canvas, aluminum, or any other metallic or non-metallic substance that is found practical for this purpose. The diaphragm chambers 7 and 8 may be provided with decorative covers 11 of grille work sufficiently open to permit the ready passage of sound. The concave disks 3 and 4 also act to reflect such sound waves as may strike their surface, so that all sound produced by the diaphragms is projected into the free air. It is thus clear that the bowl-shaped chambers 7 and 8 amplify or reinforce the sound produced by the operation of the cone-shaped diaphragms.

As seen in Fig. 2, the diaphragms 9 and 10 are of different size. The small diaphragm 9 has a high natural period of vibration, and I may therefore conveniently call this the high diaphragm. The large diaphragm 10, which has a relatively low fundamental frequency, will be referred to as the low diaphragm. The size,

weight and material of the diaphragms are so chosen as to secure the best acoustic results with each diaphragm in any particular design and size of instrument under construction, as any expert in this art can determine. When I refer to the diaphragms as cone-shaped, I do not mean that the diaphragms must be in the exact mathematical shape of a cone, but I use the term in its broad practical sense of a diaphragm constructed to give loudspeaking response. While such diaphragms are usually bulged in the shape of a cone, that is merely a mechanical convenience to impart the necessary rigidity or tautness to the sheet material of which the diaphragm is made.

The back of each bowl-shaped disk 3 and 4 has a flat surface 12 on which is rigidly secured a plate 13 by means of screws 14 or otherwise. Each plate 13 is provided with a pair of hollow screw studs or posts 15 on which is supported a vibratory strip 16 held in place by screws 17. The strip or arm 16 is made of spring steel or other suitable resilient metal. At the center of each spring strip 16 is fixed a screw-threaded bushing 18, which may consist of two parts screwed together, as shown in Fig. 4, for readily fastening the same to the spring strip. Through the bushing 18 passes a screw-threaded rod 19, which extends through an opening 19' in the center of each disk 3 and 4. The opening 19' constitutes a guide for the axially movable rod 19, the clearance being exaggerated for better illustration, as will be clear from Fig. 4. On the outer end of one of the rods 19 is mounted the diaphragm 9, and on the other rod is similarly mounted diaphragm 10, as shown in Fig. 2. In the present instance, merely by way of example, each diaphragm is provided at the center with a rearwardly extending hub 20 (see Fig. 4), which is screw-threaded to receive the outer screw-threaded end of rod 19. A fixed pin or lug 21 on rod 19 limits the inward movement of the diaphragm on the rod, and a nut 22 holds the diaphragm rigidly in place. Any other practical means may be employed for mounting the diaphragms on their respective rods 19.

It will be seen from the foregoing that the diaphragms 9 and 10 are supported at the center entirely by the vibratory spring strips 16 which are of the required strength and resiliency, as may easily be ascertained by experiment. The members 16 thus constitute resilient vibratory supports for the diaphragms, which thereby are left free at their circumferential edges and vibrate bodily with practically uniform amplitude over their entire area. Such uniform bodily vibration cannot take place where the diaphragm is held clamped around the edge, as in prior constructions, for such a diaphragm necessarily vibrates with maximum displacement at the center, from which the vibrations spread in decreasing amplitude toward the circumference. In a circular diaphragm, these transverse or radial vibrations produce so-called nodal circles, and along these nodal circles there is no vibration of the diaphragm. The essential result of this enforced manner of vibration of an edge-bound diaphragm is distortion of the acoustic reproduction. This and other defects and objections inherent in edge-bound diaphragms are obviated where the diaphragm, as in the construction above described, is free at the circumference and vibrates with substantially the same amplitude over its entire surface, thereby giving a more natural reproduction. When I say that the diaphragms 9 and 10 are free at the edge, I mean

that they are not held rigid along the circumference in a fixed support, and I do not exclude the possibility of providing a thin flexible membrane between the edge of the diaphragm and the adjacent disks 3 and 4. This is shown at 4' in Fig. 4. Such a thin membrane might be used to close off the space back of each diaphragm from the outer air, or to act as a yielding support for the circumferential edge of the cone without interfering with its free floating movements. Of course, it will be understood that, so far as other features of my invention are concerned, the diaphragms 9 and 10 may be supported for vibratory movement in any other practical way. Also, while these diaphragms are primarily intended for use without horns, they may in certain instances be made sufficiently small to require the addition of amplifying horns, as when the instrument is to be embodied in a large radio cabinet where the horns are concealed from view. Ordinarily, however, the bowl-shaped sound-amplifying chamber 7 or 8 associated with each diaphragm makes the use of a horn unnecessary.

I will now describe the electromagnetic mechanism for operating the diaphragms. A magnet indicated as a whole by M is rigidly mounted in the chamber 6 formed by the outer casing or ring member. This magnet, in the preferred construction shown, comprises a base section 23, a pair of upright end legs 24 and 25, and a middle leg 26. These parts are preferably formed out of a single piece of magnet steel, if the magnet M is to be a permanent magnet. Or, the frame 23—24—25 may be composed of steel laminae capable of retaining magnetization for a long time. In the broader aspect of my invention, magnet M may be constructed as an electromagnet, in which case the frame would be of soft iron. The middle leg 26 extends in the same plane as the base section 23, but the end legs 24 and 25 lie in planes on either side of the base section, as best shown in Fig. 7. The purpose of this lateral displacement of the legs 24 and 25 will presently become apparent. If the middle limb 26 is magnetized as the north pole N, the end legs 24 and 25 are the south poles S and S'. Obviously, the polar legs 24 and 25 may be north poles, and the middle leg 26 a south pole.

The magnet M is secured to the flat bottom 27 (or by other part) of chamber 6 by any suitable means. In Figs. 6 and 7, I have shown a pair of brackets 28 in the form of L-shaped plates, which are fastened to the base of the instrument by screws 29, and between these plates is clamped the magnet frame by bolts 30 or other means.

On the central leg 26 of magnet M is mounted a transverse polar arm 31, fixed in place by any suitable means, such as screw bolts 32. The magnetic arm 31, which may be solid or laminated, terminates in annular heads or enlargements 33 and 34, which are preferably wider than the body of the arm (see Fig. 4) to provide an air gap of sufficient depth, as will presently be explained. Into the circular opening of polar head 33 extends centrally a cylindrical pole piece 35 projecting laterally from the end of polar leg 24. In like manner, a cylindrical pole piece 36 at the end of polar leg 25 projects centrally into the opening of polar head 34. The pole pieces 35 and 36 extend laterally from their respective polar legs in opposite directions so as to lie fully within the cylindrical openings of the polar rings 33 and 34. If the pole pieces 35 and 36 are made

separate from the body of the magnet frame, they are secured to the legs 24 and 25 by screws 37 or in any other practical way. If the magnet frame is made of cast iron or steel, the pole pieces may be integral with the body of the frame. The polar ring 33 and pole piece 35 form an annular air gap 38, and the polar ring 34 and pole piece 36 form a similar air gap 39.

The polar extension 31 carries a pair of slotted lugs 40 and 41 projecting laterally from the opposite sides of the arm. On lug 40 is pivoted an arm or lever 42 by means of a pin 43 (see Fig. 4). A similar arm or lever 44 is pivoted on lug 41. The inner end of arm 42 is pivotally connected with the inner end of the rod 19 which carries the diaphragm 10. This connection may be of any practical form. In the present instance, there is a slotted nut 45 screwed on the inner end of rod 19 and carrying a pin 46 which passes through the arm 42. The inner end of the operating arm 44 is similarly connected with the rod 19 of diaphragm 9. The outer end of arm 42 carries a coil 47, and the outer end of arm 44 supports a coil 48. Coil 47 is operatively held in the annular air gap 38, and coil 48 is supported for movement in the air gap 39. A simple mounting for each coil is illustrated in Fig. 4. The coil is wound on a cylindrical shell 49 of light non-magnetic material (such as stiff paper, aluminum, etc.), and this shell is provided with radial extensions 50, which may simply be strips formed integral with the shell. The extensions 50 meet or cross each other at the central point 51, which represents a pin or stud for fastening the shell 49 to the outer end of the arm 42 (or 44). In this way, the coils 47 and 48 are rigidly connected to the arms 42 and 44, and are held in proper position within the annular air gaps 38 and 39, respectively.

Attention is called to the fact that the pivot point 43 of the operating arms or levers 42 and 44 is considerably nearer the coil-supporting end than the other end to which the diaphragms are connected. This means that the vibrations of the coils are transmitted to the respective diaphragms through the arms 42 and 44 in amplified ratio, depending on the ratio of length 43—46 to length 43—51. In the particular example illustrated, this increased transmission ratio is nearly 2:1, but it may obviously be varied as desired, depending upon the requirements of any instrument under construction.

The coils 47 and 48 are adapted to be connected in a suitable circuit of variable currents, such as a telephone receiving circuit.

The annular air gaps 38 and 39 are preferably shaped wider at the center than at the ends for the purpose of making the density of the magnetic flux more uniform across the entire depth of the air gap. This form of air gap is best obtained by curving the circumferential wall of the opening in each polar ring outwardly, as shown at *a* in Figs. 4 and 6. In an air gap with a uniform width (and therefore having uniform reluctance across its area), the magnetic lines of force have a tendency to crowd across the central portions of the spaced pole-pieces between which the air gap is formed. As a result, the density of the magnetic flux across such an air gap is lower near the outer edges of the pole-pieces than at the center. A vibratory magnetic member operating in an air gap having such a non-uniform flux distribution is not acted upon with equal force in different sections of the air gap. For instance, in loudspeakers of the so-

called electrodynamic type as heretofore constructed, where a coil operates in an annular air gap and is carried by an acoustic diaphragm, loud notes are not reproduced with the proper intensity and are therefore not given their correct acoustic value. This is due largely to the fact, as I believe, that on strong vibrations the coil operates near the ends of the air gap where the magnetic field is weaker than at the middle. This objection is overcome by so constructing the walls of the air gap that the magnetic reluctance is slightly greater at the center than at the ends, whereby a substantially uniform flux density is obtained. It is obvious that the same result may be obtained by so shaping the cylindrical pole-pieces 35 and 36 as to widen the air gaps at the center.

The normal position of the coils 47 and 48 in their respective air gaps is adjustable by simply turning the rod 19, which moves the inner end of arm 42 (or 44) either toward the magnet or away from it, depending on which way the rod is turned. The pivotal adjustment of arm 42 or 44 by the rotatable rod 19 may be accomplished by making either the part 18 or 45 a collar in which the rod turns and making the other part a nut in screw-threaded connection with the rod. For example, if part 18 is a collar in which the rod 19 turns without axial movement, it is evident that turning the rod will move the nut 45 axially of the rod. Consequently, the arm 42 is rocked about its pivot to adjust the normal position of coil 47. Or, if element 18 is a nut and element 45 a collar in which the rod 19 turns but which can not move axially of the rod, rotation of the latter causes it to move axially in nut 18 and collar 45 follows the axial (but not the rotary) movement of the rod. To permit easy adjusting of the rod 19 from outside the casing and without disturbing any part of the mechanism, the outer end of each rod 19 is slotted, as indicated at 19a, for the insertion of an instrument like a screwdriver. It will be understood that the normal position of coils 47 and 48 to some extent affects the operation of the diaphragms, particularly as to volume.

In Figs. 8, 9 and 10 there is illustrated a modified construction of field magnet for providing a pair of centrally arranged annular air gaps. The magnet M', preferably a permanent steel magnet, has two outer limbs 62 and 63, and a central limb 64. The two outer limbs constitute one pole (marked N in Fig. 8), and the limb 64 is the other pole, here assumed to be the south pole. The polar limbs 62 and 63 are connected by a pair of arms or bars 65 of soft iron or other material of high magnetic permeability. Bolts 66 or other fastening devices hold the arms 65 firmly to the ends of the polar limbs 62 and 63. Each arm 65 is formed at the center into a ring 67, the two rings being in axial alignment. The rings 67 constitute annular pole pieces. To the central limb 64 is secured a cylindrical pole piece 68, which may be in the form of a single bar held in place by a screw 69, as shown, or which may consist of two oppositely extending sections. The ends of pole piece 68 project centrally into the polar rings 67 to provide the annular air gaps 70, in which operate coils C and C' connected to diaphragms D and D'. These diaphragms and their connections with coils C and C' are indicated in Fig. 10 for the sake of simplicity in a diagrammatic way. These diaphragms may be like diaphragms 9 and 10, or of any other practical construction. Also,

the operative connections between coils C—C' and diaphragm D—D' may be like the connections shown in Fig. 4, or may comprise any other suitable means. The annular air gaps 70 may be shaped like the annular air gap in Figs. 4 and 6. The magnetic frame M' is secured to a base or other fixed support in any practical way. In Fig. 9, the dotted lines 71 represent any suitable securing means for the magnet. It will be observed that the polar arms 65 are spaced from the central limb 64 a considerable distance in order to prevent magnetic leakage across the intervening space, as such leakage would weaken the flux density across the annular air gaps.

One of the main practical advantages of the magnetic structure shown in Figs. 8-10 is a more balanced flux distribution across the annular air gaps than is possible to obtain in the magnet structure of Fig. 2. This advantage is due to the fact that in Figs. 8-10 each polar ring 67 is arranged between the polar limbs 62 and 63. Therefore, the magnetic flux enters (or leaves) the annular pole pieces 67 through two iron paths arranged symmetrically with respect to the polar limbs 62 and 63. This construction, besides increasing the uniformity of flux distribution, tends to decrease magnetic leakage.

It is hardly necessary to mention that the parts shown in the various views are not drawn to relative proportions that are mathematically exact. The drawings have been made as simple and clear as possible, and on that account the parts are spread out more than would be necessary in actual construction. The relative sizes and dimensions of the parts depend upon the particular size and design of instrument under construction, and are readily determined by the skilled experimenter. While the instrument of my invention is primarily intended for use as a telephone receiver, it will be understood that certain features may be employed in the construction of transmitters.

Although I have herein shown and described certain specific constructions, I want it understood that I have done so merely by way of example and not for the purpose of restriction or limitation. In the broader aspect of my invention, the various features of novelty may be mechanically embodied in other constructions than herein set forth. Also, it is evident that certain features of my invention may be employed without certain other features.

Having described my invention, what I claim is:

1. In an electromagnet instrument, a magnet having an annular air gap which is wider at the middle portion of its depth than at the ends thereof, so as to provide a more uniform distribution of magnetic flux across the entire depth of the air gap.

2. In a telephone instrument, a magnetic frame comprising two outer legs and a middle leg, these three legs being magnetically connected at one end, the outer legs being of the same polarity and the inner leg of opposite polarity, and means at the polar ends of said three legs for providing a pair of annular air gaps in the magnetic circuit of said frame.

3. In a loudspeaker, a field magnet frame having three polar limbs, a magnetic arm secured at the center to the middle limb and extending transversely thereof, and means whereby the ends of said arm and the ends of the two outer limbs form a pair of annular air gaps.

4. In a loudspeaker, a field magnet frame having three polar limbs, and a magnetic arm

secured at the center to the middle limb and extending transversely thereof, each end of said arm being in the form of a ring into which the ends of the two outer limbs project to form two annular air gaps.

5 5. In a telephone instrument, a permanent magnet comprising a steel frame of sufficient length to be permanently magnetized to the desired strength, said frame including three polar
10 limbs, a polar arm secured to the middle limb and extending in opposite directions toward the outer limbs, said arm terminating in ring-shaped ends, and a cylindrical pole-piece projecting laterally from each of the outer limbs into the adjacent
15 ring-shaped end of said arm, each cylindrical pole-piece and the surrounding ring-shaped end of the polar arm forming an annular air gap.

6. In a telephone instrument, a permanent magnet comprising a steel frame of sufficient
20 length to be permanently magnetized to the desired strength, said frame including three polar limbs, a pair of spaced polar arms secured to the outer limbs, each polar arm being formed at its center with a ring, said rings being in axial
25 alignment and arranged on either side of the middle limb of said frame, and a cylindrical pole

piece extending laterally from said middle limb in opposite directions into the rings on said arms, whereby said cylindrical pole-piece and said rings form two annular air gaps arranged in magnetically balanced position in the circuit of the magnetic flux. 5

7. In a loudspeaker, a field magnet frame having three polar limbs, a magnetic arm secured at the center to the middle limb and extending transversely thereof, and a pair of magnetic members
10 connected to the outer limbs and extending on opposite sides of said frame, each of said members having a ring at the center for receiving one end of said arm, whereby said rings and arm form two annular air gaps in axial alignment. 15

8. In a loudspeaker, a field magnet frame comprising a central portion and a pair of end portions, each end portion having an opening at the center, a cylindrical core magnetically connected to said central portion and extending in
20 opposite directions therefrom into said openings, whereby said end portions and core form a pair of axially aligned air gaps, a coil movable in each air gap, and a sound-reproducing means operated by said coils. 25

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