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2,552,800

MAGNETIC MICROPHONE

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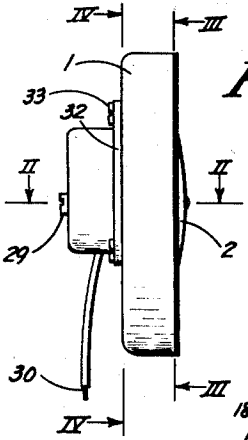


Fig. 1

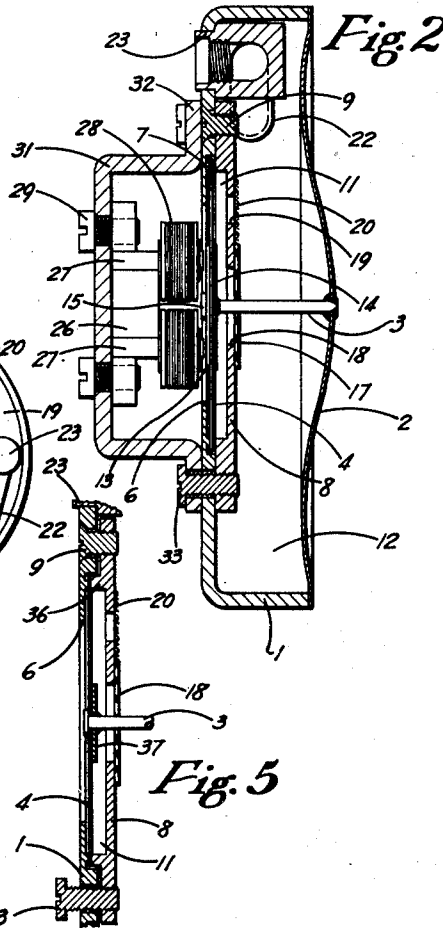


Fig. 2

Fig. 3

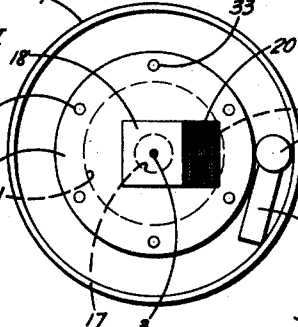


Fig. 4

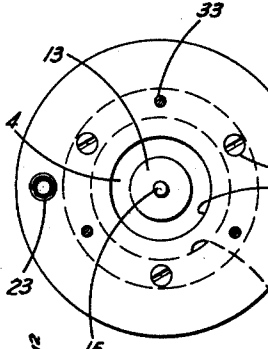


Fig. 5

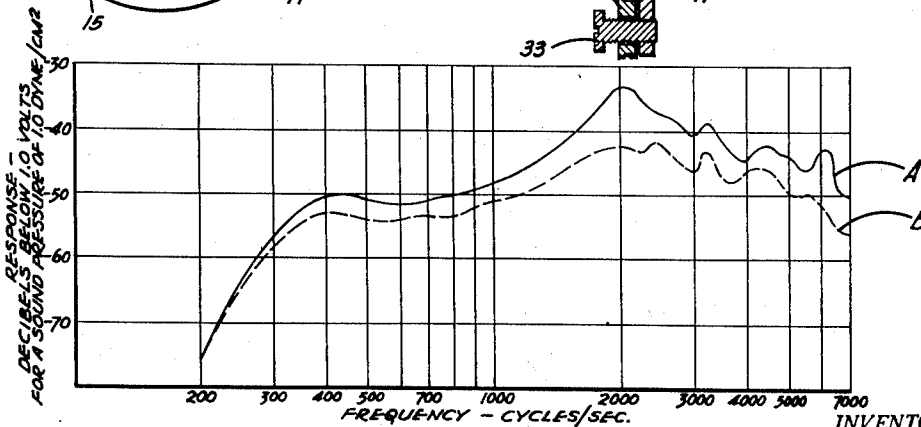


Fig. 6

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UNITED STATES PATENT OFFICE

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MAGNETIC MICROPHONE

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This invention relates to small magnetic microphones, such as used in hearing aids.

Heretofore, magnetic microphones have been either too large and bulky, or too low in efficiency for satisfactory use in hearing aids. The cost of such microphones also has been a serious factor in limiting their use. Therefore, the standard microphone for vacuum tube hearing aids has been the Rochelle salts crystal type. While efficient and cheap, the crystal microphone has some serious disadvantages. First, the crystal is destroyed by temperatures in excess of about 120° F. Second, the crystal is slowly but surely damaged by the humidity conditions encountered in hearing aid use. Third, at the usual operating temperatures of about 90° F. the efficiency is appreciably lower, particularly at the low frequencies, than at usual room temperature.

It is among the objects of this invention to provide a magnetic microphone which is free from temperature and humidity failures; which has an efficiency essentially the same as that of a good crystal microphone; which is small and light-weight; which is sufficiently sensitive for hearing aid use; which has very flexible and easily adjusted frequency response characteristics that are particularly suited to hearing aid use; which can be easily manufactured and adjusted and tested; and the output of which is not seriously affected by temperature changes.

In accordance with this invention, a diaphragm adapted to be vibrated by sound waves is connected by a drive pin to a smaller and stiffer diaphragm which therefore is driven by the first diaphragm. A magnet-pole piece system which includes the usual permanent magnet and one or more pole pieces with coils wound on them, is spaced by an air gap from the small diaphragm. Electric voltage is generated in the coil or coils as the width of the air gap is changed by the vibrating small diaphragm. The large diaphragm, which receives the sound waves and has high compliance, forms with a supporting case a relatively large chamber that does not reduce materially the compliance of the vibratory system. Almost all of the stiffness of the system is in the small diaphragm, so that a stronger magnetic system can be employed for a given desired total compliance at lower frequencies. Also, acoustical damping means are associated with the small diaphragm, and therefore a larger cavity behind the large diaphragm is permitted than would be possible if the damping system were associated with the large diaphragm, as is the usual practice.

The magnetic system preferably is mounted in a second smaller case detachably connected to the outside of the back wall of the main case, the back wall being provided with an opening that is covered by the small diaphragm. The large chamber inside the main case may be coupled to the outside of the case by an acoustic inductance to increase the response in the low frequency portion of the range covered by the microphone.

The preferred embodiment of the invention is illustrated in the accompanying drawings in which Fig. 1 is a side view of the microphone; Fig. 2 is an enlarged transverse section taken on the line II-II of Fig. 1, with the magnetic system shown in plan; Figs. 3 and 4 are vertical sections taken on the lines III-III and IV-IV, respectively, of Fig. 1; Fig. 5 is a fragmentary transverse section showing a modified arrangement for the small diaphragm; and Fig. 6 is a graph showing two different response curves.

Referring to the drawings, the main cup shape case 1 of the microphone is made of some suitable metal, the choice of which will depend on the method of diaphragm clamping. The open front of the case is closed by a diaphragm 2 cemented to the front edge. This diaphragm preferably is formed from aluminum foil and is dished to strengthen it. Inside of the case there is a drive pin 3, the front end of which is cemented to the center of the diaphragm. The rear end of the pin is connected in a manner to be described presently to the center of a second diaphragm 4, preferably of magnetically permeable material, which is considerably smaller and stiffer than the other diaphragm. The back wall of the case has a central opening 6 encircled inside the case by a recess containing a circular seat 7 machined in the back wall. The small diaphragm rests freely against the seat to provide freedom from appreciable air gap changes with temperature, and is prevented from moving radially by the wall of the seat recess. Machining of the case to give accurate spacing of the diaphragm from the outer surface of the case is accomplished easily. The small diaphragm is locked in the recess by a circular cover plate 8 fastened to the back wall of the case by screws 9. The back side of the plate is provided with a circular recess of slightly less diameter than diaphragm 4 with which the plate forms a narrow cavity or chamber 11. A large chamber 12 remains between the plate and the large diaphragm.

Although the small diaphragm may itself serve as an armature, it is preferred to mount one or

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two magnetic armatures on the center of the diaphragm to carry magnetic flux without saturation. When two armatures are used, they may be small circular disks 13 and 14 that are clamped against the opposite sides of the diaphragm by the drive pin. For this purpose the rear end of the pin has a head 15 which engages the rear disk, and the portion of the pin directly in front of the front disk is shaved back to rivet it over that disk and thus clamp the two disks against the opposite sides of the diaphragm. By initially having the center portions of the disks bowed away from the diaphragm, their edges will tightly engage it when they are flattened against the diaphragm. The use of two armatures prevents the diaphragm from being distorted by the clamping pressure.

The plate 8 is provided with a central opening 17 through which drive pin 3 extends, but this opening is sealed by a very thin sheet of rubber 18 that snugly engages the pin and is cemented to the plate. This seal has very low acoustic transmission, but is flexible enough to permit free vibration of the drive pin. The plate is provided with a second opening 19 that is covered by suitable acoustic damping resistance material, of which several kinds are well-known. One of the simplest is a piece of silk 20 cemented across the opening.

In order to increase the low frequency response, a small tube 22 having a length of the order of one-half inch and a diameter of $\frac{3}{8}$ inch is supported in the large chamber 12 of the case by a hollow angle member 23, the outer end of which is mounted in a hole in the back wall of the case near its side wall. The outer end of the hole through this member is threaded so that it may be plugged by a screw (not shown) to eliminate the increase in low frequency response produced by the tube in cases where the users hearing loss indicates that to be desirable.

The small diaphragm 4 forms part of an electro-magnetic generating system by which the movements of the diaphragms are converted into electrical energy. The rest of the generating system is formed from a magnet-pole-piece system spaced by an air gap from the back side of the small diaphragm. This system includes a permanent magnet 26, preferably of some strongly magnetic material, and forwardly extending pole-pieces 27 of highly magnetically permeable material on which electric coils 28 are mounted. The front ends of the pole-pieces are spaced a short distance from the rear armature disk 13 to provide the usual air gap. This magnetic system preferably is connected by screws 29 to the back wall of a small cup-shape case 31 that has an open front. The front edge of this case is surrounded by an integral flange 32 through which extend screws 33 that also extend through the back wall of the main case 1 and are threaded in the plate 8. The front surface of the flange 32 lies in a plane perpendicular to the axes of both cases, and the front ends of the pole-pieces project from the front of case 31 and are accessible for accurate grinding in a plane parallel to and a constant distance from the front plane of the flange. Accurate adjustment of the air gap in front of the pole tips can be accomplished, when necessary, by inserting thin shims between the two cases, or by partial demagnetization of permanent magnet 26. The latter method can be used only for a very small range of accurate adjustment. One end of coils 28 is grounded to case 31, and the other end 30

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extends through the side wall of that case for connection in a hearing aid circuit.

Although the free contact of the small diaphragm with seat 7 gives freedom from appreciable air gap changes with temperature, rattle may occur if the diaphragm is not perfectly flat or is not pulled against the seat with sufficient force by the permanent magnet. Therefore, it sometimes is desirable to clamp the edge of the diaphragm tightly between its seat and plate 8. For this purpose, as shown in Fig. 5, the back side of the plate is provided with an annular rib 36 which presses the edge of the diaphragm against the seat. If maximum freedom from thermal effects is necessary, the material of case 1 and plate 8 should have the same coefficient of thermal expansion as the diaphragm 4 to prevent reduction and possible closure of the air gap at low temperatures. It usually is desirable to use a magnetic diaphragm 4, and case 1 and plate 8 also may be made from the same magnetic material. However, small case 31 should be made of non-magnetic material to prevent serious shunting of the permanent magnet. As the small case is short in the direction perpendicular to the diaphragms, its expansion and contraction at a different rate than the pole-pieces and other parts has little effect on the air gap. By also providing diaphragm 4 with only one armature, as shown in Fig. 5, a considerably higher resonant frequency for the system can be obtained. When a single armature 37 is used, it is soldered or cemented to the front of the diaphragm so that it will not be necessary to depend on riveting, which might distort the diaphragm, to hold the armature in place. The drive pin is riveted over the armature merely to rigidly connect the pin to the armature and small diaphragm.

The primary purpose of this invention is to provide a high-output, small size magnetic microphone with frequency response characteristics suitable for hearing aid use. The response of such a microphone need not extend below a frequency of 250 to 400 cycles. This is advantageous because it reduces noise and prevents overloading from the higher speech powers encountered at low frequencies. A definite need for more amplification in the range from about 1500 to 4000 cycles than in the region below this should also be kept in mind. The effects of head diffraction and ear canal resonance give an individual who is not using a hearing aid a considerable amount of amplification at the higher frequencies above about 1500 cycles. To give a net "flat" response curve with a hearing aid, some element in the system must provide selective amplification of the high frequencies to give the most natural sounding results. Also, the baffle effect when a hearing aid is worn increases the low frequency response below about 1000 cycles, thereby further increasing the desirability of added high frequency response in the hearing aid to give balanced performance. The microphone of the present invention is particularly adapted to be constructed with response characteristics suitable for hearing aid use.

The diaphragm 2 has a relatively large effective area A_1 (about $1\frac{3}{4}$ " outside diameter is suitable) with a compliance C_1 and a mass M_1 . This diaphragm converts sound pressure on its surface into a force driving the second diaphragm assembly, consisting of the small diaphragm 4, armatures 13 and 14 and drive pin 3, having a mass M_2 , a compliance C_2 , and an effective area A_2 .

In back of the large diaphragm is a cavity of acoustical compliance CA_1 coupled to the outside of case 1 by the tube 22 having an inertia MA_1 and an acoustical resistance RA_1 . The effect is to raise the low frequency response by some fifteen decibels at some peak frequency. Generally, the resonant effect of tube 22 is made to be maximum at from 300 to 400 cycles, although it can be raised or lowered to reduce or extend the frequency range of the microphone. The cavity compliance CA_1 is also coupled to the small cavity 11, whose acoustic compliance is CA_2 , by the acoustic resistance RA_2 formed by the silk 20 covering hole 19 in plate 8. The small diaphragm is also coupled to cavity 11 since it forms one wall of it, and also it is coupled to the cavity in case 31 behind it, which has an acoustical compliance CA_3 . The acoustical compliance CA_2 of cavity 11 in front of the small diaphragm, taken in conjunction with the damping element RA_2 , can be used to control the damping of the principal peak in the microphone response. The magnetic system is coupled to the small diaphragm, and has the effect of increasing the compliance C_2 because of the action of the permanent magnet, and of increasing the effective mechanical resistance of the second or rear diaphragm system, depending on the electrical load placed across the microphone coils. The output of the microphone depends on the alternating velocity of the second diaphragm system, and for a flat output this velocity should be approximately constant with frequency. For the shape of output curve desirable for hearing aid use, the velocity should be roughly constant from 300 to 1000 cycles, and should rise to a higher level above this. Because of the increasing alternating velocity of the small diaphragm for a given amplitude of vibration at high frequencies, the response at frequencies above resonance does not drop off rapidly, but extends well over 6000 or 7000 cycles. A top limit of 4000 cycles is all that is needed for good hearing aid reproduction.

Response curves of actual experimental microphones made according to this invention are shown in Fig. 6. Approximate values for the acoustical and mechanical elements of the microphones are listed in the table below for the two curves:

	Curve A	Curve B
A_1 sq. cm.....	5	5
CA_1 cgs units.....	3×10^{-6}	3×10^{-6}
A_2 sq. cm.....	1.1	1.1
CA_2 cgs units.....	1.25×10^{-7}	0.2×10^{-7}
CA_3 cgs units.....	5×10^{-7}	5×10^{-7}
M_1-M_2 grams.....	0.25	0.25
$C_1 \times C_2$ cm./dyne.....	6×10^{-8}	6×10^{-8}
C_1+C_2 cgs units.....	3.8	3.8
RA_1 cgs units.....	900	900

While the above values are representative of successful microphones made according to this invention, relatively large departures may be made from those values without affecting the scope of the invention. Values of

$$\frac{C_1 \times C_2}{C_1 + C_2}$$

as low as 2×10^{-8} cgs units have been successfully employed.

The curves illustrated in Fig. 6 were taken in conjunction with a miniature input transformer and represent the voltage available at the grid of the first amplifier tube in the usual hearing aid amplifier. Curve A is that of a microphone hav-

ing high sensitivity with a moderate peak in response between 1500 and 3000 cycles, at the principal resonant frequency of the vibratory system. The amount of the peak response is limited by the acoustic resistance 20. At low frequencies, due to the action of the tube 22, the response holds up down to about 300 cycles.

Curve B is that of a microphone very similar to the one of curve A. The volume of cavity 11, however, has been reduced, and its compliance lowered, resulting in a much greater damping action by the acoustic resistance 20, and flattening out the peak to a gently rounded form. This type of curve is particularly well suited for hearing aid use.

According to the provisions of the patent statutes, I have explained the principle of my invention and have illustrated and described what I now consider to represent its best embodiment. However, I desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. A magnetic microphone comprising a diaphragm adapted to be vibrated by sound waves, a stiff pin having one end connected to the diaphragm and driven thereby, a smaller and stiffer diaphragm driven by the pin, a magnet-pole-piece system spaced by an air gap from the small diaphragm for generating electrical voltage as the width of said air gap is changed by the vibrating small diaphragm, a case surrounding the space between the two diaphragms and supporting them, a plate mounted in the case between the two diaphragms and separating the space between them into a large chamber behind the large diaphragm and a small chamber in front of the other diaphragm, said plate being provided with an opening for passage of said pin, and a flexible sealing member engaging the pin and secured to the plate around it to seal said opening, said plate being provided with a second opening, and acoustic damping resistance material covering said second opening.

2. A magnetic microphone comprising a diaphragm adapted to be vibrated by sound waves, a pin having one end connected to the diaphragm and driven thereby, a smaller and stiffer diaphragm driven by the opposite end of the pin, a wall separating the space between the two diaphragms into two chambers of unequal size, the small diaphragm forming one side of the smaller chamber, said smaller chamber being sealed except for an opening through said wall, acoustic damping resistance material covering said opening, and a magnet-pole-piece system outside of said chambers and spaced by an air gap from the small diaphragm for generating electrical voltage as the width of said air gap is changed by the vibrating small diaphragm.

3. A magnetic microphone comprising a case having an open front and a central opening in its back wall, a diaphragm closing the open front of the case and adapted to be vibrated by sound waves, a pin in the case having its front end connected to the diaphragm and driven thereby, a smaller and stiffer diaphragm in the case engaging the inner surface of said back wall around said opening, the rear end of the pin being connected to the small diaphragm for driving it, a magnet-pole-piece system connected to the outside of said back wall and having its pole-piece portion spaced by an air gap from the small diaphragm, a plate mounted in the case between the

two diaphragms and dividing the space between them into a large chamber behind the large diaphragm and a small chamber in front of the other diaphragm, the plate being provided with an opening for passage of said pin, flexible material engaging the pin and secured to the plate around it to seal said opening, the case being provided with a hole that opens into the space between the two diaphragms, and a small tube inside the case connected to said hole for increasing the low frequency response of the microphone, said plate being provided with a second opening, and acoustic damping resistance material covering said second opening.

4. A magnetic microphone comprising a case having an open front and a central opening in its back wall, a diaphragm closing the open front of the case and adapted to be vibrated by sound waves, a pin in the case having its front end connected to the diaphragm and driven thereby, a smaller and stiffer diaphragm in the case engaging the inside of said back wall around said opening, the rear end of the pin being connected to the small diaphragm for driving it, a plate fastened to the inside of said back wall around said opening and spaced from at least the major portion of the small diaphragm to form a chamber in front of it, said plate having an opening through it for said pin, flexible material engaging the pin and secured to the plate around it to seal said opening, said plate being provided with a second opening, acoustic damping resistance material covering the second opening, and a magnet-pole-piece system connected to the outside of said back wall and having its pole-piece portion spaced by an air gap from the small diaphragm.

5. A magnetic microphone comprising a case having an open front and a central opening in its back wall, the inside of said back wall being provided with a recess around said opening, a diaphragm closing the open front of the case and adapted to be vibrated by sound waves, a pin in the case having its front end connected to the diaphragm and driven thereby, a smaller and stiffer diaphragm in said recess engaging said back wall around said opening, the rear end of the pin being connected to the small diaphragm for driving it, a plate fastened to the inside of said back wall around said recess and having a recessed back side of smaller diameter than the small diaphragm to provide a chamber in front of the small diaphragm, said plate having an opening through it for said pin, a flexible sealing member engaging the pin and fastened to the plate around it to seal said plate opening, the plate being provided with a second opening, acoustic damping resistance material covering said second opening, and a magnet-pole-piece system connected to the outside of said back wall and having its pole-piece portion spaced by an air gap from the small diaphragm.

6. A magnetic microphone comprising an elec-

tro-magnetic generating system including a diaphragm, a drive pin connected to the diaphragm, a larger and more flexible diaphragm spaced from the other diaphragm and adapted to be vibrated by sound waves, the large diaphragm being connected to the pin for driving it, a case surrounding the space between the two diaphragms and supporting said system, and a plate mounted in the case between the two diaphragms and dividing the space between them into a large chamber behind the large diaphragm and a small chamber in front of the other diaphragm, said small chamber being sealed except for an acoustic resistance opening of very small size through the plate.

7. A magnetic microphone comprising a case having an open front and a central opening in its back wall, a diaphragm closing the open front of the case and adapted to be vibrated by sound waves, a pin in the case having its front end connected to the diaphragm and driven thereby, a smaller and stiffer diaphragm in the case engaging the inside of said back wall around said opening, the rear end of the pin being connected to the small diaphragm for driving it, a plate fastened to the inside of the back wall around said opening and spaced from at least the major portion of the small diaphragm to form a small chamber in front of it, said plate having an opening through it for said pin, means sealing said plate opening, said plate being provided with a second opening, acoustic damping resistance material covering said second opening, a second cup-like case having an open front surrounded by a flange, fastening members detachably connecting said flange to the outside of said back wall around said opening, and a magnet-pole-piece system mounted in said second case with the front face of its pole-piece portion lying in a plane parallel to the plane of the front face of said flange, said pole-piece portion being spaced by an air gap from the small diaphragm.

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