May 9, 1944.

H. F. OLSON

2,348,356

MICROPHONE

Filed Jan. 31, 1941

2 Sheets-Sheet 1

Fig.1.

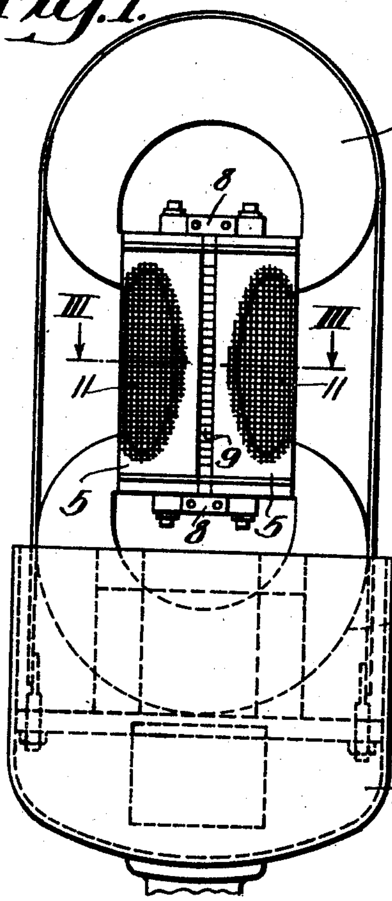


Fig.2.

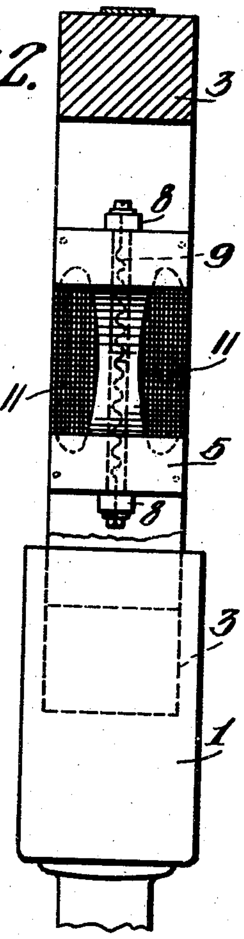


Fig.3.

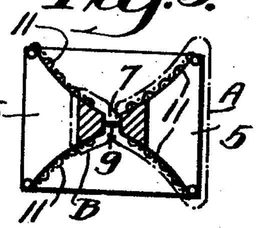
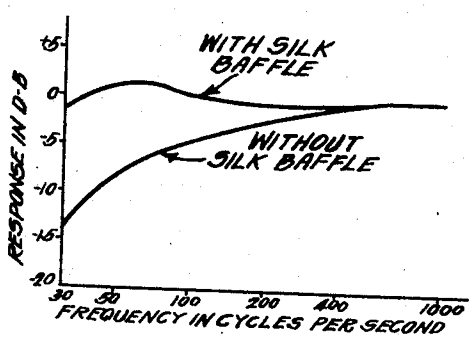


Fig.11.



Inventor

Harry F. Olson

By

Attorney

May 9, 1944. H. F. OLSON 2,348,356

MICROPHONE

Filed Jan. 31, 1941 2 Sheets-Sheet 2

Fig.4.

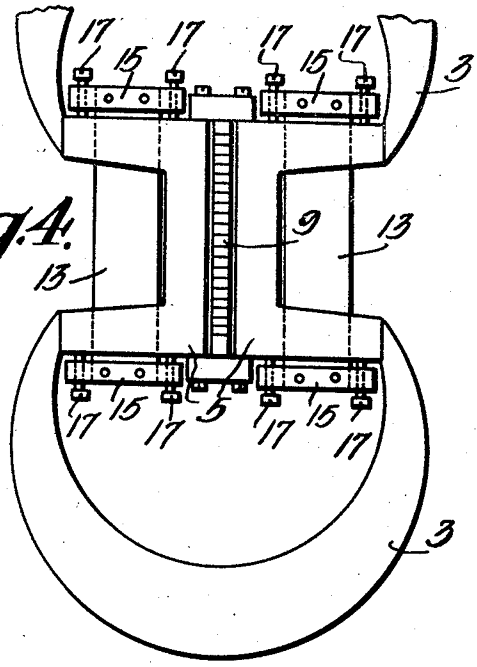


Fig.6.

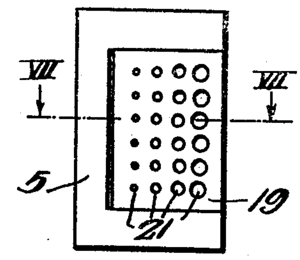


Fig.7.

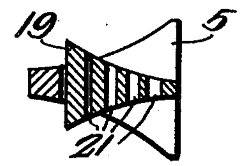


Fig.5.

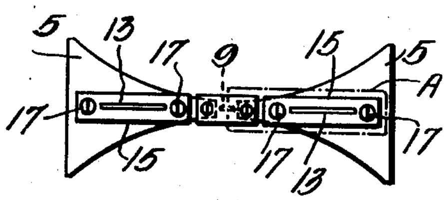


Fig.8.

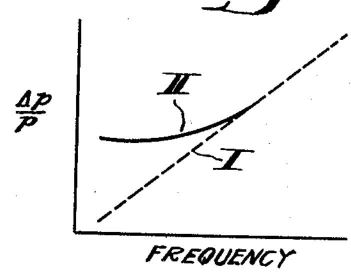


Fig.10.

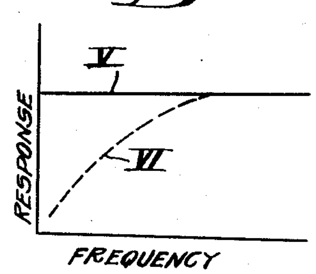
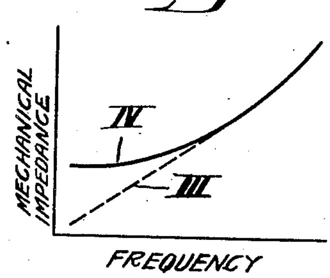


Fig.9.



Inventor

Harry F. Olson

By [signature]

Attorney

Patented May 9, 1944

2,348,356

UNITED STATES PATENT OFFICE

2,348,356

MICROPHONE

Harry F. Olson, Haddon Heights, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application January 31, 1941, Serial No. 376,861

15 Claims. (Cl. 179—138)

This invention relates to apparatus for converting sound vibrations into electrical variations, and more particularly to the baffle structure for a velocity, or pressure gradient, responsive microphone, the present invention being an improvement upon that disclosed and claimed in my U. S. Patent No. 1,885,001, of October 25, 1932.

In my aforementioned patent, there is disclosed a microphone which consists of a vibratile element disposed in the air gap of a magnetic circuit and so arranged that both sides thereof are open to the atmosphere or other fluid in which the microphone is immersed, the vibratile element having associated therewith a baffle around which the sound waves must pass in going from one side of the element to the other. The difference in sound pressure due to a difference in phase between the pressures on the two sides of the vibratile element is the source of the force which drives the element. The difference in phase between the two sides of this element is determined by the wave length of the sound and the dimensions of the baffle. In the range where the dimensions of the baffle are small compared to the wave length, the phase difference, and hence the driving force, is proportional to the size of the baffle.

The sensitivity of a velocity microphone of this sort depends upon (1) the flux density in the air gap, (2) the constants of the conductor, (3) the baffle dimensions, and (4) the connecting electrical circuit. The sensitivity may be greatly increased by so designing the flux source or magnet and the associated pole pieces that the flux density in the air gap will be a maximum. Another problem which is interconnected with the flux density in the air gap is the size of the baffle for the conductor. In the microphone disclosed in the above identified patent, the pole pieces of the magnetic circuit constitute the baffle for the conductor. Hence, the pole piece structure must be so designed that the effective path between the two sides of the ribbon is less than about half the wave length at the highest frequency to be reproduced.

When the magnetic structure is designed to provide maximum flux in the air gap, it is found that the mechanical impedance due to the electrical circuit becomes relatively large at low frequencies. In a system employing a velocity microphone as disclosed in the aforementioned patent and having high sensitivity, the response falls off at the low frequencies due to the fact that the mechanical impedance of the vibrating system is not proportional to the frequency. The primary object of my present invention is to provide an improved microphone which will not be subject to this disadvantage.

More particularly, it is an object of my present invention to provide an improved velocity microphone which will have greater sensitivity than similar microphones heretofore known without loss of response throughout its working range.

A further object of my present invention is to provide an improved velocity microphone wherein there will be no loss in response due to the reaction of the mechanical impedance resulting from the associated electrical circuit upon the conductor.

Another object of my present invention is to provide, in a velocity microphone, an improved baffle which changes its effective acoustic dimensions with changes in frequency.

Still another object of my present invention is to provide an improved velocity microphone in which driving forces for the conductor will be developed as a function of the frequency of the sound waves picked up thereby.

It is also an object of my present invention to provide an improved velocity microphone which is simple in construction, inexpensive to manufacture, and highly efficient in use.

According to my present invention, I provide a microphone with a baffle in which the acoustic path varies with the frequency of the sound waves picked up by the microphone. It is well known that the three-dimensional acoustic impedance of the path between the two sides of the ribbon increases with frequency, being very small at the low frequencies. Therefore, if at least a part of the baffle is made of a material having an acoustic resistance which will be comparable to the path impedance at the low frequencies, it will be negligible at the high frequencies. In accordance with one form of my present invention, the baffle may consist of a layer of fine mesh, foraminated material, such as silk, supported on a suitable frame and disposed adjacent the pole pieces, or the longitudinal edges of the ribbon conductor usually employed in velocity microphones. At the low frequencies, the impedance of the silk is comparable to the acoustic impedance of the path between the two sides, that is, the front and back surfaces, of the ribbon. At the high frequencies, the acoustic impedance of the silk is small compared to the acoustic impedance of this path. Thus, the baffle is not fixed but is a function of the frequency, and this means that it is possible to obtain driving forces for the ribbon which vary as a function of the frequency of the sound waves picked up by the microphone.

In accordance with another form of my invention, the baffle may be constituted by a pair of tensioned membranes somewhat similar to the ribbon itself and disposed one along each of the longitudinal edges thereof. At the low frequencies, the baffles do not move and they are, effectively, rigid members constituting a continuation of the pole pieces. At some higher frequency, depending upon such factors as the thickness of each membranous baffle, its stiffness, and so on, the baffles will resonate and the path of the sound waves from one side of the ribbon to the other will be determined, effectively, by the size of the pole pieces.

In still another form of my present invention, the baffle may be constituted by a pair of rigid members of gradually varying thickness each so disposed adjacent one edge of the ribbon that the thickest portion thereof is nearest to the ribbon and the thinnest portion thereof most remote from the ribbon. These members are provided with a series of bores or openings of progressively larger diameter and extending in the direction of movement of the ribbon, the openings with the smallest diameter being formed in the thickest portion of each baffle, and the openings with the largest diameter being formed in the thinnest portion of the baffle. At low frequencies, the impedance of each of the openings is great and therefore the low frequencies must pass entirely around the baffle to reach the opposite side of the ribbon. As the frequencies increase, the impedance of the various openings, from larger diameter to smaller diameter becomes relatively smaller gradually and therefore the high frequencies can pass through the smaller openings. Here, again, therefore, a variable acoustic path, dependent upon the frequency of the sound waves picked up, is provided.

The novel features that I consider characteristic of my invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description of several embodiments thereof, when read in connection with the accompanying drawings, in which

Figure 1 is a front elevation of one form of my improved microphone with the cover removed,

Figure 2 is a side elevation thereof, partly in section,

Figure 3 is a sectional view taken on the line III—III of Fig. 1,

Figure 4 is a front elevation of a second form of my invention,

Figure 5 is a top plan view of this form of my invention with the magnets removed,

Figure 6 is a fragmentary front elevation of a third form of my invention,

Figure 7 is a sectional view taken on the line VII—VII of Fig. 6,

Figures 8, 9 and 10 are theoretical curves showing, by comparison, various features of the conventional velocity microphone and my improved velocity microphone, and

Figure 11 is an actual response curve showing the increase in response over the conventional velocity microphone which may be obtained with my improved microphone.

Referring more particularly to the drawings, wherein similar reference characters designate corresponding parts throughout, there is shown, in Figures 1, 2 and 3, a casing 1 which supports a pair of magnets 3 to which are secured a pair of pole pieces 5, the latter being in spaced relation to each other to provide an air gap 7. Movably supported in the air gap 7 by terminal strips 8 for vibration in response to sound waves impinging on both front and back surfaces or sides thereof is a conductor 9 which may be in the form of a crimped ribbon, the ribbon or conductor 9 having its longitudinal edges spaced slightly from the pole pieces 5.

In the conventional microphone, the pole pieces 5 constitute the baffles around which the sound waves must pass from the front surface of the ribbon 9 to the back surface thereof, as clearly disclosed in Figure 10 of my above identified patent. In my improved microphone, I form the pole pieces 5 substantially C-shaped in longitudinal cross-section and secure to each of the pole pieces 5 layers of fine mesh silk, or the like, 11 which extend substantially the entire length of the ribbon 9 adjacent the longitudinal edges thereof. At the lower frequencies, the sound waves must pass entirely around the pole pieces 5 and the silk baffles 11 in a path represented by the line A (Fig. 3). At the higher frequencies, however, the sound waves can pass through the perforations of the silk screens 11 somewhat along a path represented by the line B (Fig. 3). It will be seen, therefore, that the sound wave paths between the opposite sides of the conductor 9 will vary in length, or will have effective acoustic dimensions, as a function of the frequency of the sound waves picked up by the microphone, and therefore the driving forces which actuate the conductor 9 will similarly vary as a function of the frequency of the sound waves.

In the form of my invention shown in Figs. 4 and 5, the baffles are constituted by the membranous elements or ribbons 13 which are placed under tension. For this purpose, the pole pieces 5 may be slotted at their ends for the reception of the baffles 13 the ends of which extend beyond the ends of the pole pieces and are secured to terminal blocks 15. Each of the blocks 15 may have two or more screws 17 threaded therein and bearing against, or set into, the ends of the pole pieces 5. It is obvious that the screws 17 may be adjusted to vary the tension of the baffles 13 and therefore to alter their resonant frequency. As in the case of the first described modification, the sound waves of low frequency pass around the pole pieces 5 and the baffles 13 along a path represented by the line A (Fig. 5). At some resonant frequency determined by the size, tension, etc., of the baffles 13, the baffles will resonate and the effect thereof will be to shorten the path length of the sound waves around only the pole pieces 5, to provide a shortened path similar to the path B shown in Fig. 3. In between these low and high frequencies, the baffles 13 will be only partly effective. Here again, therefore, the effective acoustic dimensions of the baffles 13 vary as a function of the frequency of the sound waves picked up by the microphone.

In the modification of my invention shown in Figs. 6 and 7, the baffles are constituted by substantially wedge-shaped members 19 disposed between the end portions of the pole pieces 5 with their thickest portions most proximate to the longitudinal edges of the ribbon 9 and their thinnest portions most remote therefrom. The baffles 19 are provided with a plurality of vertical rows of bores or passages 21 which extend therethrough in a direction normal to the plane of the ribbon 9, or in the direction of movement of the ribbon 9, the passages 21 being of gradually increasing cross-sectional dimensions in going from the thickest portion of the baffles 19 to the thinnest portion thereof. In other words, the thinnest but longest passages 21 are formed in the thichest part of the baffles 19, or nearest to the ribbon 9, and the passages 21 thereafter progressively increase in cross-sectional dimension while decreasing in length as the thinnest parts of the baffles 19 are approached. It will be obvious that, at the lower frequencies, the impedance of the passages 21 is relatively high and therefore the low frequency sounds will pass around the pole pieces 5 and the baffles 19, as in the case of the modifications previously described. As the frequency of the sound waves picked up by the microphone is increased, the impedance of the passages 21 will be gradually decreased from the larger diameter passages to the smaller diameter passages until, at the high frequencies, the baffle 19 will become ineffective and the sound waves will have to pass only around the pole pieces 5.

Referring, now, to Figs. 8 to 11, inclusive, the advantages of my improved microphone will be further pointed out. In the conventional velocity microphone, the acoustic path from the front to the back of the ribbon 9 does not vary with frequency. Therefore, the difference in pressure between the two sides of the ribbon 9 is linearly proportional to the frequency, as shown by the dotted curve I in Fig. 8. The mechanical impedance of a mass controlled ribbon, such as is commonly employed for velocity microphones, is linearly proportional to the frequency, as shown by the dotted curve III in Fig. 9. Therefore, the velocity, and hence the voltage generated by the moving conductor, is independent of the frequency, and the response of the conventional microphone is illustrated by the curve V of Fig. 10. When the sensitivity of the velocity microphone is increased in the manner indicated heretofore, the effect of the electrical circuit is reflected into the mechanical system so that the mechanical impedance characteristic becomes as shown by the non-linear curve IV of Fig. 9. The result of this is to make the response fall off at the lower frequencies, as shown by the curve VI of Fig. 10. To compensate for this loss, the baffle may be constructed in accordance with any of the forms heretofore described, or any equivalent forms. This has the effect of increasing the ratio $\Delta p/p$ (where Δp is the difference in pressure of the sound wave on the two sides of the ribbon 9, and p is the pressure of the sound wave in free space) by increasing the size of the baffle at the low frequencies, as shown by the non-linear curve II in Fig. 8. This raises the response to approximately that shown by the curve V in Fig. 10. Fig. 11 shows a set of curves similar to those of Fig. 10 but based upon actual test, whereas the curves of Fig. 10 are theoretical.

From the foregoing description, it will be apparent to those skilled in the art that I have provided an improved velocity microphone which is much more sensitive than conventional velocity microphones without loss of response or frequency discrimination. Although I have shown and described several embodiments of my present invention, it will be apparent to those skilled in the art that many other modifications thereof are also possible. I therefore do no wish to be limited except insofar as is made necessary by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. In a pressure gradient responsive microphone, the combination of means providing a magnetic path including an air gap, a conductor mounted for movement in said air gap in response to differences in sound wave pressure on opposite sides thereof, and means for deriving from the sound waves driving forces for actuating said conductor which vary as a non-linear function of the frequency of said sound waves.

2. In a pressure gradient responsive microphone, the combination of means providing a magnetic path including an air gap, a conductor mounted for movement in said air gap in response to differences in sound wave pressure on opposite sides thereof, and means associated with said conductor providing a variable acoustic path difference between said opposite sides which varies as a function of the frequency of said sound waves.

3. In a pressure gradient responsive microphone, the combination of means providing a magnetic path including an air gap, a conductor mounted for movement in said air gap in response to differences in sound wave pressure on opposite sides thereof, and baffle means associated with said conductor providing variable sound wave path differences between the opposite sides of said conductor which vary as a function of the frequency of the sound waves.

4. In a pressure gradient responsive microphone, the combination of means providing a magnetic path including an air-gap, a conductor mounted for movement in said air gap in response to differences in sound wave pressure on opposite sides thereof, and means adjacent said conductor constituting a variable baffle effective to alter the acoustic dimensions of the path to one side of said conductor to a greater extent than to the other side thereof and as a function of the frequency of the sound waves.

5. In a pressure gradient responsive microphone, the combination of means providing a magnetic path including an air gap, an elongated conductor mounted for movement in said air gap in response to differences in sound wave pressure on opposite sides thereof, and means adjacent the longitudinal edges of said conductor constituting variable baffles effective to alter the acoustic dimensions of the path to one side of said conductor to a greater extent than to the other side thereof and as a function of the frequency of the sound waves.

6. The invention set forth in claim 5 characterized in that said last named means comprises a pair of perforated members disposed one adjacent each longitudinal edge of said conductor.

7. The invention set forth in claim 5 characterized in that said last named means comprises a pair of foraminous screens of relatively fine mesh, one adjacent each longitudinal edge of said conductor.

8. The invention set forth in claim 5 characterized in that said last named means comprises a pair of fine silk screens disposed one adjacent each edge of said conductor.

9. The invention set forth in claim 5 characterized in that said last named means comprises a pair of tensioned membranous members disposed one adjacent each longitudinal edge of said conductor.

10. The invention set forth in claim 5 char-

acterized in that said last named means comprises a pair of tensioned membranous members disposed one adjacent each longitudinal edge of said conductor, and characterized further by the addition of means for varying the tension of said members.

11. The invention set forth in claim 5 characterized in that said last named means comprises a pair of members of gradually varying thickness disposed one adjacent each longitudinal edge of said conductor, said members having their thickest portions most proximate to said conductor and their thinnest portions most remote from said conductor, and each of said members having a plurality of passages therein of different cross-sectional dimensions, said passages extending through said members parallel to the direction of movement of said conductor.

12. The invention set forth in claim 5 characterized in that said last named means comprises a pair of members of gradually varying thickness disposed one adjacent each longitudinal edge of said conductor, said members having their thickest portions most proximate to said conductor and their thinnest portions most remote from said conductor, and each of said members having a plurality of passages therein of progressively larger cross-sectional dimensions from said thickest portions to said thinnest portions, and said passages extending through said members parallel to the direction of movement of said conductor.

13. In a pressure gradient responsive microphone, the combination of means providing a magnetic path including an air gap, an elongated conductor mounted for movement in said air gap in response to differences in sound wave pressure on opposite sides thereof, and means adjacent the longitudinal edges of said conductor constituting variable baffles effective to alter the acoustic dimensions of the path to one side of said conductor to a greater extent than to the other side thereof and as a function of the frequency of the sound waves, said last named means extending substantially along the entire length of said conductor.

14. Apparatus for converting sound vibrations into electrical variations which comprises a body subject at opposite sides thereof to pressure variations due to sound waves, means for supporting said body for movement in response to said pressure variations, means for converting the movement of said body into corresponding electrical variations, and means associated with said body constituting a variable baffle providing sound path differences between said opposite sides of said body which vary as a function of the frequency of the sound waves acting on said body.

15. The method of operating a microphone which includes a movable element responsive to the pressure gradient components of sound waves which comprises deriving from the sound waves actuating forces which vary as a non-linear function of the frequency of said sound waves, and causing said forces to actuate said element.

HARRY F. OLSON.