Feb. 3, 1942. H. F. OLSON 2,271,988

ELECTROACOUSTICAL APPARATUS

Filed April 29, 1939 2 Sheets-Sheet 1

Fig. 1.

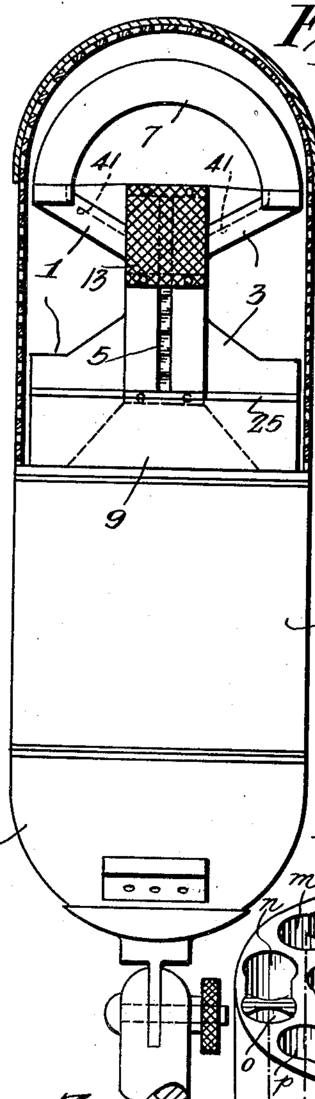

Fig. 2.

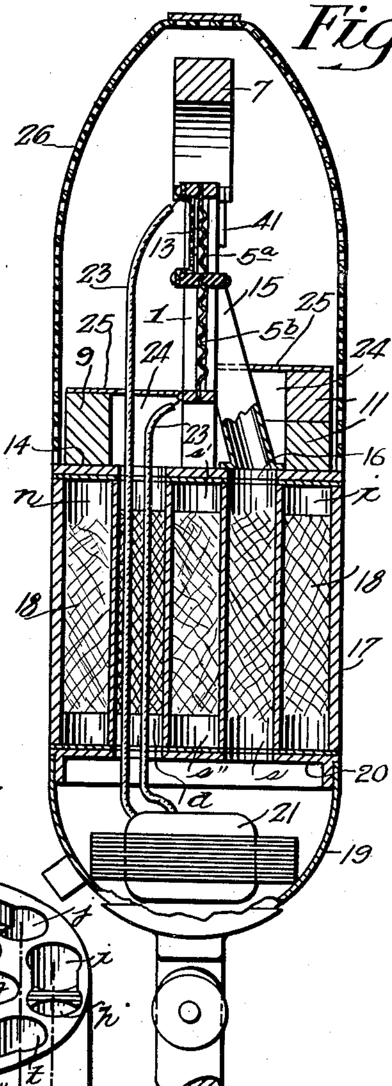

Fig. 3.

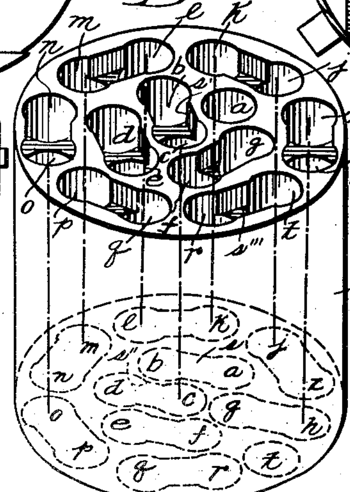

Fig. 7.

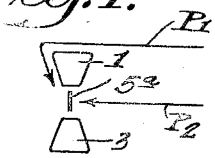

Fig. 8.

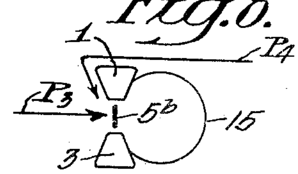

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Fig. 4.

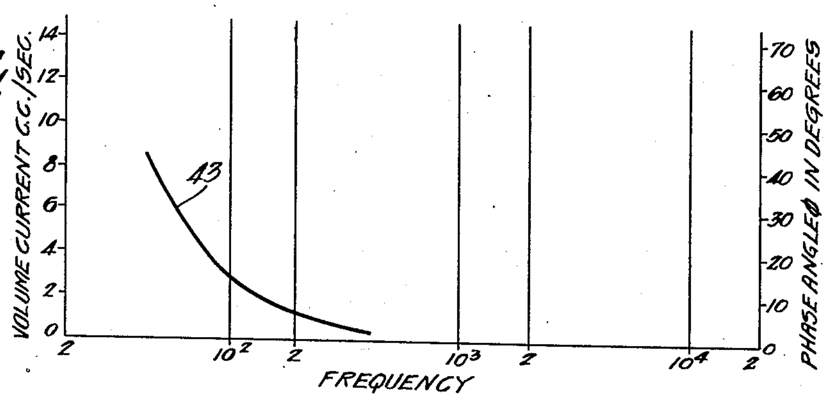


Fig. 5.

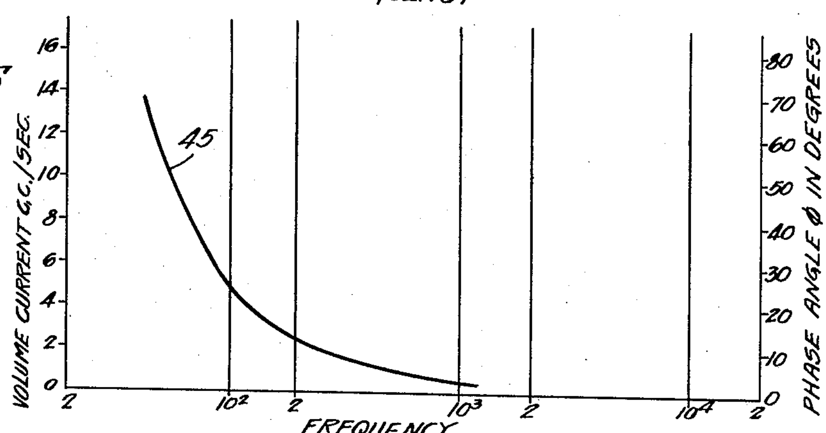
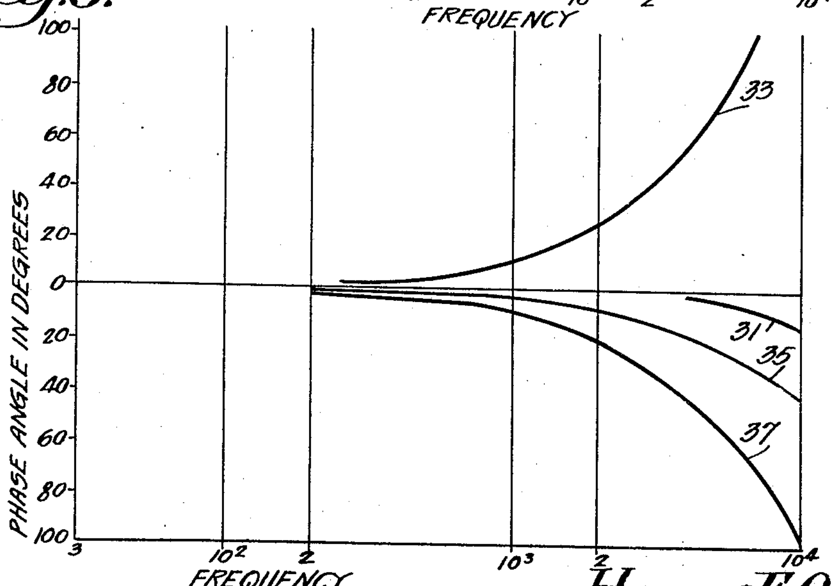


Fig. 6.



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Patented Feb. 3, 1942 2,271,988

UNITED STATES PATENT OFFICE

2,271,988

ELECTROACOUSTICAL APPARATUS

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

Application April 29, 1939, Serial No. 270,801

9 Claims. (Cl. 179—115.5)

This invention relates to electro-acoustical apparatus, and more particularly to microphones of the unidirectional type, the present invention being an improvement upon that disclosed and claimed in the copending application of Leslie J. Anderson, Serial No. 88,174, filed June 30, 1936, and assigned to Radio Corporation of America.

The unidirectional microphone has been found very useful in all types of sound collection because of its cardioid characteristic, and for this reason it is preferred as a universal microphone. As heretofore constructed, however, it has been of comparatively large size and of relatively great weight, and this has limited its use for many applications.

The primary object of my present invention is to provide an improved unidirectional microphone which is free from the aforementioned objections and which, therefore, will have a much wider application than similar microphones of the prior art.

More particularly, it is an object of my present invention to provide an improved unidirectional microphone which, while extremely rugged in construction, is nevertheless very compact and of light weight, the microphone being particularly adapted for being supported on so-called "fish-pole" supports used in sound-motion picture work, for example.

Another object of my present invention is to provide an improved unidirectional microphone as aforesaid in which the resonant frequencies of the movable conductor and of the cavities surrounding it are reduced to a minimum.

Still another object of my invention is to provide an improved unidirectional microphone wherein the acoustic resistance or pipe terminating the pressure responsive section of the movable conductor is of extremely simple construction and practically free from the possibilities of leakage.

A further object of my invention is to provide an improved unidirectional microphone wherein a high order of cancellation is obtained for sounds arriving at 180° with respect to the front of the movable conductor.

Still further objects of my invention are to provide an improved microphone as aforesaid which has greater sensitivity than previously known microphones, and to provide a unidirectional microphone which has an improved directional characteristic and greater efficiency.

In accordance with my present invention, I provide a solid supporting member for the operating parts of the microphone and form a series of intercommunicating passages in said member to constitute an acoustic labyrinth for terminating the pressure responsive section of the movable conductor of the microphone, the labyrinth terminating in a cover which houses the output transformer and the volume of which adds effectively to the length of the labyrinth. Resonances in the velocity section of the conductor are almost entirely eliminated by providing an open structure around it, and a silk screen placed over the velocity section serves not only to reduce the frequency of any resonances which may occur, but also to damp the amplitude of oscillation of the velocity section. The magnetic structure is arranged so that permanent magnets are located at the upper end of the velocity responsive section and in the vicinity of the pressure responsive section of the conductor, and suitable covers are placed over the latter magnets to eliminate resonance of the cavities formed by these magnets.

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 thereof, when read in connection with the accompanying drawings in which

Figure 1 is a front elevation of one form of microphone according to my present invention, with the cover shown in section;

Figure 2 is substantially a central sectional view thereof;

Figure 3 is an isometric view of the acoustic labyrinth;

Figure 4 is a curve showing the volume current of the pressure responsive section of microphone at low frequencies;

Figure 5 is a curve showing the volume current of the velocity responsive section of the microphone at low frequencies;

Figure 6 is a curve showing the characteristics of a unidirectional microphone according to my invention and which will give a minimum response at 180° for the higher frequencies;

Figure 7 is a diagrammatic, plan view of the pole structure and moving conductor of the velocity section of the microphone; and

Figure 8 is a similar view of the pressure section of the microphone.

Referring more particularly to the drawings, wherein similar reference numerals designate corresponding parts throughout, there is shown, in Figs. 1 and 2, a pair of pole-pieces 1 and 3 of magnetic material spaced apart to provide an air-gap therebetween for the reception of a conductive, vibratile member 5, such as a crimped aluminum ribbon. The ribbon is fixed at each of its ends and also at a point substantially midway between its ends to provide two serially connected sections 5*a* and 5*b*. Flux is provided for the air-gap by a plurality of permanent magnets 7, 9 and 11, the magnet 7 resting on top of the pole-pieces above the upper end of the section 5*a*, the magnet 9 contacting the front of the pole-pieces, and the magnets 11 contacting the rear of the pole-pieces, as clearly shown in Fig. 2.

The ribbon section 5*a* is open to the atmosphere, both at the front and rear thereof, and therefore is responsive to the particle velocity of a sound wave striking the same from either direction. Since the magnetic structure is not located behind the section 5*a*, as in conventional prior art microphones, there are no cavities formed around this section to give trouble from annoying resonances. The section 5*b* of the vibratile member 5 is terminated by an acoustical impedance comprising a folded pipe more particularly described hereinafter. Due to the finite length of this pipe, the impedance terminating the ribbon section 5*b* has a capacitive component as well as a resistive component. Therefore, the velocity of the ribbon section 5*b* leads the actuating pressure of the sound waves at the low frequencies. Using a conventional velocity microphone with this sort of pressure microphone, it is not possible to obtain good cancellation at the low frequencies for sounds reaching the ribbon 5 at either 0° or 180°. I have found, however, that if a resistance in the velocity section 5*a* of the ribbon 5 is provided and adjusted to be in phase with the pressure section for sound arriving at 0° or out of phase at 180°, good cancellation will be obtained for the low frequencies. In other words, the resistance in the velocity responsive section 5*a* compensates for the capacitive component in the line terminating the pressure section 5*b*. For this purpose, I have provided a resistance 13 in the form of a layer of silk having relatively fine interstices. The piece of silk 13 should be mounted close to the ribbon section 5*a* and should be airtight along the edges where it is mounted, so that any air blown therethrough will have to pass through the interstices thereof. The motion of the ribbon section 5*a* is thus influenced or controlled by the silk resistance 13, the two being in series.

The pressure section 5*b* of the vibratile conductor is covered at its rear by a tube 15 which communicates with one end of a relatively long, continuous passage formed in a single, solid supporting member 17. To provide this long, continuous passage, the member 17 is formed with a plurality of bores extending longitudinally therethrough in parallel relation and communicating with each other serially at opposite ends in a manner more clearly shown in Fig. 3. The pipe 15 may, for example, be coupled to the upper end of the longitudinal bore *a* in the member 17 through an opening 16 in a plate 14 which covers the top of the member 17, the bore *a* communicating at the bottom of the member 17 with the adjacent bore *b* by means of an interconnecting slot *s*. Returning to the top of the member 17 through the bore *b*, it will be noted that the bore *b* is at this point connected to the next adjacent bore *c* by a communicating slot *s'*. Thereupon, the passage continues down through the bore *c* to the bottom of the member 17 where it communicates with the next adjacent bore *d* by means of a connecting slot *s''* and so on through the bores *e, f, g, h, i, j, k, l, m, n, o, p, q* and *r*. The top of the bore *r* is connected to the final bore *t* by a communicating slot *s'''*, and the bore *t* extends downwardly and terminates, through a suitable opening in a plate 20 which covers the bottom of the member 17, into a hollow, hemispherical, cup-shaped member 19 of substantial volume, the volume of the cup 19 serving to add to the length of the continuous passage *a—t*. Theoretically, the labyrinthian passage *a—t* should be of infinite length, but since this is impossible, the passages *a—t* may be filled with suitable damping material 18, such as loosely packed, uniformly distributed hair felt or the like, in order to simulate the effect of a loading pipe of infinite length. Advantage may also be taken of the space within the cup 19 to house an output transformer 21 therein to which the ends of the ribbon 5 may be connected by suitable leads 23. This construction helps to maintain the whole structure very compact.

The magnets 9 and 11 resting, as they do, on top of the member 17 and against the bottom of the front and rear of the pole-pieces 1 and 3, form cavities in the vicinity of the ribbon section 5*b* which are apt to resonate at an objectionable frequency. To avoid such resonance, the covers 25 may be placed over the magnets. A suitable perforated screen 26 may be placed around the parts of the microphone above the supporting member 17 in order to protect these parts from injury.

As is well known, the unidirectional microphone consists of the combination of a non-directional element and a bi-directional element. To obtain a true cardioid characteristic, the response of the non-directional microphone must be independent of the direction. The response of the bi-directional unit must be a true cosine characteristic. Not only must the sensitivity of the two units be the same, but the phase difference between the two units must be either 0° or 180°.

In considering the factors involved in obtaining a high order of cancellation in the unidirectional microphone for sounds arriving at 180° with respect to the front of the ribbon 5, the first consideration will be of the deviations in the phase of the bi-directional and non-directional units. The impedance of the velocity microphone consists of the mass reactance of the ribbon, the mass reactance of the air load and the resistance of the air load. The resistive component of the air load causes a phase shift in the velocity microphone. There is also a phase shift in the velocity microphone due to diffraction. These two phase shifts may be represented, respectively, by the curves 31 and 33 shown in Fig. 6.

In the case of the pressure microphone, if the system is resistance controlled, the velocity of the ribbon will be in phase with the actuating pressure. Due to the mass reactance of the ribbon and the mass reactance of the air load, a phase shift is introduced, as represented by the curve 35 in Fig. 6. In addition to this phase shift, there is a phase shift due to diffraction for 0° and 180°, this phase shift being represented by the curve 37 in Fig. 6.

The velocity microphone is actuated by the difference in pressure between the two sides of the ribbon. Assume that the plane of the ribbon section **5**a is the reference plane in Fig. 7. The pressure on the front of the ribbon, as represented by the line P_1 in Fig. 7 may be written

$$P_1=P_0 \sin \omega t$$

where P_0 is the amplitude of the sound pressure. The pressure on the back of the ribbon, as represented by the line P_2 in Fig. 7, is

$$P_2=P_0 \sin\left(\omega t-\frac{2\pi}{\lambda}d\right)$$

where d is the difference in path lengths between the paths P_1 and P_2 as shown in Fig. 7.

Let

$$\omega t=\omega t'+\frac{\pi}{\lambda}d.$$

Then

$$P_1=P_0 \sin\left(\omega t'+\frac{\pi}{\lambda}d\right),$$

and

$$P_2=P_0 \sin\left(\omega t'-\frac{\pi}{\lambda}d\right)$$

The difference in pressure between the two sides

$$\Delta P=2P_0 \cos \omega t' \sin\frac{\pi d}{\lambda}$$

$$\Delta P=2P_0 \cos\left(\omega t-\frac{\pi}{\lambda}d\right)\sin\frac{\pi d}{\lambda}$$

This is the actuating force.

The velocity of the ribbon section **5**a, assuming mass control, is given by

$$\dot{X}=\frac{2P \cos\left(\omega t-\frac{\pi}{\lambda}d\right)\sin\left(\frac{\pi d}{\lambda}\right)}{jm}$$

$$\dot{X}=\frac{2P \sin\left(\omega t-\frac{\pi}{\lambda}d\right)\sin\left(\frac{\pi d}{\lambda}\right)}{m}$$

where m is the mass of the ribbon section **5**a.

In this consideration, a mass controlled system is taken as reference.

Referring now to Fig. 8, which relates to the pressure section of the microphone, for sound arriving at $\theta=0°$, the pressure on the ribbon is

$$P_3=P_0 \sin \omega t$$

For sound arriving at $\theta=180°$, the pressure on the ribbon is

$$P_4=P_0 \sin\left(\omega t-\frac{2\pi d}{\lambda}\right)$$

By considering all the phase shifts, it is now possible to compute the response of the unidirectional microphone for $0=0°$ and $\theta=180°$. It will be noted that the two diffraction effects tend to cancel. As a matter of fact, in the design of my improved microphone, the velocity path is made larger than the pressure path so that the various phase shift effects cancel each other. This may be done, for example, by providing the baffles **41** adjacent the velocity section **5**a (Figs. 1 and 2).

The foregoing discussion with reference to Fig. 6 deals with the higher frequencies. At the lower frequencies, the velocity of the pressure responsive section **5**b leads the pressure in the sound wave. This is due to the capacitance of the acoustic impedance line represented by the pipe **15** and the labyrinth **17** together with the cover **19**. The resistance introduced by the silk **13** causes the velocity of the velocity section **5**a of the conductor to lead the particle velocity in the sound wave. Thus, the addition of the silk impedance element **13** tends to bring the velocity section **5**a and the pressure section **5**b into phase, as shown by the curves **43** and **45** in Figs. 4 and 5, respectively. This is a distinct improvement over existing microphones which do not provide any means for compensating for the capacitance of the pipe or labyrinth.

From the foregoing description, it will be apparent to those skilled in the art that I have provided a novel and improved unidirectional microphone which is not only more compact than similar microphones heretofore known, but which is of great sensitivity and of greater efficiency than microphones of the prior art. It will also undoubtedly be apparent to those skilled in the art that, while I have shown but a single embodiment of my invention, many other modifications thereof and changes in the particular embodiment disclosed herein may be made within the spirit of my invention. I therefore desire that my invention shall not 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 electro-acoustical apparatus, a vibratile element, and means associated with at least a portion of said element for rendering said portion responsive to the pressure of a sound wave, said means including a solid member having a series of passages extending longitudinally therethrough and means affording communication between said passages to provide a continuous passage of relatively great length associated with said portion.

2. In electro-acoustical apparatus, a vibratile element, and means associated with at least a portion of said element for rendering said portion responsive to the pressure of a sound wave, said means including a solid member having a series of parallel passages extending longitudinally therethrough and means affording serial connection between said passages whereby to provide a continuous passage of relatively great length.

3. In electro-acoustical apparatus, a vibratile element, and means associated with at least a portion of said element for rendering said portion responsive to the pressure of a sound wave, said means including a solid member having a series of parallel passages extending longitudinally therethrough and means affording serial connection between said passages whereby to provide a continuous passage of relatively great length, and a tubular member coupling said continuous passage to said portion.

4. In electro-acoustical apparatus, a vibratile element, and means associated with at least a portion of said element for rendering said portion responsive to the pressure of a sound wave, said means comprising a solid member having a plurality of passages extending longitudinally therethrough and means affording serial connection between said passages to provide a continuous passage of relatively great length, a tubular member coupling said portion to one end of said continuous passage, and a hollow closure member closing the other end of said passage and constituting a terminating extension therefor.

5. The invention set forth in claim 4 charac-

terized by the addition of a transformer housed within said closure member, and characterized further in that said vibratile element is electrically connected to said transformer.

6. In a microphone, the combination of magnetic field structure including an air-gap, a vibratile conducting member mounted in said air-gap for movement therein in response to sound waves impinging thereon from both the front and back thereof, and means providing an acoustical resistance mounted closely adjacent to said element whereby said resistance and said element are acoustically in series.

7. In a microphone, the combination of magnetic field structure including an air-gap, a vibratile conducting element mounted in said air-gap for movement therein in response to sound waves impinging thereon from both the front and the back thereof, and an acoustical resistance in front of and closely adjacent to said element whereby said resistance and said element are acoustically in series.

8. The invention set forth in claim 7 characterized in that said acoustical resistance is constituted by a piece of silk.

9. In a unidirectional microphone, the combination of a vibratile conductive element having a portion responsive to the particle velocity of sound waves impinging thereon and another portion responsive to the pressure of said sound waves, said latter portion being terminated by an acoustic impedance line having a capacitance tending to cause the velocity of said second named portion to lead the pressure of the sound waves impinging thereon by a certain amount, and an acoustic resistance associated with said first named portion effective to cause the velocity of said first named portion to lead the particle velocity of said sound waves by the same amount whereby to cause the outputs of both of said portions to be in phase.

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