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MICROPHONE

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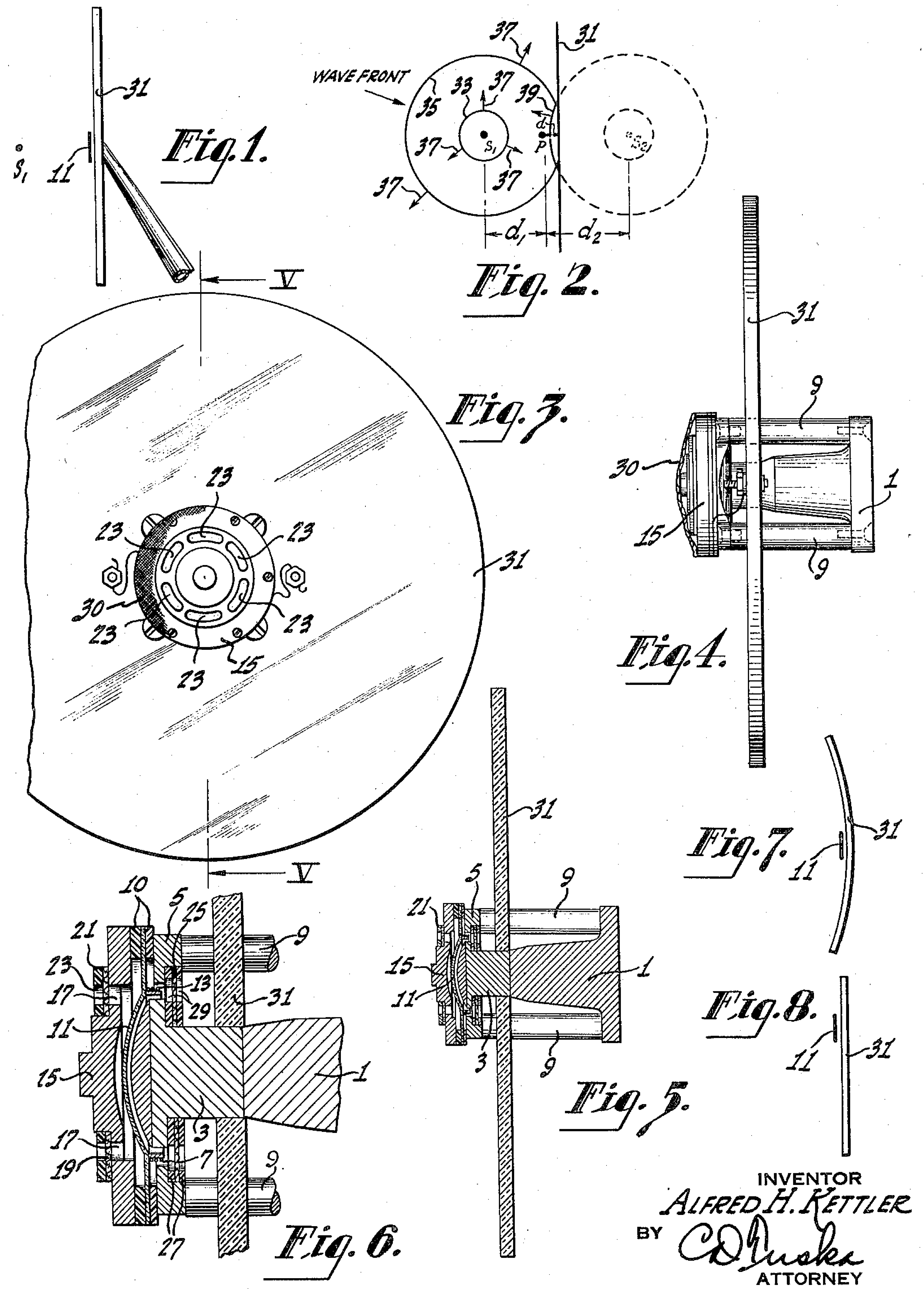


INVENTOR
ALFRED H. KETTLER
BY C. D. Tuska
ATTORNEY

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2,544,536

## MICROPHONE

Alfred H. Kettler, Collingswood, N. J., assignor to Radio Corporation of America, a corporation of Delaware

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This invention relates to microphones, and more particularly to a pressure gradient responsive microphone which has highly desirable discriminating characteristics against unwanted sounds.

The undesirable pick up of noise by microphones has long been a problem, particularly in aircraft, engine rooms, engine test rooms, power plants, etc. It has also been the experience of users of microphones that the undesirable pick up of the speech of nearby persons in announce booths, paging booths, offices, etc., is annoying and frequently embarrassing. Similarly, the undesirable pick up of amplified speech in public address or amplifier systems which leads to "feed-back" (whistles, howls, etc.) under conditions of high amplification has also been a source of considerable annoyance. In prior attempts to solve these and other similar problems in connection with the pick up of sound by microphones, various types of microphones have been proposed, among them being the pressure operated microphones, throat microphones, pressure gradient or "velocity" microphones of the first order, and second order gradient microphones. However, each of these is subject to one or another disadvantage which renders it not entirely suitable.

Of the several types of prior art microphones mentioned in the preceding paragraph, perhaps the most satisfactory is a second order gradient microphone of the type disclosed in the Olson Patent, 2,301,744. In a microphone of this type, the difference in output of two first order pressure gradient microphones placed very close together is employed so as to give, effectively, the pressure gradient of the pressure gradient. This arrangement has the advantages that it provides considerably less response to distant noises than the first order gradient type of microphone, and also that it provides considerably less response to random direction noise than the latter type of microphone. Because of its improved discrimination, this second order gradient microphone need not be used directly against the lips or against the throat of the user, as with the other types. It is, however, a more complicated structure than any of the other microphones mentioned above, requiring two units which should be as nearly identical in sensitivity and frequency response as possible, and also requiring small size so that the spacing between the individual first order gradient microphone units may be made very small. Another disadvantage of this type of second order gradient microphone

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is that the air stream may also cause disturbing noises.

The primary object of my present invention is to provide an improved pressure gradient responsive microphone which can be operated to provide a second order gradient effect and which will be free from the above mentioned and other disadvantages characteristic of prior art microphones.

More particularly, it is an object of my present invention to provide an improved pressure gradient responsive microphone which will have superior discriminating characteristics against unwanted sounds, particularly those arising at a distance of several feet or more.

Another object of my present invention is to provide an improved pressure gradient responsive microphones as aforesaid, which, while offering performance at least equal to that of the above noted Olson microphone, is nevertheless of greatly simplified construction and can be manufactured at a much lower cost.

Still another object of my present invention is to provide an improved pressure gradient responsive microphone as above set forth which has a substantially unidirectional characteristic, particularly at the higher frequencies.

It is also an object of my present invention to provide an improved pressure gradient responsive microphone as above set forth which is very simple in construction, economical in cost, and highly efficient in use.

In accordance with my present invention, I make use of but a single first order pressure gradient or "velocity" responsive microphone and place in close proximity to one side of the vibratile member thereof a reflector, preferably in the form of a disk made of rigid, non-resonant material. This reflector disk has an area which is considerably larger than that of the vibratile member of the microphone. The microphone is small (the size limitation being, for example, the high frequency performance which is desired), and it is so constructed that its moving element may be placed close to the reflector. The arrangement is such that a sound wave from a source external to the microphone can pass directly to both surfaces of the vibratory element thereof. The sound wave is also reflected back to the vibratory element by the reflector which is in close proximity to it. Thus, the vibratory element can be actuated simultaneously by the pressure gradients of both the direct sound and the reflected sound, so that, the pressure gradient of these pressure gradients provides the force which moves the movable element. It is apparent, therefore, that the movable element of the microphone is moved according to a second order pressure gradient effect.

The distance between the movable element of the microphone and the reflector should be small compared to the focal length of the reflector. In one microphone constructed in accordance with the present invention, this distance was of the order of 1/8'', although it could be made either smaller or larger depending upon the frequency below which best discrimination is desired. In general, the smaller this distance is, the higher this frequency. The reflector should preferably be of non-resonant material, approximately 1/8'' thick and of the order of 6'' in diameter where, for example, the movable element or diaphragm of the microphone is of the order of 3/4'' in diameter. The reflector may be in the form of a flat, transparent disk arranged coaxially with the diaphragm. A disk made of transparent material, such, for example, as certain polymerized methyl methacrylate resins available in the market in transparent form, has the advantage that it offers no obstruction to vision when the user is looking downward, the disk reflector being usually out of the line of sight when the speaker is looking straight ahead. If desired, the reflector may be made concave or convex, the degree of curvature determining speech diffracting and focusing effects. If desired, also, the reflector may be mounted off center with respect to the diaphragm axis so as to avoid symmetry and so to provide increased vision clearance.

The novel features of my present invention, both as to its organization and method of operation, as well as additional objects and advantages thereof, will better be understood from the following description, when read in connection with the accompanying drawing in which

Figures 1 and 2 are diagrammatic views, in side elevation, of a microphone in accordance with my present invention, these figures being referred to hereinafter for the purpose of explaining the principle involved in its operation,

Figure 3 is a front elevation of one form of microphone constructed in accordance with my present invention,

Figure 4 is a side elevation thereof,

Figure 5 is a sectional view taken on the line V—V of Fig. 3 with the wind screen omitted,

Figure 6 is an enlarged, fragmentary sectional view of a portion of the structure shown in Fig. 5, and

Figures 7 and 8 are diagrammatic views, in side elevation, showing slightly different forms of microphones in accordance with my present invention.

Referring more particularly, first, to Figs. 3 to 6, inclusive, there is shown a pressure gradient responsive microphone having a field structure consisting of a magnet **1**, a center pole piece **3** thereon, an annular pole piece **5** arranged concentrically with the pole piece **3** and spaced therefrom to provide an air gap **7**, and a plurality of studs **9** of magnetic material which connect the annular pole piece **5** with the base of the magnet **1**. Suitably supported on the annular pole piece **5** between a pair of clamping rings **10** is a vibratory diaphragm **11** which is provided with a voice coil or conductive element **13** disposed in the air gap **7** in well-known manner. The microphone is provided with a cap **15** having a plurality of circumferentially spaced slots or openings **17** therein through which sound waves from an external source may pass to the front surface of the diaphragm **11**. A screen **19** of silk or the like may be placed over the openings **17** and held thereon by a suitable clamping ring **21** which is provided with circumferentially spaced openings **23** corresponding in number and size to the openings **17**. A second screen **25**, also of silk or the like, may be held in place behind the air gap **7** by a pair of clamping rings **27**. At the same time that sound waves from an external source reach the front surface of the diaphragm **11** through the openings **17**, the sound waves may reach the rear surface of the diaphragm **11** through a plurality of circumferentially spaced, aligned openings **29** in the clamping rings **27**. It will be apparent, therefore, that the instantaneous differences of sound pressure on the opposite sides of the diaphragm **11** will cause the diaphragm to vibrate and thus produce signal currents in the voice coil **13**. This is the manner of operation of the well-known, first order pressure gradient or velocity type microphones. A wind screen **30** of silk or any other suitable material may be placed over the cap **15**, if desired.

In accordance with my present invention, I place in proximity to the rear surface of the diaphragm **11** a reflector **31** for reflecting back to the diaphragm **11** sound waves which are emitted by and reach it from the above mentioned sound source. The reflector **31** is preferably in the form of a disk made of a rigid, non-resonant material. In order to place the disk **31** in close proximity to the rear surface of the diaphragm **11**, the disk may be mounted on the field structure of the microphone with the center pole piece **3** and the studs **9** extending therethrough. With this arrangement, it will be noted that the magnet **1** and the major portion of each of the studs **9** are behind the rear surface of the disk **31**, while the pole pieces **3** and **5** and the diaphragm **11** are disposed in front of the front surface of the disk **31**. If desired, the central portion of the reflector **31** may be designed into the magnet assembly and the whole made a removable, central section of the reflector **31**.

The theory or principle of operation of my improved microphone may be readily understood by reference to Figs. 1 and 2 wherein the diaphragm **11** and the reflector **31** are shown diagrammatically. Let it be assumed that sound is emitted by a source $S_1$ in front of the diaphragm **11** and that the sound wave will have a wave front represented by the circles **33**, **35** expanding in the directions of the arrows **37**. When this sound wave strikes the reflector **31**, it is reflected thereby back toward the point P along a wave front **39** which has an image source $S_2$. If the diaphragm **11** is located at the point P spaced a distance $d$ from the reflector **31** (Fig. 2), there is a path difference equal to $d_2 - d_1$ between the distance of the real source $S_1$ from the point P and the distance of the image source $S_2$ from the point P. This path difference is equal to twice the spacing of the point P from the reflector **31**. The location of the image source $S_2$ with reference to the point P (that is, the distance $d_2$) may be varied or controlled by the curvature of the reflector **31** so as to give greater or less than twice the spacing from the point P to the reflector as the path difference. Thus, the reflector **31** may be made concave relative to the diaphragm **11**, as illustrated in Fig. 7, or its reflecting surface may be made convex relative to the diaphragm **11**.

If the microphone is of the first order pressure gradient type, as in the present case, the output of the microphone will be reduced due to the presence of the reflector since the particle velocity of a sound wave is reflected from a rigid surface with a reversal of phase. The output of the microphone is thus due to the difference in the pressure gradients of the sound wave at two points separated by a distance $2d$ in the case of a flat reflector. More precisely, the force actuating the diaphragm may be represented by the following equation:

$$F=\frac{dp}{dx_1}\Delta x+\frac{dp}{dx_2}\Delta x$$

where

$x$=the distance as measured from the sound source $S_1$, to the diaphragm.

$\frac{dp}{dx_1}$=the derivative of the sound pressure of the incident wave with respect to distance (pressure gradient) where the value of $x_1$ is taken at the point P,

$\frac{dp}{dx_2}$=the derivative of the sound pressure of the reflected sound wave with respect to distance, in this case where the value of $x_2$ corresponds to the distance $2d$ from the point P,

$\Delta x$=the path difference between the front and back sides of the diaphragm.

It is understood, however, that the expression

$$\frac{dp}{dx_2}$$

is negative as compared to the expression

$$\frac{dp}{dx_1}$$

because of the phase reversal due to reflection of the sound wave from a rigid surface. Consequently, the actuating force for the diaphragm is the difference between two pressure gradients separated a distance $2d$. As a result, it will be recognized that this provides the same result as that obtained by the use of two oppositely phased pressure gradient units spaced apart a distance $2d$. As taught by the above-mentioned Olson Patent 2,301,744, this defines a second order gradient microphone. In other words, the pressure gradient of the pressure gradients of the sound wave is obtained for actuating the diaphragm.

In one microphone constructed in accordance with the present invention, the reflector **31** was a plane disk of transparent resin such as specified above approximately 6″ in diameter and the vibratory portion of the diaphragm was approximately ¾″ in diameter. The disk **31** was about ⅛″ thick and spaced from the diaphragm **11** about 5/32″. This microphone had a fundamental resonance at approximately 1100 C. P. S. and a secondary resonance at from 4000 to 5000 C. P. S., both suitably damped. The above frequencies were chosen for the type of response characteristic that was desired. In this microphone, the following improvement was measured:

A. Improvement in discrimination against distant sound (that is, sound originating at distances of 4 feet or more from the microphone) due to the addition of the reflector **31**:

(1) Front side—on the microphone axis:

95 cycles/second, 13½ decibels
200 cycles/second, 15½ decibels
500 cycles/second, 16½ decibels
1000 cycles/second, 14 decibels
2000 cycles/second, 6½ decibels
3600 cycles/second, 0 decibels

(2) Back side—on the microphone axis:

Below 1000 cycles/second—same as front side
2000 cycles/second, 13½ decibels below front response
3600 cycles/second, 18 decibels below front response

(3) At various angles:

Below 1000 cycles/second, the directional pattern approximated to the cosine squared characteristic.
Above 1000 cycles/second, there was a decided unidirectional effect, the response at the rear being as much as 25 db below response at the front at some frequencies.

B. Total discrimination:

To obtain the total discrimination against distant sound as compared to a pressure microphone used at a speaking distance of ½ inch from the microphone, the advantage given under (1) and (2) above must be added to that obtained by using the first order gradient unit. The latter is quite appreciable, being approximately 20 db at 500 cycles/second and 12 db at 1000 cycles/second. Thus, the total discrimination is approximately 36 db at 500 cycles/second (more at lower frequencies) and 26 db at 1000 cycles/second, decreasing with increasing frequency.

From the foregoing description, it will be apparent to those skilled in the art that I have provided an improved, second order pressure gradient microphone of very simple construction which is highly effective in discriminating against unwanted sounds. Although I have shown and described but a single embodiment of my invention, it will undoubtedly be apparent to those skilled in the art that many other forms thereof, as well as changes in the particular ones described, are possible within the spirit of my invention. For example, as pointed out heretofore, and as illustrated in Fig. 8, the reflector **31** may be disposed off center with respect to the axis of the diaphragm **11** so that the axis of the disk **31**, while parallel with that of the diaphragm **11**, is spaced laterally therefrom. This will provide better vision clearance at the top. If desired, the reflector **31** may be so disposed that its axis will be angularly related to that of the diaphragm **11**. Furthermore, it will undoubtedly be apparent that a reflector in accordance with the present invention may be employed in connection with a first order pressure gradient responsive microphone which utilizes a vibratory conductive ribbon, as disclosed, for example, in the Olson Patent 1,885,001. Also, if desired, the reflector **31** may be made, at least in part, of acoustically absorbent or semi-acoustically-conducting material to obtain certain phase shifting and/or directional effects. Various other changes will, no doubt, readily suggest themselves to those skilled in the art. I therefore desire that the above description shall be taken as illustrative and not as limiting.

I claim as my invention:

1. A microphone comprising means for producing a magnetic field, said means including an air gap, a vibratile member mounted for vibration in response to instantaneous differences of sound pressure on opposite sides thereof, said vibratile member including a conductive element disposed

in said air gap, the vibrations of said conductive element in said air gap serving to convert vibrations of said vibratile member into electrical variations, and an acoustical reflector disposed in close proximity to one side of said member, the spacing between said member and said reflector being small compared to the focal length of said reflector.

2. A microphone comprising means for producing a magnetic field, said means including an air gap, a vibratile member mounted for vibration in response to instantaneous differences of sound pressure on opposite sides thereof, said vibratile member including a conductive element disposed in said air gap, the vibrations of said conductive element in said air gap serving to convert vibrations of said vibratile member into electrical variations, and an acoustical reflector disposed in close proximity to one side of said member, the spacing between said member and said reflector being small compared to the focal length of said reflector, said reflector having an area which is large compared to that of said vibratile member.

3. A microphone comprising means for producing a magnetic field, said means including an air gap, a vibratile member mounted for vibration in response to instantaneous differences of sound pressure on opposite sides thereof, said vibratile member including a conductive element disposed in said air gap, the vibrations of said conductive element in said air gap serving to convert vibrations of said vibratile member into electrical variations, and an acoustical reflector disposed in close proximity to one side of said member, the spacing between said member and said reflector being small compared to the focal length of said reflector, said reflector having an area which is large compared to that of said vibratile member, and the axes of said member and said reflector being coincident.

4. A microphone comprising means for producing a magnetic field, said means including an air gap, a vibratile member mounted for vibration in response to instantaneous differences of sound pressure on opposite sides thereof, said vibratile member including a conductive element disposed in said air gap, the vibrations of said conductive element in said air gap serving to convert vibrations of said vibratile member into electrical variations, and an acoustical reflector disposed in close proximity to one side of said member, said reflector having an area which is large compared to that of said vibratile member, and the axes of said member and said reflector being laterally offset from each other.

5. A microphone comprising means for producing a magnetic field, said means including an air gap, a vibratile member mounted for vibration in response to instantaneous differences of sound pressure on opposite sides thereof, said vibratile member including a conductive element disposed in said air gap, the vibrations of said conductive element in said air gap serving to convert vibrations of said vibratile member into electrical variations, and an acoustical reflector disposed in close proximity to one side of said member, said reflector having an area which is large compared to that of said vibratile member, and the axes of said member and said reflector being laterally offset from but parallel to each other.

6. A microphone according to claim 1 wherein said reflector is rigid.

7. A microphone according to claim 1 wherein said reflector is of non-resonant material.

8. A microphone comprising a magnetic field structure having an air gap, a vibratile member including a conductor mounted for vibration in said air gap, said member being responsive to the pressure gradient component of a sound wave, and an acoustical reflector supported by said field structure in close proximity to one side of said member for reflecting back to said member sound waves reaching said reflector from a source external thereto, the spacing between said member and said reflector being small compared to the focal length of said reflector.

9. A microphone comprising a magnetic field structure having an air gap, a vibratile member including a conductor mounted for vibration in said air gap, said member being responsive to the pressure gradient component of a sound wave, and an acoustical reflector supported by said field structure in close proximity to one side of said member for reflecting back to said member sound waves reaching said reflector from a source external thereto, said field structure extending through said reflector.

10. A microphone comprising a magnetic field structure having a magnet and a pair of pole pieces associated with said magnet and spaced from each other to provide an air gap, a vibratile member including a conductor mounted for vibration in said air gap, said member being responsive to the pressure gradient component of a sound wave, and an acoustical reflector supported by said field structure in close proximity to one side of said member for reflecting back to said member sound waves reaching said reflector from a source external thereto, said pole pieces being disposed on one side of said reflector and said magnet on the other side thereof.

11. A microphone comprising a magnetic field structure having an air gap, a vibratile member including a conductor mounted for vibration in said air gap, said member being responsive to the pressure gradient component of a sound wave, and an acoustical reflector comprising a disc of non-resonant material supported by said field structure in close proximity to one side of said member for reflecting back to said member sound waves reaching said reflector from a source external thereto, the spacing between said member and said reflector being small compared to the focal length of said reflector.

12. A microphone according to claim 8 wherein said reflector comprises a disk of non-resonant material, said disk having an area which is large compared to that of said vibratile member.

ALFRED H. KETTLER.

## REFERENCES CITED

The following references are of record in the file of this patent:


UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 1,430,256 | Pridham et al. | Sept. 26, 1922 |
| 1,885,001 | Olson et al. | Oct. 25, 1932 |
| 1,899,994 | Spotts | Mar. 7, 1933 |
| 1,975,283 | Mueller | Oct. 2, 1934 |
| 2,049,586 | Hanson et al. | Aug. 4, 1936 |
| 2,085,721 | Wornke | June 29, 1937 |
| 2,352,305 | Anderson | June 27, 1944 |