

Aug. 20, 1946.

A. L. W. WILLIAMS ET AL

2,406,119

MICROPHONE

Filed March 11, 1942

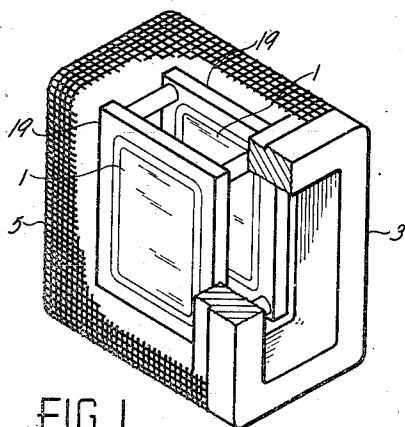


FIG. 1

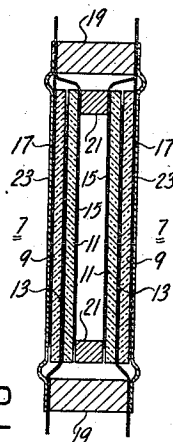


FIG. 2

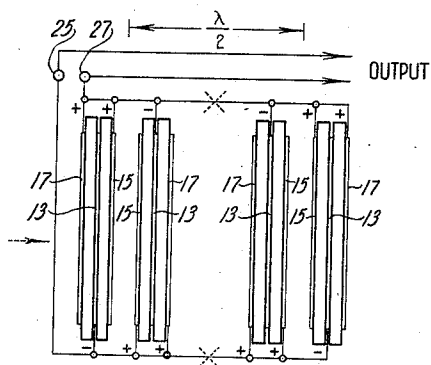


FIG. 3

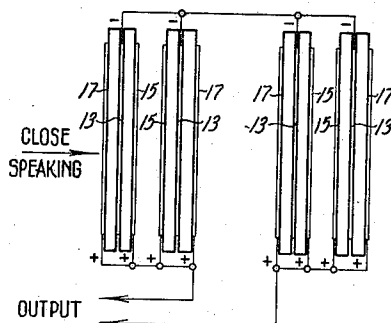


FIG. 4

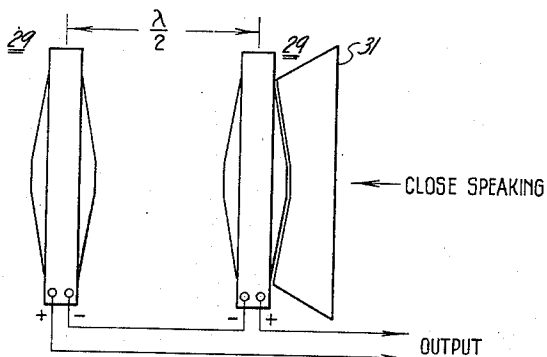


FIG. 5

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## UNITED STATES PATENT OFFICE

2,406,119

## MICROPHONE

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Application March 11, 1942, Serial No. 434,158

11 Claims. (Cl. 179—110)

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This invention relates to microphones and more particularly to microphones of the close speaking type, useful in noisy locations.

In locations such as factories, mills, and the like, where microphones are utilized as integral parts of an interphone system or for the purpose of communicating over a public address system, it is highly desirable that such microphones be substantially insensitive to plane sound waves at relatively low frequencies while displaying sufficient sensitivity to spherical waves from a nearby source, such as voice waves, to render a transmitted message intelligible. For that purpose it has been proposed to utilize bidirectional pressure gradient microphones of the ribbon type, but it has been found that such microphones are not entirely satisfactory.

The response of the usual ribbon type of pressure gradient microphone near a point source of sound is such that the low frequency output is very greatly exaggerated. Specifically, if such a microphone is placed  $\frac{1}{2}$  inch from a source of spherical sound waves, the pressure gradient magnitude will increase below 2,000 cycles as the frequency is lowered, at the rate of 6 db. per octave above the value that would be obtained from a plane wave. This results in the speech being extremely "boomy," and is a very undesirable characteristic.

It is, accordingly, an object of this invention to provide a close speaking microphone, the response characteristic of which to close speech shall be better than that of microphones heretofore known.

Another object of the invention is to provide a pressure gradient microphone that shall be relatively insensitive to interference from plane sound waves at frequencies lying within the useful voice range.

A further object of this invention is to provide a close speaking microphone that shall have substantially flat response to spherical sound waves from a nearby source.

The foregoing objects and other objects ancillary thereto are obtained through utilization of one or more stiffness controlled piezoelectric transducers in a very small microphone of the pressure gradient type. Through utilization of such element or elements for the purpose of inducing potentials responsive to sound pressures, the frequency-response characteristic of the improved microphone in a plane sound wave will rise 6 db. per octave with increase in frequency. When such a microphone is disposed close to a point source of sound, the rising characteristic

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of the element or elements will offset the falling characteristic of pressure gradient microphones in general with the result that the response is substantially flat over the major portion of the speech frequency range. Accordingly, the discrimination against noise of a pressure gradient microphone comprising a piezoelectric crystal element is two-fold. In the first place, there is ordinary discrimination resulting from the "cosine pattern" of the pressure gradient unit, and secondarily, there is further discrimination, increasing as the frequency decreases, due to the loss in sensitivity at decreasing frequencies in a plane wave sound field such as is produced by a distant sound source.

The novel features of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation together with further objects and advantages thereof, will be understood best from a consideration of the following description of certain specific embodiments taken in connection with the accompanying drawing in which:

Fig. 1 is a view in perspective of a preferred embodiment of the invention, partly broken away.

Fig. 2 is an enlarged cross-sectional view of one of the piezoelectric crystal element assemblies, known as a "Sound Cell," of the general type utilized in the device shown in Fig. 1.

Fig. 3 is a greatly enlarged and dimensionally exaggerated diagrammatic view, in end elevation, of the "Sound Cells," utilized in the device shown in Fig. 1.

Fig. 4 is an enlarged and dimensionally distorted view, partly in elevation and partly diagrammatic, exemplifying another embodiment of the invention, and

Fig. 5 is an enlarged and dimensionally distorted view, partly in side elevation and partly diagrammatic, exemplifying another embodiment of the invention.

In all figures of the drawing, identical elements are similarly designated.

Referring now to Fig. 1 of the drawing, a preferred embodiment of the invention includes two "Sound Cells" 1, 1 of the general type disclosed in the United States Letters Patents to A. L. W. Williams, 2,126,436 and 2,126,438, and in the United States Letters Patent to C. B. Sawyer, 2,105,010, suitably supported in spaced apart parallel relation and provided with means such as a mouthpiece 2 for directing the voice between them when the device is utilized for close speaking. In Fig. 1 it will be noted that the mouth-

piece is spaced away from the forward edges of the "Sound Cells" and that a foraminous housing 5 permits plane waves from distant sources to reach both of the cells simultaneously.

Each cell is preferably constructed as exemplified by Fig. 6 of the Williams Patent 2,126,436 or by the several figures in the Williams Patent 2,126,438 and the Sawyer Patent 2,105,010.

Referring now to Fig. 2 of the drawing, each "Sound Cell" comprises two crystal-element units 10 or of the multiplate type generally designated 7, 7. Each element includes two plate-like crystal elements 9 and 11, and it is provided with a central electrode 13 and two surface electrodes 15 and 17. The crystal plates 9 and 11 are cut 15 parallel to the plane of the *b* and *c* axes of the mother crystal of Rochelle salt or the like, with the sides or edges of the plates disposed at 45° to said *b* and *c* axes.

The crystal units 7, 7 are mounted in parallel 20 spaced relation in a frame-like support designated in its entirety by the numeral 19. The two units 7, 7 are spaced apart and supported in relation to each other by blocks 21, 21 around which the units flex when subjected to sound pressures. The two crystal units are held in 25 position on the lugs by elastic cement, or the like, and by sheets 23, 23 of suitable material such as thin paper, rubber, Koroseal, parchment, or the like, which are cemented to the faces of the crystal units and to the top and bottom faces of the frame 19, respectively. Preferably, the sheets are impervious to moisture, but if per- 30 vious, they may be given a coat of water-proof material after assembly. The opposed faces of the units are shielded against sound by the frame and the covering sheets.

Although this invention is and hereinafter will be described as utilizing "Sound Cells" comprising four crystal sections each, it is not to be 40 inferred thereby that it is limited by such description. On the contrary, each crystal unit may be replaced by a plurality of units such, for example, as shown in Fig. 4 of the Williams Patent 2,126,436, provided the electrodes are suit- 45 ably connected into the output circuit as hereinafter will be described in connection with Figures 3, 4 and 6 of the drawing.

Referring now to Fig. 3 of the drawing, it will be noted that, according to this invention, the 50 central electrode 13 of one multiplate element of each "Sound Cell" is connected to the surface electrodes 15, 17 of the neighboring element in the same cell to form a parallel opposing circuit so that the "Sound Cell" has pressure gradient characteristics and that the "Sound Cells" are 55 connected together in a parallel opposing circuit. Since each "Sound Cell" itself has pressure gradient characteristics and a number of "Sound Cells" are connected together in opposition it will be seen that the microphone may be made 60 relatively insensitive insofar as interfering plane waves are concerned, the space between the multiplate elements of each cell and the space between the cells being sufficiently small so that the frequency of maximum sensitivity may be placed far above the highest frequency of the 65 interfering sounds. For example, the space may be of the order of .3 inch, placing the maximum sensitivity to plane waves at 20,000 cycles, 60,000 cycles, etc. Inasmuch as closer spacing is possible, it will be seen that the microphone may be made substantially "dead" insofar as interfering plane waves are concerned, the spacing between the "Sound Cells" being the controlling factor. 70

When used as a close speaking microphone, the mouth is held closely against the mouthpiece 3 and the voice is directed between the spaced 5 apart "Sound Cells." Accordingly, the two inner multiplate elements are subjected to greater sound pressures than the two outer elements of each cell with the result that alternating potentials appear across the output terminals. Thus the mouthpiece 3 directs the voice onto one of 10 the two sound sensitive surfaces of each of the two pressure gradient "Sound Cells." The connections of the microphones are such that the outputs of the two pressure gradient microphones add for sounds directed by the mouthpiece. In- 15 terfering sounds originating at a distance act substantially equally on the two sound sensitive surfaces. Since the sound sensitive surfaces of each "Sound Cell" have, so to speak, opposite polarities, the outputs of the cells are small for interfering sounds and these small outputs fur- 20 thermore tend to cancel each other by virtue of the opposite connection of the "Sound Cells."

The instantaneous response of the assembly to a plane wave simultaneously reaching both 25 "Sound Cells" is indicated by the plus and minus signs in Fig. 3 of the drawing. When such waves arrive from a direction substantially parallel to the median plane of the cells, such response is substantially zero.

It also lies within the scope of this invention 30 to omit one of the sound cells, as indicated at *x* in Fig. 3, and to direct the voice against the face of the remaining sound cell instead of between the two cells, as indicated by the dotted arrow in Fig. 3.

Furthermore, according to our invention we may connect the several sound cells in series-op- 35 posing balanced relation for substantially simultaneous actuation by sounds from distant sources, the entire assembly, as exemplified by Fig. 4 of the drawing then being comparable to a single pressure gradient microphone. In this case the pressure gradient assembly has, with re- 40 spect to the output terminals, two sound sensitive surfaces of one polarity (the surfaces of one sound cell) and two sound sensitive surfaces of the opposite polarity (the surfaces of the other sound cell). In such event, the output, as indi- 45 cated by the plus signs at the terminals, is zero when sounds arrive from a source lying in a plane midway between the two inner "Bimorphs" and parallel thereto. For close speaking, the voice is directed against one of the end crystal element assemblies which induces sufficient po- 50 tential to disturb the balanced condition referred to above. The lowest frequency to which the assembly has maximum response to plane waves is determined by the space between the sound cells.

Further, and still within the scope of this in- 55 vention, two non-directional microphones of the type disclosed in the copending application of Alfred L. W. Williams and Dean R. Christian, Serial No. 429,896, filed February 7, 1942, and assigned to the Brush Development Company, may be utilized. Such modification is exemplified by Fig. 5 of the drawing and comprises two 60 microphones 29, 29 disposed in spaced apart relation with the axes of the diaphragms therein substantially parallel. As disclosed in the co- 65 pending application, but not illustrated herein, each microphone includes a "Bimorph" of the twister type and two opposed diaphragms, the said diaphragms being so coupled to opposite 70 corners of the "Bimorph" element that the force

applied to the said "Bimorph" in response to sound pressure on the diaphragms is cumulative. Such being the case, the direction from which the sound arrives is not controlling and the microphone is substantially non-directional. When two such microphones are utilized as shown in Fig. 5, the leads therefrom are connected to the output terminals of the assembly in series-opposing relation. Accordingly, the assembly is insensitive to sound waves that reach all four diaphragms simultaneously but behaves as a pressure gradient microphone with respect to plane waves arriving from such an angle that there is a lag between reception by one microphone and reception by the other. Thus the diaphragms of one unit 29 of the pressure gradient assembly may be considered as the sound sensitive surfaces of one polarity and the diaphragms of the other unit 29 may be considered as the sound sensitive surfaces of the opposite polarity.

For close speaking, the voice is confined to one microphone by utilization of a mouthpiece, 31, or the like, and in that event the potentials developed by the said microphone in response thereto appear across the output terminals.

Although certain modifications of this invention have been illustrated and described in detail, many others will be apparent to those skilled in the art. The invention, therefore, is not to be limited except insofar as is necessitated by the prior art and by the spirit of the following claims.

What is claimed is:

1. In a close speaking microphone assembly: at least two pressure gradient microphones each having a sound sensitive element so placed with respect to each other that their planes of zero response are spaced apart, means for electrically connecting the said two microphones together with such polarity that their outputs tend to cancel when the assembly is subjected to a plane low frequency wave, means associated with said two microphones for directing between the said two microphones sound waves which originate near-by whereby the outputs from the said two microphones are added for said sound waves which originate near-by.

2. The invention as set forth in claim 1 further characterized in this: that the said spaced apart planes of zero response are parallel to each other.

3. The invention as set forth in claim 1 further characterized in this: that each of the said microphone units is stiffness controlled.

4. The invention as set forth in claim 1 further characterized in this: that each of the said

microphone units is stiffness controlled and the output of each unit is approximately proportional to the displacement of its sound sensitive element.

5. The invention as set forth in claim 1 further characterized in this: that each of the said microphone units includes piezoelectric generating means.

6. The invention as set forth in claim 1 further characterized in this: that each of said pressure gradient microphones comprises a multiplate flexing element of Rochelle salt piezoelectric material having the planes of its major faces parallel to its said plane of zero response.

7. A microphone for close speaking comprising an assembly of two similar pressure gradient microphone units each of which comprises a sound sensitive element and a pair of electrical terminals, means for supporting said units with their sound sensitive elements in spaced apart face-to-face relationship, circuit means between the electrical terminals of said two microphone units connecting the said two units together with such polarity that when the microphone assembly is subjected to a plane sound wave of low frequency the outputs of the two units tend to cancel and when sound originates close to and is directed into the space between said units a sound sensitive element of each of the two units is actuated to develop an output which is added to the output of the other, and terminals for said microphone assembly connected to said circuit means and between which said additive output is available.

8. The invention as set forth in claim 7 further characterized in this: that each of the said microphone units is stiffness controlled.

9. The invention as set forth in claim 7 further characterized in this: that each of the said microphone units is stiffness controlled and the output of each unit is approximately proportional to the displacement of its sound sensitive element.

10. The invention as set forth in claim 7 further characterized in this: that each of the said microphone units includes piezoelectric generating means.

11. The invention as set forth in claim 7 further characterized in this: that each of the said pressure gradient microphones comprises a multiplate flexing element of Rochelle salt piezoelectric material having the planes of its major face parallel to the plane of the major face of the multiplate flexing element spaced from it.

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