June 25, 1963 W. A. BEAVERSON ET AL 3,095,484

UNIDIRECTIONAL MICROPHONE

Filed Oct. 22, 1959

Fig-1

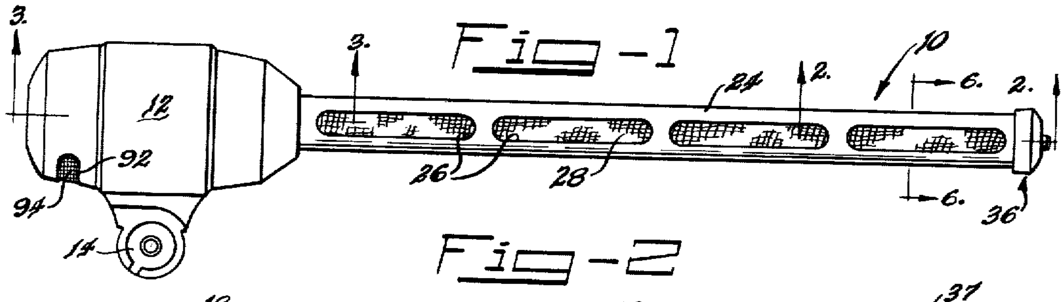


Fig-2

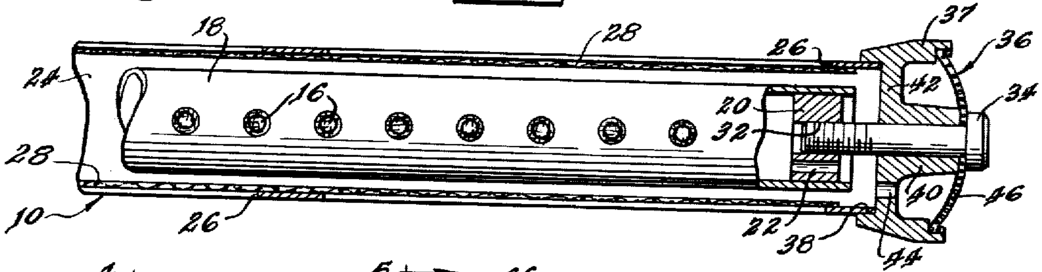


Fig-3

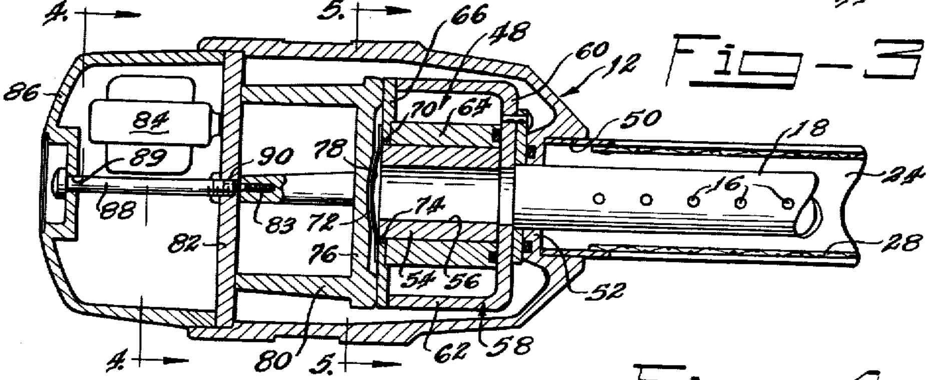


Fig-6

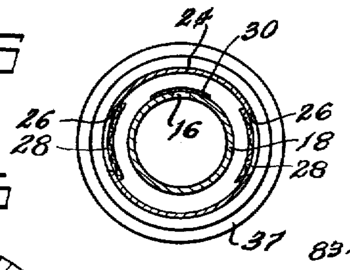


Fig-4

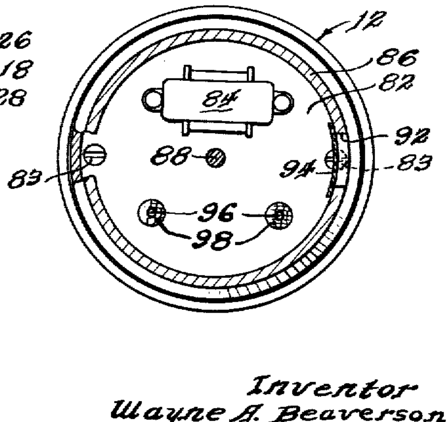
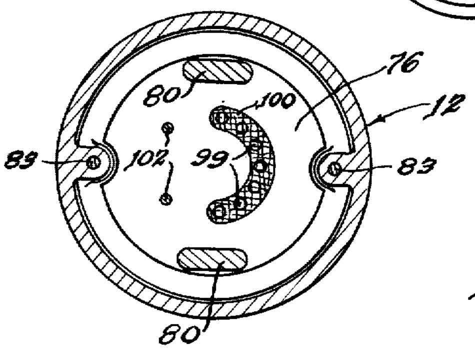


Fig-5



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3,095,484
UNIDIRECTIONAL MICROPHONE

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10 Claims. (Cl. 179—115.5)

The present invention relates generally to devices for translating acoustical energy into electrical energy, and more particularly to directional microphones.

There are many occasions, particularly in sound recording for motion pictures, sound pickup of television programs, and large stage productions for radio broadcasts, when it is desirable to keep the microphone out of the field of action, and it is therefore necessary on such occasions to place the microphone at a considerable distance from the point at which sound originates. Directional microphones are particularly advantageous for such uses in order to reduce background noises and avoid picking up reflected sounds.

Microphones having cardioid response patterns are well known, and these microphones produce negligible response to sounds impinging on the microphone from the rear of the microphone. The patent application of Alpha M. Wiggins, entitled "Unidirectional Microphone," No. 403,099, filed January 11, 1954, is an example of a microphone with a cardioid response pattern.

A microphone with a cardioid response pattern does not have sharp directivity, that is, the microphone will respond to sounds occurring on either side of the microphone as well as in front of the microphone so that it discriminates principally against those sounds originating at the rear of the microphone. It is one of the objects of the present invention to provide a microphone with greater directivity than conventional cardioid microphones.

The patents of Harry F. Olson, No. 2,228,886 and No. 2,299,342, disclose another type of directional microphone which may be referred to as a line microphone. In this type of microphone, a plurality of different length acoustical paths extend in front of the microphones so that only those sounds traveling directly toward the microphone will arrive at the electroacoustical transducer of the microphone in proper phase. Modified forms of line microphones are shown in the patents of Fred Daniels, No. 2,739,659 and No. 2,789,651. The line microphones previously known to the art have been too large and cumbersome for commercial sound, radio, and television use, the Daniels patents disclosing such a microphone with a length of 1980 feet, although it is to be understood that this particular construction represents the longest known line microphone at that time. It is therefore a further object of the present invention to provide a directional microphone of the line type which is substantially smaller than those heretofore known to the art for a given directional frequency range.

The novel features which are characteristic of the present invention are set forth with particularity in the appended claims. The invention itself, both as to its organization and method of operation, together with additional objects and advantages thereof, particularly will best be understood from the following description of a preferred embodiment thereof, when read in connection with the accompanying drawings, in which:

FIGURE 1 is a side elevational view of a microphone with a preferred construction of the present invention;

FIGURE 2 is an enlarged fragmentary sectional view of a portion of the microphone of FIGURE 1 taken along the line 2—2 thereof;

FIGURE 3 is an enlarged fragmentary sectional view of the microphone of FIGURES 1 and 2 taken on the same plane as FIGURE 2;

FIGURE 4 is a sectional view taken along the line 4—4 of FIGURE 3;

FIGURE 5 is a sectional view taken along the line 5—5 of FIGURE 3; and

FIGURE 6 is a sectional view taken along the line 6—6 of FIGURE 1.

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The following description of the microphone illustrated in the figures will set forth a pressure gradient electroacoustical transducer with a diaphragm coupled to the atmosphere at its front side by a plurality of acoustical paths of different lengths, and coupled at its rear side through an acoustical resistance. As a result of this construction, the microphone has much greater directivity than a line microphone of comparable dimensions with a pressure electroacoustical transducer, or a cardioid microphone.

The Olson patent, No. 2,228,886, referred to above, includes a disclosure of a line microphone with two forwardly directed acoustical transmission lines coupled to opposite sides of a pressure gradient transducer, each of the acoustical transmission lines having a plurality of acoustical paths of different lengths. The pressure gradient line microphone of the present invention achieves substantially the same directivity as the Olson microphone without the complexity and space requirements of a second multiple path acoustical transmission line, and also facilitates cancellation of sounds originating behind the microphone.

FIGURE 1 illustrates the side view of the microphone and shows a multipath acoustical transmission line **10** in the form of a cylindrical tube extending from the transducer housing **12**. The housing **12** is provided with an outwardly extending circular plate **14** which is adapted to be journaled within a pair of bifurcations of a mounting stand of conventional construction.

The acoustical transmission line **10** must provide a plurality of different length acoustical paths to the transducer within the housing **12**. In the construction shown in FIGURES 1 and 2, this is achieved by providing a sound permeable window in the form of a plurality of holes **16** equally spaced along a line parallel with the axis of a hollow cylindrical tube **18**. One end of the tube **18** is sealed within the housing **12** for the transducer, and the other end of the tube **18** is sealed by an end plug **20**. The end plug **20** is also provided with a bore **22** extending therethrough to permit sound waves to enter into the tube from the end thereof. The bore **22** particularly aids the response and performance of the microphone when used for close talking.

The acoustical transmission line **10** also has a second hollow cylindrical tube or sleeve **24** coaxially disposed about the tube **18** and spaced therefrom. The sleeve **24** is provided with a number of elongated slots **26** equally spaced along two lines disposed on opposite sides of the sleeve and displaced from the line of the holes in the tube by 90 degrees relative to the common axis. The purpose of the sleeve **24** is to keep dirt and foreign particles out of the tube **18**, and otherwise protect the tube. For this reason, the slots **26** are provided with sound permeable windows **28**, such as a cloth layer.

The holes **16** in the tube **18** are provided with a layer of material **30**, as illustrated in FIGURE 6, which forms with the holes **16** an acoustical impedance. The acoustical impedance of the holes adjacent to the housing **12** is greater than that of the remote holes **16** and layers **30** so that the holes **16** act as an extended opening parallel to the axis of the tube, and sound pressures exerted at all points along the tube **18** result in equal sound pressures in the housing **12**.

The plug **20** has an axial threaded channel **32** which accommodates a mounting screw 34 for a sound permeable cap 36. The cap 36 has a circular rim 37 with an indentation 38 which fits about the exterior surface of the sleeve 24, and an axial hub 40 which is attached to the rim 37 by a disc portion 42. The disc portion has an opening 44 extending therethrough and aligned with the bore 22 in the plug 20, and a sound permeable screen 46 extends from the hub 40 to the rim 37 to keep particles out of the tube 18.

FIGURES 3, 4 and 5 illustrate the details of the housing 12 and the electrocoustical transducer disposed within the housing, designated 48. The housing 12 has a cylindrical cross section and an axial opening 50 at one end which engages the end of the sleeve 24 opposite the cap 36. The housing 12 also has a circular shoulder 52 which extends inwardly from the opening 50 to engage the end of the tube 18 opposite the cap 36. The transducer 48 has a cylindrical permanent magnet 54 which has a channel 56 therethrough which has the same diameter as the tube 18 and is aligned with the tube 18. The transducer 48 also has a yoke 58 which has a leg 60 secured to the housing 12 and disposed between the magnet 54 and the housing 12, the leg 60 being integral with a second leg 62 normal thereto extending parallel to the magnet 54. A magnetically impermeable hollow sleeve 64 is disposed about the magnet 54 and extends from the leg 60 of the yoke 58 to a plate 66 of magnetically permeable material which completes the yoke.

The plate 66 has a cylindrical opening therein confronting the magnet 54 and spaced therefrom to form a circular gap 70. A domed diaphragm 72 is mounted at its periphery on the plate 66 and is positioned to seal the channel 56 of the magnet, so that the diaphragm 72 is coupled on one side to the acoustical transmission line 10. The diaphragm 72 supports a voice coil 74 which is disposed within the gap 70 and the voice coil is translatable parallel to the axis of the magnet responsive to sound pressures from the acoustical transmission line 10. It is to be understood that some other electromechanical transducer may be employed with the diaphragm 72 rather than the electromagnetic transducer disclosed, such as a piezoelectric electromechanical transducer.

A plate 76 is mounted to the peripheral portions of the plate 66 of the magnetic yoke, and the plate 76 is provided with an indentation 78 confronting the dome of the diaphragm 72. The plate 76 is constructed of nonmagnetic material, and it is provided with two legs 80 on opposite sides thereof which extend normal thereto. The legs 80 abut opposite sides of a disc 82 which is secured to the housing 12 by screws 83 anchored in the housing, and thus the legs 80 transmit pressure to maintain the transducer 48 in position.

A transformer 84 for matching the impedance of the transducer voice coil to an electrical transmission line is mounted to the side of the disc 82 opposite the transducer 48, and a hollow cover 86 is disposed about the transformer 84. The cover 86 is cup shaped and sealed to the housing and maintained in position by a bolt 88 extending through an axial opening 89 in the cover 88 and anchored in a threaded bore 90 on the axis of the disc 82. As illustrated in FIGURE 4, the cover 86 is provided with a slot shaped opening 92 on its surface adjacent to the circular plate 14 of the mounting means for the microphone, and a sound permeable covering 94 is disposed over the slot 92.

Sound pressures are free to enter into the interior of the cover 86 through the slot 92. The disc 82 then permits the sound pressures to pass through two small bores 96 in the disc, shown in FIGURE 4. The bores 96 are spaced from each other and located remote from the transformer. A layer 98 of cloth is disposed over the bores 96. The plate 76 is also provided with a plurality of holes 99 disposed in an arc which confront the periphery of the diaphragm dome. The holes 99 are also covered with a cloth layer 100. FIGURE 5 also illustrates two holes 102 which accommodate the leads to the voice coil 74 from the transformer 84.

The slot 92, interior of the cover 86, bores 96 in the disc 82, and holes 99 in the plate 76 form a path for sound pressures to the side of the diaphragm 72 opposite the acoustical transmission line 10. This acoustical path is provided with a first acoustical impedance formed by the bores 96 and layers 98, and a second acoustical impedance formed by the holes 99 and layers 100. This construction is designed to perform three separate functions.

First, the acoustical path is provided with the proper phase shift and amplitude attenuation to provide a cardioid polar response pattern for the lower frequencies of the response range of the microphone. The first acoustical impedance and the chamber between the plate 76 and disc 82 are most prominent in providing the desired phase shift and amplitude attenuation for this purpose.

Second, the first and second acoustical impedances provide a relatively sharp frequency cut-off for the acoustical path at a frequency from 200 cycles per second to 800 cycles per second, thus preventing sound pressures of frequencies above the cut-off frequency from impinging on the side of the diaphragm opposite the transmission line 10. For frequencies above the cut-off frequency, the microphone operates as a line microphone.

Third, the second acoustical impedance and the chamber between the plate 76 and disc 82, and to a lesser extent the first acoustical impedance and the chamber within the cap 86, damp the mechanical resonance of the diaphragm 72.

In one particular construction of a microphone according to the teachings of this invention, the tube 18 has an outer diameter of ½ inch and has a length of 11⁹⁄₃₂ inches. Thirty-two holes 16 are spaced by a distance of 11⁄32 inch along the tube, and the diameter of the holes is approximately 0.094 inch. The sleeve 24 is spaced from the tube 18 by approximately ¼ inch, and four slots 26 are disposed in each side of the sleeve 24 with a width of ⁵⁄₁₆ inch and a length of 2½ inches. The tube 18 is constructed of steel and the sleeve 24 is constructed of brass, although it is to be understood that other materials are also suitable.

Operation of the microphone may be described as follows. The acoustical transmission line 10 provides a plurality of paths to the diaphragm 72 of different length, each path being defined by one of the holes 16. For sounds traveling along the axis of the microphone from the front thereof, the total path length to the diaphragm is the same for all holes 16 through which the sound may enter the transmission line 10. Therefore, each of the acoustical paths delivers sound energy to the diaphragm which is of the same phase, and there is no cancellation of sound on the front side of the diaphragm. Sound energy directed toward the microphone from any other direction than the front, passes through the plurality of acoustical paths of the transmission line 10 with different total length paths, which results in phase differences and cancellation at the front of the diaphragm provided the line is at least a half wavelength along.

If the transmission line 10 is less than a half wavelength in length, there will be incomplete cancellation at the diaphragm of sounds originating off of the forward axis of the microphone. For this reason, the cut-off frequency of the path to the rear of the microphone is selected to be approximately equal to the frequency at which the transmission line 10 is a half wavelength. As a result, the microphone is directional above the cut-off frequency by virtue of the directivity of the acoustical transmission line, and directional below the cut-off frequency by virtue of the cardioid response resulting from the sound path to the rear of a diaphragm. Hence, the microphone is directional throughout its entire response range, even though the acoustical transmission line is too short to produce significant directivity at the lower frequencies of the response range.

In the frequency range near the cut-off frequency, both the cardioid response from the sound path to the rear of the diaphragm and the directional charcteristics of the acoustical transmission line **10** occur, and these are combined at the diaphragm to maintain the directivity of the microphone. In this frequency range, sounds originating at the rear of the microphone are not completely cancelled by the multi-path transmission line **10**, and sound pressure passing through the path to the rear of the diaphragm is beneficial to provide this cancellation.

From the foregoing disclosure, those skilled in the art will readily devise many modifications and improvements upon the microphone described herein which are within the spirit of this invention. For example, the multi-path transmission line can clearly be formed by a single slot in the tube **18**, rather than a plurality of holes **16** spaced along the tube; or the transmission line could be constructed by a plurality of separate tubes of different length, as described in the art. It is therefore intended that the scope of the present invention be not limited by the foregoing disclosure, but rather only by the appended claims.

The invention claimed is:

1. A microphone responsive through a frequency range comprising an electroacoustical transducer having a diaphragm, said transducer generating an electrical signal responsive to the difference in pressures exerted on opposite sides of the diaphragm, a casing enclosing said transducer and having a portion defining at least one acoustical transmission line extending from one side of the diaphragm, said casing having means located at a plurality of distances from the diaphragm to admit sound into the transmission line, thus forming a plurality of sound paths to the diaphragm of different lengths, the longest of said paths being less than a half wavelength longer than the shortest of said paths at the lowest frequency of the response range, said casing including means defining an acoustical path extending from the other side of the diaphragm having a cavity and an opening on said other side of the diaphragm spaced from the diaphragm by a distance less than one-half the length of the longest path of the transmission line, said path having an acoustical impedance disposed therein and a band pass extending from the lowest frequency of the range of the microphone to the frequency at which the longest of the paths of the transmission line is a half wavelength, the volume of said cavity and the magnitude of said impedance comprising means for producing an acoustical phase shift approximately equal to the shift in phase of a sound wave in said pass band traveling between the diaphragm and opening whereby the microphone achieves a directional response in the portion of the frequency range of the microphone covered by the band pass of said acoustical path to said other side of the diaphragm.

2. A microphone comprising the elements of claim 1 wherein the means defining an acoustical path from the other side of the diaphragm comprises means defining a chamber having an opening therein to the ambient atmosphere and a bore in said chamber defining means in communication with the chamber and the diaphragm, and a layer of acoustical resistance material disposed over the bore.

3. A microphone comprising the elements of claim 1 wherein the portion of the casing extending from one side of the diaphragm forming the transmission line comprises an elongated tube having a wall defining a channel therein.

4. A microphone comprising the elements of claim 2 wherein the end of the tube opposite the transducer is provided with an opening for admitting sound therein.

5. A microphone comprising the elements of claim 1 wherein the electromechanical transducer comprises a cylindrical magnet mounted on the housing having an axial channel therein communicating and aligned with the acoustical transmission line, a magnetic yoke mounted on the magnet on the end thereof adjacent the transmission line and forming a circular gap at the opposite end of the magnet, a diaphragm sealed across the channel at the end thereof opposite the transmission line, and a voice coil disposed within the circular gap and mounted on the diaphragm.

6. A microphone comprising the elements of claim 5 in combination with an air impermeable plate on the yoke and disposed on the side of the diaphragm opposite the electromechanical transducer and spaced therefrom, the perimeter of said plate being acoustically sealed to the housing and said plate having a plurality of holes therethrough adjacent to the diaphragm, a layer of material forming an acoustical resistance disposed over the holes.

7. A microphone responsive through a frequency range comprising an electroacoustical transducer having a diaphragm, said transducer generating an electrical signal responsive to the difference in pressures exerted on opposite sides of the diaphragm, a casing enclosing said transducer and having a portion defining at least one acoustical transmission line extending from one side of the diaphragm, said portion of the casing having a straight elongated hollow tube having a sound permeable window disposed along an axis parallel to the axis of the tube, the sound permeable window admitting sound into the transmission line at points located at a plurality of distances from the diaphragm, thus forming a plurality of sound paths to the diaphragm of different lengths, the longest of the sound paths being less than a half wavelength longer than the shortest of said paths at the lowest frequency of the response range, and a hollow cylindrical sleeve mounted coaxially about the tube and spaced therefrom, said sleeve having an elongated slot parallel to the axis thereof confronting the tube, said casing including means defining an acoustical path extending from the other side of the diaphragm and having an opening on said other side of the diaphragm, said path having an acoustical impedance disposed therein and a band pass extending from the lowest frequency of the range of the microphone to the frequency at which the longest of the paths of the transmission line is a half wavelength, the length of said path and the magnitude of said impedance providing a directional response in the portion of the frequency range of the microphone covered by the band pass of said acoustical path to said other side of the diaphragm.

8. A microphone having a frequency response band comprising, in combination, an air impermeable hollow housing having a cylindrical opening and a coaxial circular recess in the exterior surface of the housing about the opening, a hollow cylindrical tube mounted on the housing within the opening and extending from the housing, said tube having a plurality of spaced holes therethrough on a line parallel to the axis of elongation thereof, the holes extending along the line a distance less than a half wavelength at the lowest frequency in the response band of the microphone, a hollow cylindrical sleeve disposed coaxially about the tube and spaced therefrom, said sleeve being mounted in the recess of the housing and having a plurality of slots along two lines on opposite sides of the sleeve parallel to the axis of elongation, said lines of slots being equidistant from the line of holes in the tube, a plug sealed within the end of the tube opposite the housing having a bore extending therethrough, a sound permeable cap mounted on the end of the sleeve opposite the housing confronting the plug, an electroacoustical transducer mounted within the housing having a diaphragm sealed to the housing and confronting the tube on one side, and means defining an acoustical path coupled to the other side of the diaphragm, said path having an opening on the side of the diaphragm opposite the tube and an acoustical impedance therein, said means defining an acoustical path to the other side of the diaphragm having a band pass extending from the lowest frequency of the range of the microphone to the frequency at which the

distance between the nearest and farthest holes of the tube from the housing is a half wave length.

9. A microphone having a frequency response band comprising, in combination, an air impermeable hollow housing having a cylindrical opening in the exterior surface thereof, a hollow cylindrical tube mounted on the housing within the opening and extending from the housing, said tube having a plurality of spaced holes therethrough, the hole farthest from the housing being spaced from the hole closest to the housing by a distance less than a half wave length at the lowest frequency in the response band of the microphone, an electroacoustical transducer mounted within the housing having a diaphragm sealed to the housing and confronting the tube on one side thereof, means defining a first chamber confronting the other side of the diaphragm, including a bore, and means defining a second chamber confronting the bore of the first chamber, said second chamber having an opening to the ambient atmosphere, and a layer of acoustical resistance material disposed over the bore, said first and second chambers and acoustical resistance material defining an acoustical path to the other side of the diaphragm having a band pass extending from the lowest frequency of the range of the microphone to the frequency at which the distance between the nearest and farthest holes of the tube from the housing is a half wave lengh.

10. A microphone having a frequency response band comprising, in combination, a hollow housing constructed of air impermeable material having a cylindrical opening and a coaxial circular recess in the exterior surface of the housing about the opening, a hollow cylindrical tube mounted on the housing within the opening and extending from the housing, said tube having a plurality of spaced holes therethrough on a line parallel to the axis of elongation thereof, the holes extending along the line a distance less than a half wavelength at the lowest frequency in the response band of the microphone, a hollow cylindrical sleeve disposed coaxially about the tube and spaced therefrom, said sleeve being mounted in the recess of the housing and having a plurality of slots along two lines on opposite sides of the sleeve parallel to the axis of elongation, said lines of slots being equidistant from the line of holes in the tube, a plug sealed within the end of the tube opposite the housing having a bore extending therethrough, a sound impermeable cap mounted on the end of the sleeve opposite the housing confronting the plug, an electroacoustical transducer mounted within the housing including a diaphragm acoustically sealed about its perimeter to the housing and disposed normal to the tube, said electroacoustical transducer also including a voice coil mounted on the diaphragm coaxially with and confronting the tube, a hollow cylindrical magnet mounted within the housing coaxial with the tube and having one end disposed adjacent to the voice coil, and a ferromagnetic yoke having a plate provided with a circular aperture disposed about the voice coil and a cup-shaped portion extending from the perimeter of the plate to the end of the magnet opposite the voice coil, said cup-shaped portion having an aperture aligned with the tube, said housing having a plate disposed therein on the side of the diaphragm opposite the tube dividing the housing into two chambers, said plate having a bore therein, a layer of resistance material disposed over the bore, and said housing having an opening from the exterior into the chamber thereof remote from the diaphragm, the opening, chamber remote from the diaphragm, bore, resistance material, and chamber adjacent to the diaphragm forming a low pass acoustical transmission line for sound waves having a wavelength greater than twice the length of the tube.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,095,484 June 25, 1963

Wayne A. Beaverson et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 63, strike out "particularly" and insert the same after "thereof," in line 65, same column 1; column 6, line 7, after "plate" insert -- mounted --.

Signed and sealed this 7th day of April 1964.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents