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MICROPHONE WITH LOW FREQUENCY FILTER

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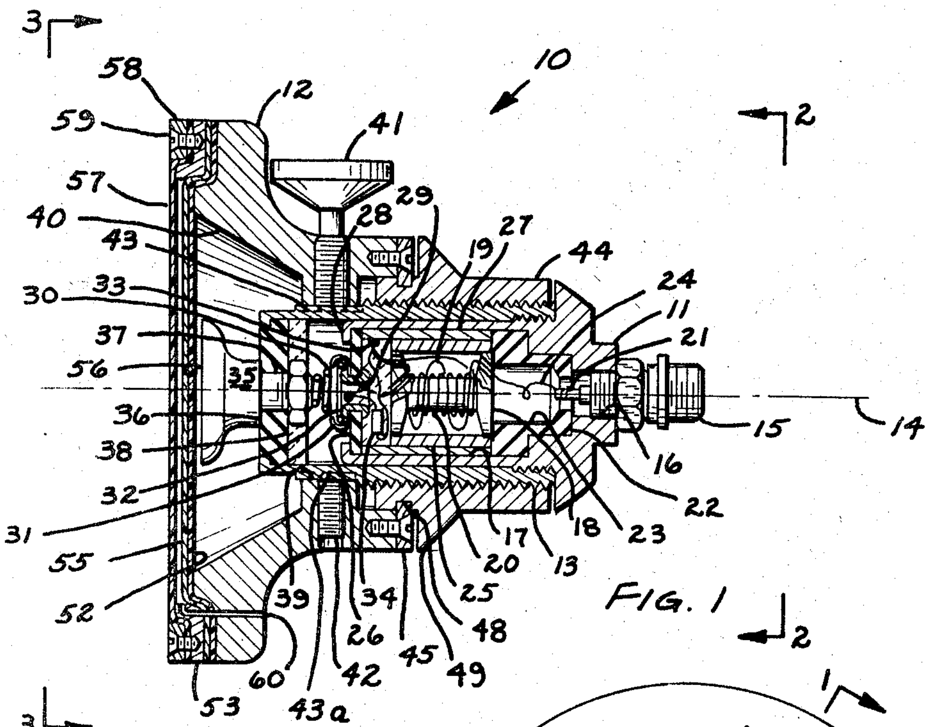

FIG. 1

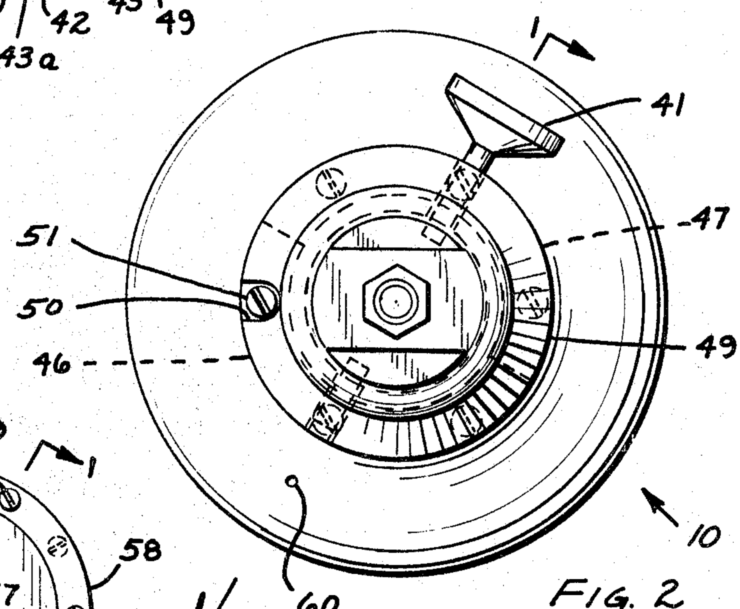

FIG. 2

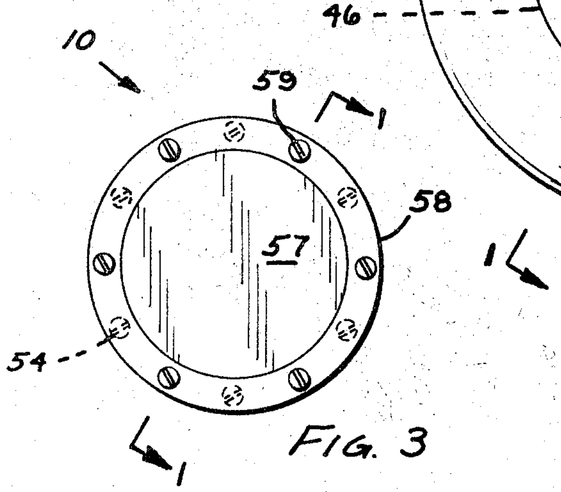

FIG. 3

INVENTOR.
CARL E. GRINSTEAD

BY
Angus & Mon

ATTORNEYS.

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MICROPHONE WITH LOW FREQUENCY FILTER

Carl E. Grinstead, 1600 S. Baldwin, Arcadia, Calif. 91006

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This invention relates to sound detection devices and more particularly, to a microphone for the detection of sounds emanating from the heart.

An object of this invention is to provide a microphone and a readout means for detecting, measuring and reading out frequencies emitted by the human body, such as by its heart, which will not be obscured by concomitant low-frequency effects such as results from breathing, gradual body movements, and the like.

An additional object of the invention is to provide means for accomplishing the foregoing in a device which remains tuned for optimum effect in the presence of said low-frequency effects, which has means for varying the sensitivity of the microphone, and which is designed to make a close coupling with the chest of the body for optimum transmission without upsetting relationships between internal electrical components of the microphone.

The invention will be fully understood from the following detailed description and accompanying drawings in which:

FIG. 1 is a cross-sectional view of the microphone and taken at line 1—1 of FIG. 2, and line 1—1 of FIG. 3;

FIG. 2 is an end view taken at line 2—2 of FIG. 1; and

FIG. 3 is an end view of the microphone taken at line 3—3 of FIG. 1.

The drawings show a microphone **10** comprising a coil housing **11**, a body **12**, and a housing adapter **13** to connect the coil housing **11** to the body **12** along a longitudinal axis **14**. A co-axial receptacle **15**, such as Microdot No. 13–01, Series S–50 manufactured by Microdot Incorporated, South Pasadena, California, is threaded into a hole **16** in an end of coil housing **11**.

The coil housing **11** has an inner cavity **17** and a cylindrical coil spool **18** disposed therein. Coil spool **18** is made of a ferrite material such as powdered iron, and has a primary winding **19** and a secondary winding **20** wound around the spool as two windings of a transformer. The co-axial receptacle **15** is spaced from the spool by an insulator **22** and has an inner stem **21** insulated from said housing. Insulator **22** has an inner cavity **23** to allow a wire **24** to pass from the stem **21** to the primary winding **19**. A tubular coil sleeve **25** extends around the periphery of the coil and is made of a ferrite material such as powdered iron. The purpose of the sleeve **25** is to complete the magnetic circuit for the windings on spool **18** and to shield the windings from any extraneous magnetic fields which would hinder operation of the device. A disc **26** is spaced from the coil spool at the end of the coil housing opposite the co-axial connector **15** and has an outer periphery defined by the inner wall of cavity **17** of coil housing **11**. A tubular copper sleeve **27** is disposed in the coil housing **11** and has a length defined by the spacing between insulator **22** and disc **26** and a wall thickness defined by the outer periphery of coil sleeve **25** and the inner wall of cavity **17** of the coil housing. The disc is disposed within the cavity **17** and a crimp **28** is formed on the end of housing **11** to hold the disc assembled therewith.

The disc **26** is made of an insulating material and has a central hole **29**. A spring **30**, being conical in shape, is attached by its base to the insulator disc **26** at hole **29** by a contact spring retainer **31** and a tubular contact spring retainer rivet **32**. The shank of the retainer rivet **32** passes through hole **29** with the head of the rivet

bearing against a side of the insulated disc **26** and end of the shank of the rivet opposite the head of the rivet is swaged outwardly to rigidly attach the contact spring retainer to the disc **26**.

In assembling the various components into the coil housing, wire **24** is soldered to stem **21** and receptacle **15** is then threaded into hole **16** of the coil housing. Insulator **22** is then inserted into the cavity **17** of the housing and wire **24** is then attached to the primary winding **19** on coil spool **18**. Spool **18** is then inserted into the housing and ferrite sleeve **25** and copper sleeve **27** are inserted into their respective positions. The unconnected end of primary winding **19** and an end of the secondary winding are soldered at point **33** to the inside wall of copper sleeve **27** which has the same potential as the coil housing and is at ground potential when the microphone is in operation. The unconnected end of the secondary winding **20** is soldered to contact spring retainer rivet **32** which is electrically connected to contact spring **30** through the contact spring retainer **31**. A capacitor **34** is connected between rivet **32** and the copper sleeve **27**. Disc **26** with the spring attached is inserted within the cavity to bear against the end of copper sleeve **27** and the end of the housing adjacent disc **26** is swaged inwardly to securely hold the disc against sleeve **27**. A bonding material with good electrical insulation characteristics may then be inserted into the space between the spool **18** and the disc **26** to insure that there will be no shorting of wires in the space.

Housing adapter **13** is a tubular shaped member attached to coil housing **11** and extending longitudinally away from the end of the coil housing opposite co-axial connector **15**. At the end of housing adapter **13** is attached an electrode **35** insulated from housing adapter **13** by an insulating disc **36**. The electrode has a shank **37** passing through the disc and making electrical contact with the contact spring **30**. The electrode is secured to the insulating disc by a nut threaded onto the shank. A layer of bonding material **38** is applied to the insulating disc on the inside of the housing adapter and has a thickness sufficient to secure the insulated disc and electrode rigidly to the housing adapter **13**. Coil housing **11** and housing adapter **13** are threaded so that the housing adapter may be rigidly attached to the coil housing. The two windings of the coil are mutually inductive and their assembly acts as a current transformer wherein the secondary has a greater number of turns than the primary. For example, the secondary winding has three hundred turns and the primary winding has eight turns. A low value temperature-sensitive capacitor **34** such as 8.5 mmf. is connected from the brass rivet **32** to the cooper sleeve **27** for the purpose of maintaining impedance stability of the resonant circuit should the microphone be exposed to changes in temperature during operation. The capacitor's capacitance decreases with increasing temperature to offset the concomitant increase in inductance of the coil.

The body **12** is a tubular shaped member with a centrally located hole **39** at one end to accept the end of the housing adapter **13** opposite the coil housing **11**. The body **12** has a frusto-conical cavity **40** to enclose the electrode **35**. Two holes spaced diametrically opposite each other on the body **12** are tapped to accept a lock screw **41** and a guide screw **42**. The holes are disposed such that the screws **41** and **42** are brought to bear against two chamfered keyways, **43** and **43***a* respectively, on housing adapter **13**. The keyways **43** and **43***a* extend longitudinally along the outer wall of the housing adapter **13** such that when the locking screw **41** is loosened, the housing adapter and coil housing **11** may be moved independently of the body **12**.

An adjusting barrel **44** is threaded onto the housing adapter **13** and disposed between the body **12** and the coil housing **11**. The adjusting barrel **44** is rotatable about the housing adapter and is guided by a locking ring **45** rigidly attached to body **12** at an end thereof. For assembly and removal of body **12** from the adjusting barrel the locking ring **45** comprises two semicircular rings **46** and **47** attached to the end of the body **12** as shown in FIG. 2. Ring **45** has an inner periphery defined by the bottom of an annular groove **48** in the outer wall of the adjusting barrel **44**. Adjusting barrel **44** is rotatable about longitudinal axis **14** and body **12**, and is held in a fixed longitudinal position to body **12** by the locking ring. A flange **49** extends outwardly from the wall of the adjusting barrel and is disposed adjacent the locking ring **45**. The flange **49** has a notch **50** to allow the removal of screws such as **51** which attach the locking ring **45** to the body **12**.

A diaphragm **52** is spaced from the electrode **35** and is attached by a clamping ring **53** to the body **12** by the use of screws such as **54** shown in FIG. 3. The diaphragm **52** is metallized with a layer **55** of an electrically conductive material such as aluminum. The diaphragm is made of a thin flexible material such as Mylar. The diaphragm is approximately 0.0005" thick and the metallized layer **55** is caused to be at ground potential by screws **54**. The metallized diaphragm acts as one plate of an air gap capacitor, with electrode **35** acting as the other plate. The electrode has a face **56** disposed adjacent metallized diaphragm **52** and substantially parallel to the diaphragm. The metal layer **55** is on the opposite side of the diaphragm from the electrode, thereby adding the capacitance of the diaphragm to the system. This is advantageous in that the electrode **35** and metallized layer **55** will never come into contact with each other.

The adjusting barrel is held captive to the body **12** by ring **45** when the barrel is rotated such that the coil housing and housing adapter move along longitudinal axis **14** relative to metallized diaphragm **52**. Since electrode **35** is rigidly attached to the housing adapter, the electrode will move relative to the diaphragm thereby causing the capacitance between the electrode and the diaphragm to vary.

It is desirable to attenuate the very low frequency oscillations of the heartbeat so that a better signal to noise ratio may be obtained for vibrations above the frequency of the beat of the heart, that is, frequencies above about one cycle per second. This is accomplished by a filter which filters out frequencies below about 1 c.p.s. This filter comprises a membrane **57** disposed over the diaphragm **52** and spaced from the diaphragm by clamping ring **53** forming a pocket (sometimes called an "air space") therebetween. This membrane may be a Mylar sheet about 0.00025" thick. A second clamping ring **58** is used to attach membrane **57** to the body **12** with screws such as **59** shown in FIG. 3. A suitable spacing between the diaphragm and the membrane is approximately $\frac{1}{16}$ of an inch. A hole **60** extends through the clamping ring **53** and the body **12** to allow air to pass from the pocket to the atmosphere. The hole is approximately five to ten thousandths of an inch in diameter such that the time required to evacuate the pocket of air is about one second.

The microphone acts as a sonic detector whereby vibrations from substantially zero c.p.s. to frequencies high in the sonic spectrum will strike membrane **57** causing the membrane to vibrate accordingly. Pulsations having a frequency from zero to one cycle per second have a relatively long period of oscillation in comparison to the higher frequencies. Upon striking the outer membrane **57**, these low frequency impulses will cause air to pass from the pocket between membrane **57** and diaphragm **52** through opening **60** as the membrane vibrates transferring relatively little vibration to the diaphragm **52**. However, at frequencies above one c.p.s. do not cause appreciable air flow through the hole **60**, due to the inertia of the air. These will be transmitted to the diaphragm **52** causing the diaphragm to oscillate accordingly. The lower frequencies will thereby be mechanically filtered out. These lower frequencies include those derived from slow movements of the chest due to breathing or shifting of the body, as well as certain low-frequency movements within the heart itself.

The electric capacitance between electrode **35** and the metallized diaphragm **52** is determined by the spacing between the diaphragm and the electrode and a vibration of the metallized diaphragm **52** along the longitudinal axis will cause the capacitance to vary accordingly. The transformer has a tuned secondary comprising the secondary winding **20** to the transformer, the fixed capacitor **34**, and the variable capacitor as defined by electrode **35** and metallized diaphragm **52** all connected in parallel. The reactance of the capacitors in the tuned secondary is reflected to the primary coil **19** of the transformer and as the spacing between the diaphragm **52** and electrode **35** changes, the effective reactance looking at the primary coil will vary accordingly.

A particular application of this invention is to detect sound waves of frequencies from about one c.p.s. to about 5000 c.p.s. emanating from the heart. The microphone is connected through a shielded coaxial cable to an RF oscillator and the output of the oscillator is connected to an oscilloscope to provide a visual presentation of the vibrations detected by the microphone. The shield of the cable electrically connects the body and coil housing to ground potential. In use, the membrane **57** of the microphone is coated with petroleum jelly and the microphone is applied to the chest wall of the patient so that the membrane is closely coupled to the chest. Optimum results are obtained when the petroleum jelly provides good surface contact between membrane **57** of the microphone and the surface of the skin with no air therebetween. Any movements of the chest wall will be transmitted directly to the membrane of the microphone.

Locking screw **41** is loosened and the microphone sensitivity is adjusted by rotating adjusting barrel **44** until the spacing between metallized diaphragm **52** and electrode **35** produces the optimum signal to noise ratio where the desired information is best presented on the oscilloscope. Because of the keyways **43*a*** and guide screw **42**, the electrode will not rotate about the longitudinal axis of the transducer. This will minimize changes in capacitance caused by any irregular surface configuration in either the electrode or the diaphragm. Locking screw **41** is tightened after the sensitivity is adjusted to maintain a consistent spacing between the diaphragm and the electrode when using the microphone.

The microphone output at RF connector **15** may be connected to a detecting device such as an RF oscillator where the primary coil is an integral element of the tuned circuit of the oscillator. A change in the spacing between the diaphragm and the electrode will cause a change in the frequency of oscillation of the RF oscillator where the output signal strength of the oscillator is proportional to the frequency of oscillation. The output of the oscillator may be connected to the vertical amplifiers of the oscilloscope in which the horizontal sweep circuit is triggered by the heartbeat taken from voltages induced from an electrocardiograph of the patient. This will put a presentation upon the screen of the oscilloscope displaying the frequencies detected by the microphone as a function of the output of the oscillator for each heartbeat.

Other means for measuring the output of the microphone are useful in addition to that described, which other means include, for example, the use of D.C. polarized voltage, and a capacitance bridge.

This invention is not to be limited by the embodiment shown in the drawings and described in the description which is given by way of example and not limitation, but only in accordance with the scope of the appended claims.

What is claimed is:

1. A microphone comprising a capacitor and a filter, said capacitor having a first plate and a second plate, said plates being spaced from each other and having an electrical capacitance between them which varies according to the spacing between said plates, said spacing between said plates being variable by externally produced sound waves striking said first plate, said filter comprising a membrane spaced from said first plate forming a pocket therebetween, the pocket being closed, there being a restricted fluid passageway from the pocket to atmosphere so proportioned as to permit flow of air therethrough in response to forces of relatively low frequencies imposed on the membrane, and to impede said flow in response to forces of relatively higher frequencies imposed on the membrane, whereby to act as a mechanical filter limiting the transmission of the lower frequencies to the first plate.

2. A microphone in accordance with claim 1 wherein said spacing between said first plate and said second plate is adjustable.

3. A microphone in accordance with claim 1 wherein said capacitor is electrically connected as part of a resonant circuit, said resonant circuit having a resonant frequency of oscillation, said variation of said capacitance causing said resonant frequency of oscillation to vary.

4. A microphone comprising a capacitor and a coil and a filter, said capacitor and said coil being electrically connected in a resonant circuit having a resonant frequency of oscillation, said capacitor comprising a first plate attached to a housing and a second plate disposed within the housing and spaced from said first plate, said capacitor plates having an electrical capacitance which varies according to the spacing between said plates, said filter comprising a membrane disposed on the opposite side of said first plate from said second plate, said membrane spaced from said first plate and forming a pocket therebetween, said pocket containing a fluid, an opening extending from said pocket to the atmosphere to allow said fluid to pass in and out of said pocket, the pocket being closed, there being a restricted fluid passageway from the pocket to atmosphere so proportioned as to permit flow of air therethrough in response to forces of relatively low frequencies imposed on the membrane, and to impede said flow in response to forces of relatively higher frequencies imposed on the membrane, whereby to act as a mechanical filter limiting the transmission of the lower frequencies to the first plate, said membrane being caused to vibrate by externally produced compression waves, said spacing between said plates being variable by compression waves striking said first plate from said fluid.

5. A microphone in accordance with claim 4 wherein said capacitor is connected in parallel with said coil.

6. A microphone in accordance with claim 4 wherein said spacing between said first plate and said second plate is adjustable.

7. A microphone in accordance with claim 4 wherein said resonant circuit comprises a second capacitor, said second capacitor acting to stabilize said resonant frequency of oscillation with changes in temperature of said microphone.

8. A microphone in accordance with claim 7 wherein said second capacitor is connected in parallel with said coil.

9. A microphone comprising a capacitor and a coil and a filter, said capacitor and said coil being electrically connected in a resonant circuit having a resonant frequency of oscillation, said resonant circuit comprising a second capacitor, said second capacitor acting to maintain impedance stability of said resonant circuit with changes in temperature of said microphone, said capacitor comprising a first plate attached to a housing and a second plate disposed within said housing and spaced from said first plate, said capacitor plates having an electrical capacitance which varies according to the spacing between said plates, said spacing between said plates being variable by vibrations from sound waves, said coil having a primary winding and a secondary winding mutually inductive with said primary winding, said capacitor being electrically connected to said secondary winding, said spacing between said first plate and said second plate being adjustable, said filter blocking undesirable vibrations from varying said spacing between said plates.

10. A microphone comprising a capacitor and a filter, said capacitor comprising a first plate and a second plate, said plates being spaced from each other and having an electrical capacitance which varies according to the spacing between said plates, said filter comprising a membrane spaced from the first plate forming a pocket therebetween and disposed on the side opposite the second plate, said membrane being adapted to be closely coupled to a body which has an outer surface subject to externally caused changes in its contour, said membrane being caused to vibrate by compression waves originating within said body, the shape and volume of said pocket being changeable in response to said compression waves and changes in contour, said spacing between said plates being variable by compression waves striking said first plate, the pocket being closed, there being a restricted fluid passageway from the pocket to atmosphere so proportioned as to permit flow of air therethrough in response to forces of relatively low frequencies imposed on the membrane, and to impede said flow in response to forces of relatively higher frequencies imposed on the membrane, whereby to act as a mechanical filter restricting the transmission of lower frequencies to the first plate.

11. A microphone in accordance with claim 10 wherein said spacing between said first plate and said second plate is adjustable.

12. A microphone in accordance with claim 10 wherein said first plate comprises a diaphragm and a metallized layer disposed adjacent one side thereof, said diaphragm being an electrical insulator, said metallized layer disposed on the side of said diaphragm opposite said second plate.

13. A microphone in accordance with claim 10 wherein said capacitor is electrically connected as part of a resonant circuit, said resonant circuit having a resonant frequency of oscillation, said variation of said capacitance causing said resonant frequency of oscillation to vary.

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KATHLEEN H. CLAFFY, *Primary Examiner.*

R. MURRAY, *Assistant Examiner.*