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Alibert

[54] HEARTBEAT TRANSDUCER FOR A MONITORING DEVICE

[72] Inventor: **Vernon F. Alibert**, Ivy Lane, Chester Heights, Pa.

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[51] **Int. Cl.** **A61b 5/02**

[58] **Field of Search** ....128/2.05 E, 2.05 N, 2.05 P, 128/2.05 R, 2.05 S, 2.05 T; 179/1 ST; 181/24; 73/69, 70

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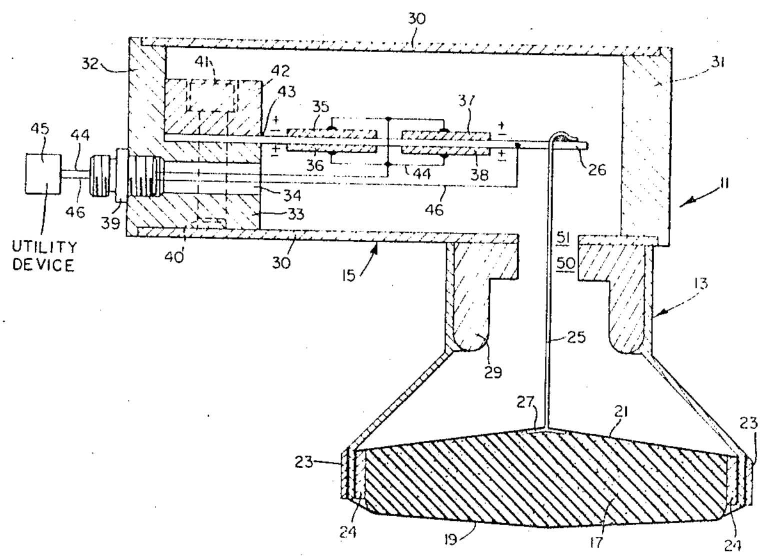
Primary Examiner—William E. Kamm
Attorney—William E. Cleaver

[57] **ABSTRACT**

The present device is a means for monitoring or listening to a heartbeat which provides an acoustical impedance to the nose generated at the area of contact between the present device and the human and/or animal body, thereby virtually eliminating such noise. In addition, the present device provides a transducer of high sensitivity which translates each heat of the heart into a meaningful signal so that each beat propogated as a force (pressure or strain) pulse can be monitored dynamically (through ear phones or the like) and/or graphically (through a cathode ray tube, a responsive pen writing on a roll of graph paper or on a suitable daylight projection and enlarging system).

5 Claims, 2 Drawing Figures



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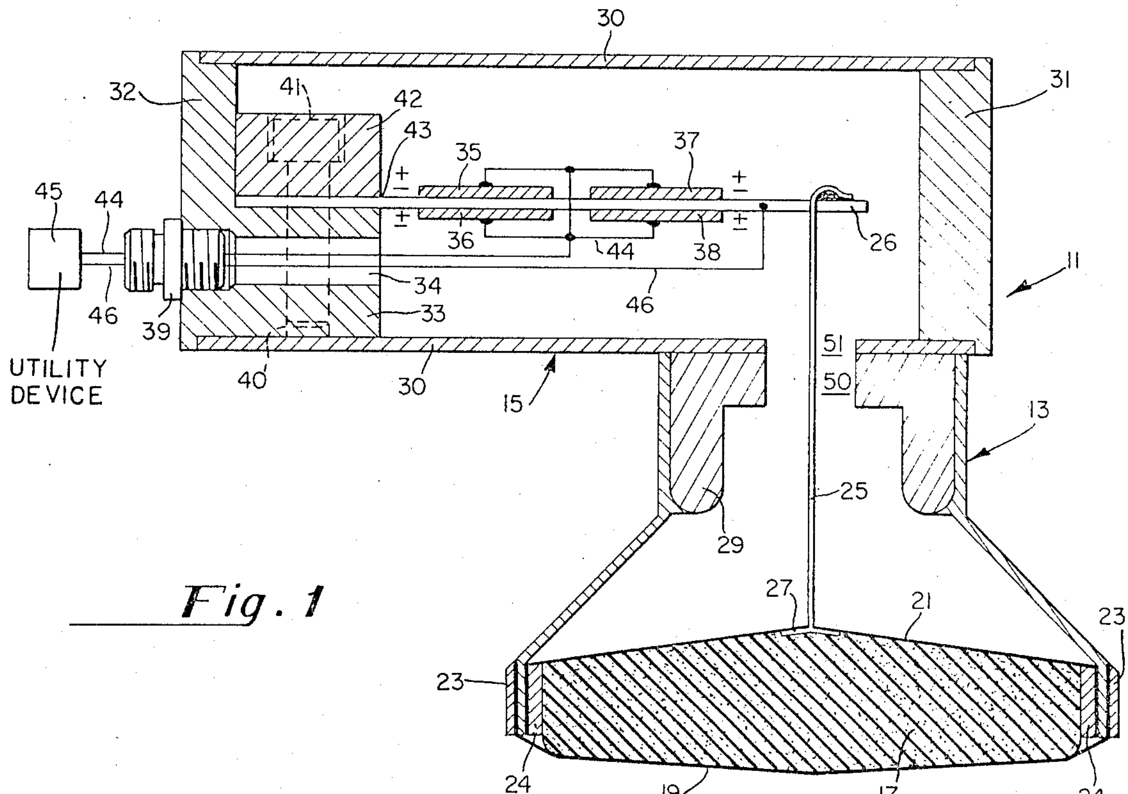

Fig. 1

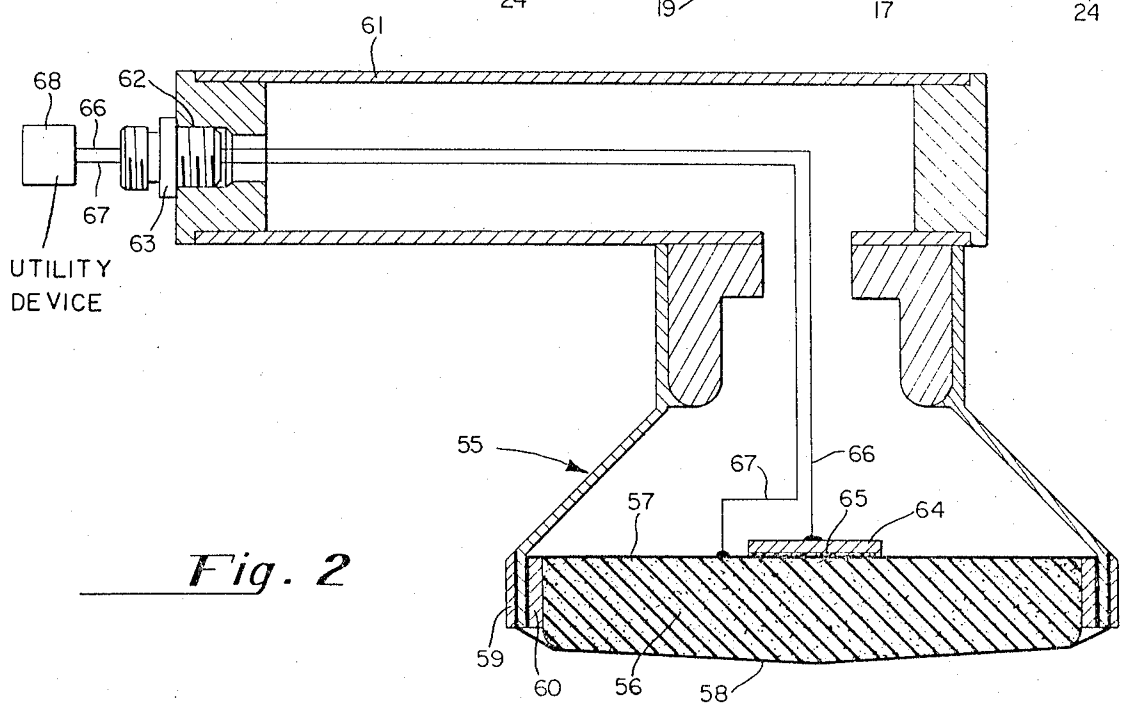

Fig. 2

INVENTOR.
VERNON F. ALIBERT

BY *William E. Cleaver*

ATTORNEY.

HEARTBEAT TRANSDUCER FOR A MONITORING DEVICE

BACKGROUND

The monitoring of or listening to heartbeats is most popularly accomplished with a stethoscope. Normally a physician who wants to monitor a patient's heartbeat places his stethoscope at a location on the patient's body which he believes to be in close proximity to the location of the patient's heart. The stethoscope is an acoustical device having a horn or a body piece connected by some hollow rubber tubing to a set of ear pieces. The horn receives acoustical energy (sound) generated by the heart, i.e., when it contracts and expands it transmits a sound to the physician's ear.

If the physician does not hear a meaningful beat he may have to relocate the stethoscope to a better location whereat the sound of the heartbeat is better transmitted through the chest cavity to the horn of the stethoscope. In accordance with this procedure, the physician must become skilled so as to be able to filter out the noise, i.e., the rustling of the hair on the patient's body or the rubbing of the horn over the patient's skin, etc. which sounds are generated as the chest cavity expands and contracts. In addition the sounds which are heard by the stethoscope are in no way amplified in the sense of electronic amplification and hence the sensitivity of such a procedure is quite limited. While the stethoscope procedure is certainly an improvement over having the physician put his ear against the patient's chest (as was the practice many years ago) and has been adequate for a number of years for many physical conditions, it has been recognized that the procedure indeed can be improved.

An improvement over the stethoscope technique, of course, is the well known electrocardiograph. In this approach the patient is "wired" to a plurality of probes which are sensitive to electrical impulses. Electrical impulses are generated in response to the muscular spasms, that is, the contractions and expansions of the heart muscle. The probes serve to transmit the tiny electrical impulses or signals to further electrical networks where they are amplified many times and ultimately transmitted to move a pen upward and downward on or across a piece of paper to create a graph. At least one of the problems now present in the electrocardiograph arrangement is the complexity of setting it up on a patient, especially if the information determined thereby would be useful in an emergency situation. In addition since the body generates a plurality of electrical impulses in response to other muscular contractions and expansions, these spurious signals must be filtered out. At least one way of mitigating the generation of these noise signals is to keep the patient extremely quiet when the electrocardiograph is being taken. Since the noise signals are never completely eliminated the graphs which are produced by an electrocardiograph must be reviewed by one who is skilled in reading such graphs, so that the true meaning of the graphs can be determined. As is often the situation if there are any doubts, the physician will normally take the electrocardiograph at a number of different times during the day and make comparisons thereof.

The present device employs a different approach in detecting the heartbeat which eliminates many of the problems of the prior art.

SUMMARY

The present device detects the heartbeat in response to a pattern of changes of force, i.e., pressure or strain propogated as a pulse. When the heart expands (the diastole phase of the heartbeat) and contracts (the systole phase of the heartbeat) the actions generate forces which are transmitted to the outer wall of the chest cavity. These forces are detected by the present device with a pressure or strain sensitive transducer. Since the acoustical (sound) energy generated by rubbing the hair and the skin, etc. also produce forces, the present device provides an impedance to the unwanted acoustical energy forces and permits only the forces resulting in response to the contractions and expansions of the heart that are propagated as pulses to the surface of the chest to be effective. As will be explained hereinafter the present device is highly sensitive so that it need not be located at the optimum location (with respect to the heart) on the patient's body to generate meaningful signals.

The objects and features of the present invention will be better understood from the following description taken in accordance with the drawings wherein:

FIG. **1** depicts a schematic sectional view of one embodiment of the present invention; and

FIG. **2** depicts a schematic sectional view of a second embodiment of the present invention.

In FIG. **1** there is shown the housing **11** which is made up of two sections, namely, the contact section **13** and the signal generating section **15**.

The contact section **13** is shaped somewhat like a trunicated cone, having a relatively wide base and an elongated throat portion which fits into the generating section **15**. The base of the contact section **13** is open and located therein is a pad **17**. The pad **17** in the preferred embodiment is made of foam rubber covered by a membrane **19** of nylon fiber fabric or some other durable material and secured on its inner surface by an inner membrane **21** which can also be formed of nylon fiber fabric or some other durable material. It should be understood that while the preferred embodiment describes a pad **17** of foam rubber this filler medium could be other forms of material which would serve as a suitable impedance to the acoustical energy or sound generated by the heart and as a dampener to the acoustical energy generated by the rubbing of hair and skin, etc. against the membrane **19**. In other words, the medium **17** is specifically chosen to dampen the unwanted acoustical energy which would be transmitted from the outer walls of the chest cavity into the contact section **13**. It has been determined by experiment that foam rubber, when held tightly by a pair of support members mounted taut, effectively dampens this unwanted acoustic energy so that the device only becomes responsive to the forces (strain or pressure forces) generated by the heart and propogated to the surface of the chest. In other words, the foam rubber when held between a tightly pulled (taut) support members, provides a proper impedance match so that the forces generated by the heart action are effective on the transducer.

The contact pad **17** is secured to the contact section **13** by virtue of an outer ring **23** and an inner ring **24** which are formed to press fit the outer membrane **19** and the inner membrane **21** respectively with the contact section **13**. In other words, first the inner membrane **21** is stretched or pulled taut across the contact pad **17** and is fitted between the inner ring **24** and the contact section **13**. The inner ring **24** is pressed onto the contact section **13** over the membrane **21** and securely holds the membrane **21** therebetween thus causing the membrane **21** to act as an upper support for pad **17**. In a like manner the outer membrane **19** is next stretched across the inner portion of the contact pad **17** and is secured between the outer ring **23** and the contact section **13** by the press fit action of the outer ring **24** thus causing the membrane **19** to act as an outer support member for pad **17**. The outer membrane **19** is formed to extend beyond the downward end of the contact section **13**. This extension provides a cushion effect and when the pad is deformed or squeezed toward the inner membrane **21** the pad **17** readily transmits each force applied against the outer membrane **19** to the inner membrane **21**.

Located through an aperture in the inner membrane **21** is a wire **25** whose upper end is secured to a flexure member **26**. The length of the wire **25** is carefully chosen so that the membrane **21** is held taut by the foot formation **27** on the base of the wire **25** in response to the wire being pulled by the flexure member **26**. In other words if the wire were too long the membrane **21** would not be held taut and any pressures applied against said membrane would not necessarily result in an action which would cause the wire **25** to be moved upwardly or pulled downwardly in response to those forces.

The length of the wire **25** serves a second purpose and that is to hold the flexure element **26** in a slightly deformed mode by pulling the flexure element **26** downward. In other words, when the wire **25** is formed, the length thereof is chosen to hold the membrane **21** taut and upward toward the flexure as well as to pull the flexure member **26** downward. Accordingly, any movement of the membrane **21** is immediately transmitted through the wire **25** to the flexure element **26**. In the preferred embodiment, the wire **25** is made of beryllium copper and is only a few thousandths of an inch in diameter. However, other suitable metals can be used. The wire **25** is bonded to the flexure member **26** and in the preferred embodiment is secured by soldering, ultrasonic brazing or the like so that when the wire moves upward and downward any hinging action which might take place would not be sufficient to tear the wire **25** from the flexure member **26**.

It will also be noted that within the elongated throat portion of the contact section **13** there is found a support member **29**. The support member **29** is a ring-like structure formed with a shelf on the upper end thereof to lend support to the throat portion of the contact section **13**. The support member **29** in the preferred embodiment is made of stainless steel but could be made of any other rigid material.

The contact section **13** is secured to the lower wall of the generator section **15** by bonding the support member **29** and the edges of the throat portion of the contact section to said lower wall with a suitable epoxy glue. However, it should be understood that other means of securing the contact section to the generator section could be used. The aperture **50** in the throat portion of the contact section opens into an aperture **51** in the generator section to permit the wire **25** to pass therethrough and be secured to the flexure element **26**.

As can be seen in the drawing the generator section **15** is composed of a housing **30** and two end sections **31** and **32**. The housing **30** and the end sections **31** and **32** are made of stainless steel although other rigid materials could be used. The end section **32** has a protrusion formed therewith which has an aperture **34** passing therethrough to the outer wall of the end section **32**. The aperture **34**, as is apparent, permits the electrical wires connected to the piezoelectric crystals **35**, **36**, **37** and **38** and the flexure element **26** to pass therethrough. Inserted into the aperture **34** is a threaded connector **39** which permits the electrical apparatus with which the present monitor head is used to be connected. It will be further noted that the protrusion **33** has a threaded portion **40** therein into which there is disposed a bolt or screw **41**. The bolt **41** secures the block **42** to the end piece **32** or more specifically to the protrusion **33** so that the flexure element **26** can be secured to the housing of the generator section **15**. The flexure element **26** has an aperture therein through which the bolt **41** passes so that when the block **42** is bolted down or secured to the protrusion **33** the flexure element **26** is held rigid and permitted to extend to the generator section **15**.

Located on the flexure element **26** as can be seen in FIG. **1** are four piezo electric crystals **35** through **38**. The piezoelectric crystals **35** through **38** are bonded to the flexure element **26** by conductive epoxy glue. It will be noted that there are electrical connections to each of the outer surfaces of the piezoelectric crystals **38** as well as an electrical connection to the flexure element **26**. Further it will be noted that there is a polarization symbology located by each of the piezoelectric crystals **35** through **38** which indicates that if there is a force applied to the lower surfaces of each of these crystals there will be a positive voltage generated at the upper surfaces of each of these crystals. With the foregoing convention in mind it becomes apparent that if the flexure element **26** is pulled downward and accordingly there is an attempt to bend that flexure element about the point **43**, then the forces effectively applied to the crystals **35** and **37** are toward the top of the housing, hence generating a voltage in accordance with the plus and minus symbols shown in FIG. **1**. By the same reasoning, the crystals **36** and **38** are effectively subjected to a force opposite to the polarization shown and accordingly generate a positive voltage at the outer surfaces thereof. Therefore the four crystals are shown connected in parallel, thus providing a relatively low "electrical output impedance" to the system and a greater source of charge. While in the preferred embodiment piezoelectric crystals are used, it should be understood that other pressure sensing elements may be employed. Further it should be understood that the flexure element **26** is fabricated from electrically nonconducting material such as a phenolic board. However there is provided an electrical conducting path (such as a copper clad path) between the conducting epoxy material which bonds the crystals **35** through **38** to the flexure element **26** and the connecting point of wire **46**.

FIG. **2** depicts a second embodiment of the present invention. In FIG. **2** there is shown a housing **55** which has a contact section that is also shaped as a truncated cone with a pad **56** disposed in the open base. The pad **56** in the preferred embodiment is fabricated from foam rubber but as mentioned with respect to pad **17**, other materials with suitable impedance characteristics could be used.

The pad 57 is supported on the inside of the contact section by a metal sheet 57 which in the preferred embodiment is made of stainless steel approximately 0.010 inches thick. Other forms of thin electrically conducting sheets of metal can be employed or other materials which can be held taut to deform the crystal 64 in response to forces applied to the membrane 50. The outer support for the pad 56 is a thin membrane 58 of nylon fabric or some other suitable material. The outer membrane 58 is formed to provide an extension beyond the lower end of the housing 55 when stretched around the pad 56.

The membrane 58 and the inner metal support 57 are held secure by the press fit rings 59 and 60 in a manner described in connection with rings 23 and 24 of FIG. 1. The handle section 61 of the housing 55 has an aperture 62 therein into which is mounted a connector 63.

Mounted to the inner support 57 is a piezoelectric crystal 64. The piezoelectric crystal 64 is bonded by a conducting epoxy material 65. A wire 66 is connected to the piezoelectric crystal 64 and another wire 67 is connected to the metal support 57. The wires 66 and 67 are located to pass through the connector 63 to the utility device 68. Accordingly, when the membrane 58 is held against the chest of the patient, the pad 56 is squeezed or deformed toward the metal support 57. Thus any forces applied against the membrane 58 are transmitted to the metal sheet 57 to deform the piezoelectric crystal 64 and generate voltages in accordance therewith. When the description mentions pressures or strains applied against it is meant to include pressures or strains removed therefrom since a deformation of piezoelectric crystal either upwardly from the membrane 58 or downwardly toward the membrane 58 would generate voltages (although of different polarities). It should also be understood that the metal sheet 57 is electrically insulated from the housing 55 by coating the portions whereat it comes in contact with the housing 55 and the ring 60 with a suitable insulator such as epoxy resin. Other forms of electrical insulation can be employed. The other portions of the structure are similar to the structure of FIG. 1 and hence are not discussed.

OPERATION

When the physician uses the present monitor head (the description being in connection with the device shown in FIG. 1 by way of example) he places the pad 17 against the chest cavity of the patient squeezing the pad toward the inner membrane. The forces which are generated by the propogation of pressure or strain pulses resulting from the contraction and expansion of the heart are then applied against the pad 17 and are transmitted through the foam rubber to the membrane 21. The forces applied to the membrane 21 cause the wire 25 to react in response thereto and hence the flexure element 26 is subjected to these forces. When the flexure element 26 responds to the forces, the piezoelectric crystals 35 through 38 generate voltages in accordance therewith and the signals thus generated are transmitted along the lead 44 to the utility device 45. The other side of the circuit is completed by the lead wire 46 which is connected to the flexure element 26 and hence to the other side of the four piezoelectric crystals 35 through 38. Now the acoustical energy which also might have been effective to create or apply forces to the membrane 21 is dampened or attenuated by the pad 17. Accordingly, it is only the changes in pressure or strain and the forces which emanate therefrom that are effective on the membrane 21 and hence on the flexure element 26. These changes in pressure are used to deform the piezoelectric crystals 35 through 38 and hence generate the voltage signals which are used to create sound in earphones (to which the physician can listen) and/or to simultaneously create signals which can be employed with a cathode ray tube to show graphically the heartbeat or with a movable pen or recording oscillograph which will create ink or light sensitive patterns on moving graph paper, film or clear cellophane that may be easily projected and enlarged on a screen.

If a physician were to use the device as depicted in FIG. 2, the forces generated by the changes in pressure from the heart beat would be directly transmitted to the crystal 64 through the pad 56. The deformations of the crystal 64 would generate voltages in accordance with the heart beats and these voltages would be transmitted to the utility device 68.

The present device while it has been described in connection with monitoring heartbeats at the chest location can be advantageously used to monitor the heartbeat at the wrist location, normally considered the location at which a patient's "pulse" is taken, or at the forearm location at the time that a blood pressure reading is taken or at other suitable places.

What is claimed is:

1. A contact device to be employed with a heartbeat monitoring system comprising in combination: housing means having a cavity and at least one aperture formed therein; pad member means mounted to fill said aperture having an inner surface lying toward said cavity and an outer surface lying away from said cavity; inner support means mounted taut across said aperture in abutment with said inner surface of said pad member; outer support means mounted taut across said aperture in abutment with said outer surface of said pad member to hold said pad member packed tightly between said inner support means and said outer support means; piezoelectric crystal means; means for coupling said piezoelectric crystal means to said inner support means whereby said piezoelectric crystal means generate electrical signals in response to heartbeat forces applied to said outer support means; and circuitry means mounted in said cavity and connected to said piezoelectric crystal means and adapted for further connection to utility means.

2. A contact device according to claim 1 wherein said means for coupling includes a flexure member means, said flexure member means mounted at one end thereof in said cavity; and wherein said means for coupling further includes connecting means connecting said flexure member means to said inner support means to transmit forces applied to said outer support means, through said pad member and said inner support means, to said flexure member means and wherein said piezoelectric crystal means is secured to said flexure member means to generate electrical signals in

response to forces applied to said flexure member means.

3. A contact device according to claim 1 whereing said pad member is made of foam rubber and is held in shape by said inner and said outer support means.

4. A contact device according to claim 2 wherein said connecting means is a rigid wire member formed to be connected between said inner support means and said flexure member means such that forces applied to said outer support means are transmitted through said pad member, through said inner support means and through said rigid wire to said flexure member means.

5. A contact device to be employed with a heartbeat monitoring system according to claim 4 wherein said rigid wire member is formed to slightly deform said flexure member means to thereby deform said piezoelectric crystal means and hence increase the sensitivity of said contact device.

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