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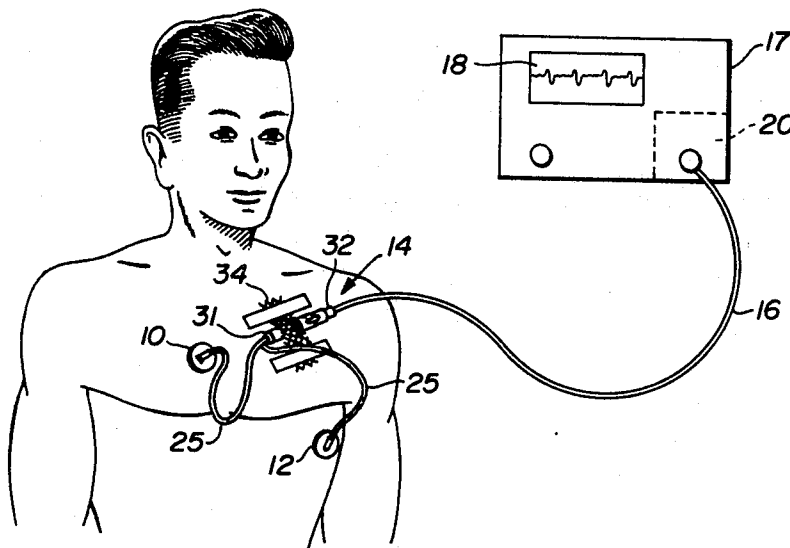
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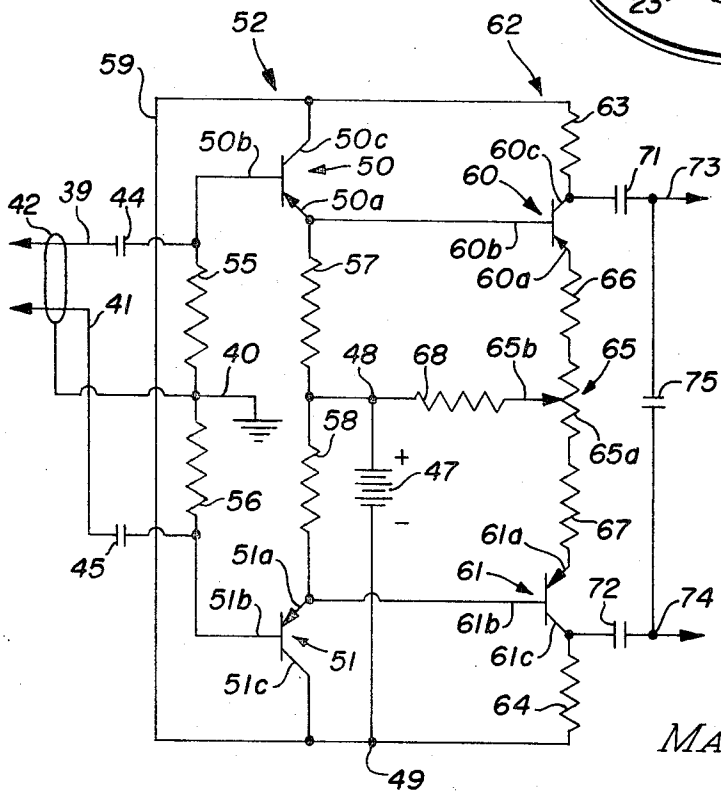
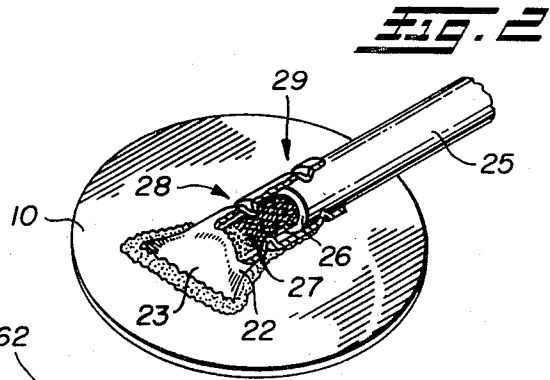
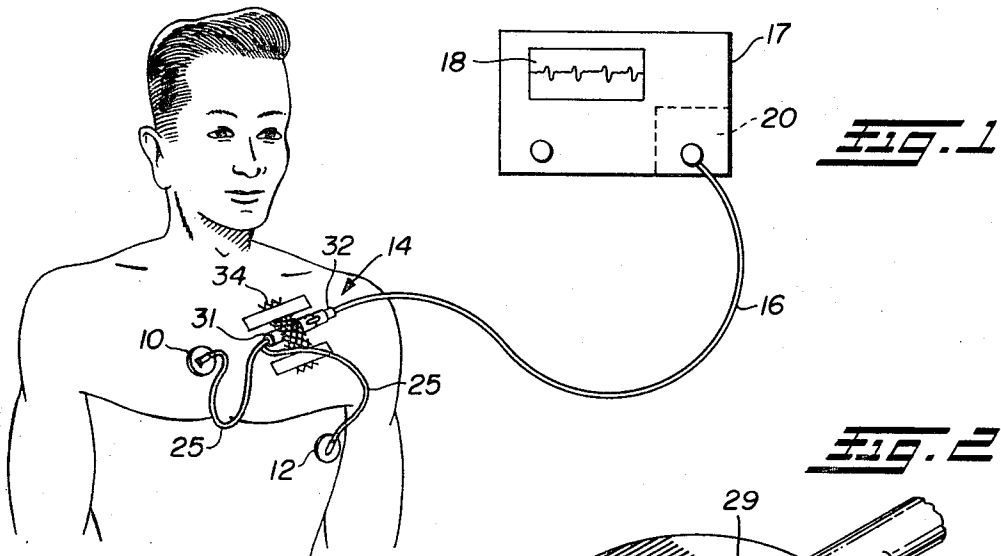
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[52] **U.S. Cl.**..... 128/2.06,
128/416, 128/417
[51] **Int. Cl.**..... **A61b 5/04**
[50] **Field of Search**..... 128/2.06
(Pick-up Digest), 416, 417; 330/30D. 69

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ABSTRACT: A cardiac monitoring system comprising a dual electrode pickup arrangement characterized by the absence of a grounded or reference electrode and including an improved electrode construction utilizing tinsel cordage as the signal transmitting medium and a corresponding dual-input preamplifier for providing a signal to an indicating meter.





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ELECTROCARDIOGRAPHIC MONITORING APPARATUS AND SYSTEM

DISCLOSURE

This invention relates to cardiac monitoring devices and more particularly to an electronic system comprising a pair of electrodes adapted for placement in a preferred location on a patient, an improved electrode construction and associated preamplifier design for converting impulses received at the electrodes to usable signals for driving the visual or recording indicator.

Coronary care units for the special care of patients who have suffered heart attacks have now become commonplace in many hospital facilities. A plurality of beds may be located in such a constant care unit and the beds may be equipped with cardiac monitors, these being electronic devices which record or display the rhythm and other characteristics of patients' heartbeats. Such information may be displayed at the patient's bedside and often for economy of hospital personnel is displayed on a central console at a nursing station so that a single observer might be able to care for a great number of patients.

Sophisticated instrumentation is already well known in these areas wherein the occurrence of severe cardiac complications can be immediately recognized and rapid care can be effected. Thus, there are presently existing electronic devices which automatically monitor the output of systems such as this which can provide an automatic warning signal when an abnormality is detected. Similarly, automatic recordings of the heartbeat indications can be initiated simultaneously or as in some systems, automatic recording of a previous interval of time may be retained.

It is apparent then that it is necessary that reliable and maintenance-free apparatus be utilized in this connection so that faulty signals will not be generated and so that constant personal supervision of each patient is not necessary. Such improved systems also find application in the modern day space probes and the like wherein constant surveillance of the condition of space personnel must be constantly telemetered and where maintenance of the system is not possible.

Therefore, it is an object of this invention to provide an improved electrocardiographic monitoring system having a smaller number of components than previously required resulting in economy of cost and weight and providing greater reliability.

It is another object of this invention to provide improved electrodes for utilization in such a system wherein high reliability is attained, the levering and shifting of electrodes being eliminated by the unique construction.

It is a further object of this invention to provide an improved cardiographic monitoring system using only two pickup electrodes and a preamplifier design which obviates the necessity for having a grounded or reference electrode.

Other objects and advantages of the present invention will become apparent as the following description proceeds.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawing setting forth in detail a certain illustrative embodiment of the invention, this being indicative, however, of but one of the various ways in which the principle of the invention may be employed.

In said annexed drawing:

FIG. 1 is an environmental drawing of the apparatus of the invention showing the electrodes positioned on a patient;

FIG. 2 is an enlarged perspective view of one of the electrodes utilized in the FIG. 1 embodiment of this invention;

FIG. 3 is a schematic circuit diagram of the preamplifier portion of the monitoring instrument shown in FIG. 1.

Referring now to FIG. 1, the apparatus of the invention includes a pair of electrodes 10, 12 affixed on the chest of a patient in a manner to be described in more detail hereinafter, joined by way of a connector 14 and a cable 16 to a remote in-

dicating device 17. The indicating device 17 may be a visual indicating monitor as shown schematically in FIG. 1 providing an indication of signal fluctuations on an oscillographic screen 18 or may be any other instrument which indicates or records signals derived from heart fluctuations such as a heart rate meter or pen recording instrument. The lower right-hand portion of the indicating device 17 is shown in outline form by dashed lines and comprises the preamplifier portion 20 of such indicating instrument 17. Under the teachings of this invention such preamplifier portion 20 cooperates with the remainder of the apparatus of the invention and the output of such preamplifier 20 provides an electrical signal for utilization by the previously mentioned recording or indicating device 17. The circuit diagram of the preamplifier 20 is shown in schematic form in FIG. 3 and will be described in greater detail hereinafter.

Previous electrocardiograph systems utilize relatively large electrode devices attached to relatively large and stiff wires for transmission of signals to a remote indicating device. This type of system is subject to false signals or noise occurrences due in part to movement of the patient which causes a shifting of the electrode or a levering due to the weight and stiffness of the cables. During long term monitoring such movement will allow the entrance of air beneath the electrodes and will dry out the contact paste used to attach the electrodes to the patient. Many attempts have been made in the past to alleviate this shifting and levering effect. However, none have been so successful as the results obtained from the apparatus of the instant invention.

Referring now to FIG. 2, the electrode 10 consists of a thin disc composed of gold or silver or other preferred metal or of a base plated surface. The electrode disc 10 is on the order of approximately fifteen-sixteenths inch in diameter and of a thickness of approximately 15 thousandths of an inch. A short section of tubing 22 is soldered on the upper surface of the disc 10 at the central portion thereof and the tubing 22 has one end 23 crimped and soldered closed. The conductor wire 25 leading from each electrode 10, 12 to the connector 14 is a length of tinsel cordage having an outer insulative coating 26. The tinsel cordage is not wire in the usual sense but rather consists of strands of fibers of nylon or silk and the like upon which ribbons of copper are individually wrapped. A bundle 27 of these copper wound strands form the center portion of the conductor wire 25 and electrically transmit the signal received at the electrode 10 to the connector 14. In the preferred embodiment of this invention, the tubing 22 is crimped after insertion of a length of the conductor wire 25 having an end section stripped of insulation 26 so that the crimped portions of the tubing 22 bear down upon the bundle 27 of conductive strands as at 28, and upon the insulative jacket 26 as at 29. It will be appreciated that the tubing crimp on the conductive bundle 27 will provide a suitable electrical contact while the tubing crimp on the insulative jacket 26 will serve to retain the tinsel cordage conductor wire 25 within the tubing 22 and will provide a measure of sealing the interior of the tubing 22 from the entrance of contaminants, especially the corrosive paste used to bond the disc 10 to the patient.

Thus, bending of the conductor wire 25 beyond the outer crimp 29 of the tubing 22 effects not so much a bending of the copper conductors contained therein and the generation of faulty signals and a high failure rate, but rather bends the fibers supporting the copper conductors. Such tinsel cordage conductor wire 25 is often described as a super flexible form of wire and it is apparent that the use of such will alleviate many of the problems of levering and shifting of the electrodes 10, 12. Such electrode construction provides maximum flexibility and permanence compatible with relatively small size and a simplified design to produce optimum monitoring results.

The electrodes 10, 12 shown in FIG. 1 are identical in construction and the conductor wires 25 attached thereto are brought into the connector 14 and affixed therein in a similar crimped manner. The connector 14 consists of a secured por-

tion 31 and a releasable portion 32 comprising a typical pin jack shielded type of connector. The secured portion 31 of the connector 14 has affixed thereon a length of plastic webbing 34 by means of an attachment screw such that the webbing 34 and thus the secured portion 31 of the connector 14 may be positioned and secured to the patient either by pinning the webbing 34 to the gown of the patient near the shoulder area or by taping both ends of the webbing directly to the chest of the patient as shown in FIG. 1.

The electrodes 10, 12 are attached to the patient in the usual manner with electrocardiograph cream under the disc and are retained in place with a covering of gauze and surgical tape. It is preferable to saturate the gauze also with the electrocardiograph cream which then will seal off the electrode from environmental conditions and prevent drying out of the cream beneath the electrode. Such technique will aid in retaining the electrodes in position and will avoid much of the bulkiness associated with prior art devices which affect the levering and shifting tendency of the electrodes. Further the conductor wires 25 may be taped down in several locations intermediate the electrodes 10, 12 and the connector 14 to avoid accidental snagging and movement thereof.

The conductive cable 16 connecting the releasable portion 32 of the connector 14 to the preamplifier 20 of the indicating device 17 is a common form of coaxial shielded wire cable, having a pair of conductive wires therein surrounded by a shield of wire mesh and encapsulated in an insulative jacket. Each of the conductive wires located therein is connected by way of the connector 14 to each of the conductive wires 25 leading to the electrodes 10, 12. The outer shield of the coaxial cable is connected to the metal portion of the connector 14 at one end of the cable 16 and to an electrical ground 40 located within the preamplifier 20 at the metering end of the cable 16. Such technique of grounding acquires its reference from within the preamplifier 20 and provides a measure of shielding at least along the coaxial cable 16 up to and including the connector 14 located on the patient. It should be noted that neither of the electrodes 10, 12 is directly connected to the ground terminal 40 of the circuit to provide a reference basis for the signals which is a common expedient in conventional electrocardiograph systems.

Referring now to FIG. 3, showing the circuit diagram of the preamplifier portion 20 of the indicating device 17, a completely transistorized and self-contained unit is described which converts the electrical impulses received from the electrodes 10, 12 located on the patient to usable electrical signals for is a common expedient in conventional electrocardiograph systems.

Referring now to FIG. 3, showing the circuit diagram of the preamplifier portion 20 of the indicating device 17, a completely transistorized and self-contained unit is described which converts the electrical impulses received from the electrodes 10, 12 located on the patient to usable electrical signals for driving the conventional circuitry of the indicating device 17 whether it be an oscillographic type recorder, recording pen with associated amplifier circuitry or indicating meter. The characteristics of any of these indicating devices are well understood by those skilled in the art and it will be appreciated that only a suitable electrical signal need be applied to these devices in order to obtain the desired response.

The signal leads from the electrodes 10, 12 via conductor wires 25, connector 14 and coaxial cable 16 are shown in FIG. 3 as input leads 39, 41 enclosed schematically in the shielded jacket of the coaxial cable 16 by the loop 42. The shield or loop 42 is connected directly to ground 40 within the circuitry while the two input leads 39, 41 connect to input capacitors 44, 45 respectively, for coupling the signal to the pre-amplifier circuit while providing direct current isolation. A source of power 47 consisting of a battery is shown connected between junctions 48, 49 for energizing the preamplifier circuit. Such power source 47 may be completely contained within the circuit as shown in FIG. 3 to make the preamplifier a removable and portable device, compatible with any other type of in-

dicating instrument. However, it is feasible as well to have the preamplifier unit receive its energization from an existing source of power within the indicating device 17 requiring only the application of a specific voltage at relatively low current levels.

The input condensers 44, 45 and thus, the signals received from the electrodes 10, 12 are coupled directly to the base electrodes 50b, 51b of a pair of transistors 50, 51 comprising the first stage 52 of the preamplifier. The transistors 50, 51 are connected in an emitter follower configuration, primarily for providing a desired input impedance at the preamplifier circuit for matching the impedance of the electrode configuration. The base electrodes 50b, 51b of the transistors are connected to the ground 40 through respective base resistances 55, 56. The emitter electrodes 50a, 51a of the transistors 50, 51 are connected to the positive terminal 48 of the battery 47 through respective emitter resistors 57, 58 and the collector electrodes 50c, 51c of the transistors are connected to the negative terminal 49 of the battery 47 by way of a common bus 59. It is noted that the battery 47 is not referenced directly to ground 40 in the preamplifier circuit and thus, it remains relatively floating. Bias conditions for the transistors 50, 51 are provided primarily by the current flow through the collectors 50c, 51c of the transistors and the emitter resistors 50a, 51a. The AC signal coupled through the input condensers 44, 45 to the bases 50b, 51b of the transistors 50, 51 is amplified in the first stage 52 to provide an increased signal at the emitters 50a, 51a of the transistors.

A second pair of transistors 60, 61 having base, 60b, 61b, emitter 60a, 61a and collector 60c, 61c electrodes respectively, is provided to supply a second stage 62 of amplification for the signal from the emitters 50a, 51a of the first stage 52 of the preamplifier circuit. The collectors 60c, 61c of the transistors are connected through respective collector resistors 63, 64 to the negative terminal 49 of the battery source via the common negative bus 59, while the base electrodes 60b, 61b are connected directly to the emitter electrodes 50a, 51a of the emitter follower stage 52. The emitter electrodes 60a, 61a of the transistors 60, 61 are coupled to either end of the resistance element 65a of a potentiometer 65 through respective fixed emitter resistors 66, 67. The movable slider 65b of the potentiometer 65 is connected through a fixed resistor 68 to the positive terminal 48 of the battery 47. Thus, the configuration of the second stage 62 of the preamplifier circuit is a form of differential amplifier, wherein the balance of the stage 62 is varied by the setting of the movable slider 65b of the potentiometer 65. The output of the preamplifier circuit is taken from the collector electrodes 60c, 61c of the respective transistors 60, 61 and is decoupled by means of serially connected condensers 71, 72 to provide signals at the output terminals 73, 74 of the preamplifier for actuating the oscillographic trace of the indicating device 17 or for utilization in any other manner. A condenser 75 of small capacity is shunted across the output terminals 73, 74 to prevent the occurrence of spurious high frequency signals.

Thus, the bias relationships of the second stage 62 of the preamplifier are set up through the relative values of the fixed resistors in the emitter and collector circuits of the transistors 60, 61 and the setting of the movable slider 65b of the potentiometer 65 in relation to the output level of the emitter follower stage 52 of the preamplifier. It will be apparent that signals occurring at one transistor of the second stage 62 will cause bias fluctuation through the common fixed resistor 68 which will be reflected as a signal in the second transistor of the second stage 62. Such circuitry provides many of the advantages of a typical differential amplifier stage in rejecting simultaneously occurring signals received from the electrodes 10, 12 to produce output signals indicative of only the difference of the electrode signals. As pointed out previously, the battery 47 is floating in respect to the ground terminal 40 of the preamplifier circuit and this particular configuration allows an adjustment in bias conditions of the second stage 62 of the preamplifier circuit by the potentiometer 65 to effect a

reference level of the second stage 62 which corresponds to the ground level of the emitter follower stage 52 and which achieves a balance in amplification of transistors 60, 61.

In a preferred embodiment of this circuit, typical values of the components would be as follows:

Resistors 55, 56	ohms	100K
Resistors 57, 58	do	24K
Resistors 63, 64	do	10K
Resistors 66, 67	do	390
Resistor 68	do	20K
Potentiometer 65	do	200
Condensers 44, 45	mfd	22
Condensers 71, 72	mfd	47
Condenser 75	mfd	47
Transistors 50, 51, 60, 61	PNP	
Battery 47	volts	6

It will be apparent from the relative values of components used within the preamplifier circuit that a relatively high input impedance is provided for the signals received on lines 39, 41 in comparison with the impedance of the electrodes 10, 12. Such high input impedance is advantageous in matching the characteristics of the electrodes 10, 12 attached to the patient and provides a high realization of input signal. Such efficient coupling allows the use of the relatively small electrodes 10, 12 to prevent the levering and slippage problems of prior art systems and is compatible with the relatively minute signals generated at the electrodes 10, 12. However, such impedance arrangement is further characterized in realizing a much lower impedance than that of known prior art systems which provided an extremely high input impedance to immunize the system against the variations in connections to the patient. The instant system with relatively low impedance has the advantages of deemphasizing electrode 10, 12 noise, of being less susceptible to electromagnetic interference and of allowing the deletion of the conventional ground electrode on the patient. Such advantages are vital to long term monitoring in the state of the nursing and hospital art and result in a highly reliable and minimal maintenance system. For typical examples, electrodes 10, 12 exhibit an impedance of approximately 1,000 to 5,000 ohms, while the input impedance of the preamplifier circuit is on the order of 100 K ohms, as compared with prior art systems having input impedances of 1 megohm or greater.

Although a dual output at terminal 73, 74 is shown in the preferred embodiment of the preamplifier circuit of FIG. 3, it is possible as well to realize a single-ended output from the cir-

cuit. Thus, instead of providing a floating, nongrounded signal for utilization by the indicating device 17, one of the terminals, for example, terminal 74 may be connected to a ground potential and the output signal will appear at terminal 73, referenced to such ground potential.

Other modes of applying the principles of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

I claim:

1. Apparatus for monitoring cardiac variations in body electrical potentials comprising a pair of electrodes adapted for placement on the chest of a patient, a separable connector adapted for securement on the chest area, a pair of tinsel cordage wires in encapsulation jackets connecting said electrodes with said connector, each said electrode comprising a thin disc of conductive metal adapted for retainment on an area of the chest in a paste electrolyte, a short length of conductive tubing having one end compressed and adapted to lie across the upper surface of said disc, and means for bonding said tubing in electrical contact with said disc, said means sealing the compressed end of said tubing, said tubing being crimped adjacent the open end for sealing engagement with the encapsulation jacket and being crimped adjacent the compressed end for electrical engagement with said tinsel cordage wire, a dual conductor shielded cable connected to said connector for transmission of the signals received at said electrodes, and a first and second stage amplifier connected to said cable for combining the signals from said electrodes, said second stage amplifier comprising a pair of transistors in a common emitter differential amplifier configuration, and a potentiometer interconnected between the emitters of said transistors, said potentiometer having a movable tap referenced to a source of potential.

2. Apparatus as set forth in claim 1 wherein said first stage amplifier comprises a pair of transistors connected in emitter follower configuration for driving said differential amplifier stage, said first stage transistors having signal input base resistors referenced to ground potential and emitter resistors referenced to the source of potential for said differential amplifier stage.

3. Apparatus as set forth in claim 2 further including an indicating monitor for recording the combined signals from said electrodes, said monitor being connected to receive the signals from said differential amplifier stage as a single ended input.

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