An electrocardiograph apparatus including a recorder electrically connected by a patient cable to a number of electrical terminals in a distribution head so that each terminal forms a contact point for a series of lead wires each adapted to receive electrical impulses from a selected location of the patient’s body. To assist verification of correct interconnection, the distribution head incorporates the configuration of a schematic representation of the body with the position of each distributor terminal corresponding to actual examination locations on the patient. As another verification check, the lead wires may be of varying length corresponding to the distance between the terminals and the patient’s contact points. An indicator light in the electrocardiograph circuit is de-energized upon establishing connection with the patient to indicate satisfactory contact. Electronic circuitry is provided for comparing and controlling various voltages and reference ground with the patient to derive standard output signals commonly used in EKG analysis.

5 Claims, 8 Drawing Figures
ELECTROCARDIOGRAPH LEAD DISTRIBUTION AND CONTACT TESTING APPARATUS

BACKGROUND OF THE INVENTION AND OBJECTS

Electrocardiographs are widely used in cardiology to examine patients for their function irregularities. These devices produce electrocardiogram strip charts in response to electrical signals produced by sensing various points of the body by electrodes from which lead wires connect to terminals on the electrocardiograph. In connecting such leads to the body, there is a standard system for the placement of each specific lead so that the resulting recording is presented as a standard format to facilitate reading and analysis. Such systems include the standard 12-lead system and the Frank system, and may use identifiers to indicate proper connection points such as the abbreviations RA, LA for the right and left arms. This type of labeling has usually been placed on the patient cable junction or at the end of each lead wire to specify the proper connection.

The above type of electrocardiograph system is subject to two principal sources of error. First, there are enough leads that frequently the lead for a specific portion of the body is mislocated by the technician. A second source of error is that of the technician making insufficient electrical contact of the electrode to the patient thereby resulting in an inaccurate electrocardiogram.

Also, the electrical signals being sensed are small and subject to electrical interference, particularly where remote station operation is desired, and there is, therefore a need for a new and improved electrocardiograph apparatus.

SUMMARY OF THE INVENTION AND OBJECTS

In general, it is an object of the present invention to provide an electrocardiograph apparatus which overcomes the above disadvantages and limitations.

It is a more particular object of the invention to provide a distributor in the above system which decreases the probability of human error in mislocating the lead wires on the patient.

It is another object of the invention to provide in the above system an indicator responsive to faulty contact of the electrodes with the patient.

Another object of the invention is to provide a distributor and electrocardiograph apparatus of the above character which is adapted for multistation use with a single electrocardiograph recorder.

The invention is directed to electrocardiograph apparatus in which an electrocardiograph base station provides a plurality of electrical input terminals for receiving electrical signals and for amplifying and recording such signals. A patient cable is also provided and terminates in a remotely located distribution head having a distribution means including a plurality of lead wires each adapted to receive electrical impulses from an electrode positioned at selected examination regions of the patient. The head is provided with a representation of the human body and the lead wires emerge from the distribution head at regions of said representation corresponding to actual examination regions on the patient. In one preferred embodiment indicator lights are associated on the representation adjacent to each of the associated examination regions and serve to provide visual indication of the effectiveness of connection of the electrode. One suitable indicator is a small electric light which remains energized until proper connection of the electrode is made to the patient.

The distribution head is provided with electronic circuitry for facilitating remote electronic operation and includes preamplifier buffer stages, driven ground control circuit and summing amplifier for generating a common signal. In one form of the invention commercial electrocardiograph may be employed, but preferably an electrocardiograph of the present invention is used and provides special trace control and centering functions.

Additional objects and features of the invention will be apparent from the following description in which the preferred embodiments are set forth in detail in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a drawing illustrating the electrocardiograph apparatus of the present invention.

FIG. 2 is an electrical schematic of a representative portion of the circuitry used in the apparatus of FIG. 1.

FIG. 3 shows a block diagram of the circuit of the electrocardiograph apparatus of the present invention.

FIG. 4 shows a schematic diagram of a buffer preamplifier circuit of the apparatus of FIG. 3.

FIG. 5 shows a summing amplifier circuit as used in the apparatus of FIG. 3.

FIG. 6 shows a schematic diagram of a driven ground circuit constructed for use in the apparatus of FIG. 3.

FIG. 7 shows a schematic diagram of trace control circuitry as used in the circuit of FIG. 3.

FIG. 8 shows another embodiment of the distribution head for use with the apparatus of FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown an electrocardiograph system constructed in accordance with the present invention and includes an electrocardiograph signal processor and recorder 11 such as is shown in detail in FIG. 3. Commercial electrocardiographs such as Model 5000 manufactured by Hewlett Packard Corporation of Palo Alto, California or Brush Model 260 manufactured by Brush Instruments of Cleveland, Ohio, may also be employed with reduced features.

The electrocardiograph 11 input is electrically connected by a multiconductor patient cable 12 to a remote distribution head 13.

Distribution head 13 consists of a case 13a which contains the associated electronics and incorporates a representation 10 of a human form from which associated terminals connect to respective ones of a plurality of lead wires 15a–j. Each lead wire is disposed upon representation 10 in positions corresponding to the desired point of connections to the patient such that terminal 14a, wire 15a emerges from the right arm of the representation; terminal 14b, wire 15b the left arm; and 14c, 15c and 14d, 15d emerge from the left and right foot respectively. Terminals 14e–j and wires 15e–j are located in any convenient position, such as on the side of the distribution head, and correspond to chest connections commonly designated V1–V6. If space permits, these are preferably placed in corresponding positions on the chest of the representation as shown in FIG. 1 and indicated as terminals 14e′–14j′.
The other ends of lead wires 15a-j are connected to electrodes 16a-j respectively of the conventional type and style which are adapted for connection with selected external portions of a patient at corresponding contact points 17a-j respectively for the sensing of body functions thereat and transmission of electrical impulses from the patient's circulatory system. For these small impulses to be transmitted with repetitive accuracy to recorder 11, it is important that a reproducible contact be established at points 17a-j. For this purpose, known procedures such as the application of conductive adhesive liquids or creams may be used between the electrode transducers 16a-j and patient 19 before placement.

As shown in FIG. 1, the representation 10 on distribution head 13 can be formed with a planar surface 18 having an outline in the general shape of the human body and may be of contrasting color to that of the case itself. Thus, terminals 14a-j are disposed on surface 18 corresponding to the proper points of application on patient 19, i.e., the proper patient contact points 17a-j so that each body terminal is associated with a point 14 on the representation 10 corresponding to the patient 19 to which the respective wire and electrode should be attached. This arrangement enables the electrocardiograph technician to instantly locate and verify the proper one of electrodes 16 for each contact point 17 on the patient by placing the distribution head on or adjacent the patient in the same general orientation used with the primary aid of physical correspondence connecting each associated electrode to the patient.

As an even further check on the correct placement of the lead wires, terminals 14 can be labeled according to common designations used in the industry (e.g., RA for right arm, RF for right foot, V1, V2, V3 . . . V6 for particular areas of the chest, etc.). Color labeling may be used in addition to or in place of such letter labeling.

In a further verification feature of the present invention, the distributor box is located in close proximity to the patient and the lead wires connected to the contact points are of varying length. The proper distances between the terminals on the box and the contact points on a patient of average size with only sufficient excess length to accommodate tall patients. The distributor box can be positioned at any point near the patient, such as directly on the chest or adjacent to him. By this arrangement, on a proper mating of body terminals distributor terminals, each lead wire is of sufficient length for interconnection with its corresponding terminals. On the other hand, if a technician mistakenly links a terminal associated with a long lead (e.g., a leg terminal) with a contact point only requiring a short lead wire (e.g., a chest terminal), this error will become apparent with the difficulty encountered in an attempt to connect the remaining chest terminal, with a short lead wire, to the leg contact point.

Referring to FIGS. 1-2, indicator means are provided for visually indicating inadequate coupling between patient 19 and EKG 11 via lead wires 15 and electrodes 16. The indicator means preferably takes the form of individual lights 21a-j connected respectively in each electrode circuit as shown, lights 21a-j are physically positioned adjacent each respective terminal 14a-j and in this manner, each respective light is energized next to that terminal of any lead wire that remains inadequately connected to the patient.

Since distribution head 13 is mobile, it is usually placed near the subject. Thus, it is quite convenient to locate the indicators and terminals directly on head 13. Furthermore, due to the availability of minute transistors and integrated circuits, it is preferable to also place buffer preamplifier circuitry required to amplify the electrical impulse received from each point on the patient directly in the distribution head. In this way, the present arrangement facilitates the use of one recording system 11 or console with multiple remote patient examination stations each station employing its own remotely operated distributor and preamplifier box. And, the signal emitted from distributor box 13 is then strong enough to be relatively unaffected by any noise or loading introduced by cable 12, and accordingly, long arrangements from remote stations located far from the basic EKG console can be used.

Referring to FIG. 2, there is shown an example of one suitable logic circuit for a single EKG connection point 17a and associated terminal such as 14a. It is to be understood that each of the points 17 is provided with such a circuit constructed and operated in a similar manner.

As shown in FIG. 2, let it be assumed that the electrode 17a and associated wire 15a terminate on the input lead 31a of an operational amplifier used as a bridging amplifier stage 33a connected as shown. Also assume that the patient is grounded or referenced to a given potential. When lead 31a and electrode 17a are not properly connected to the patient, they represent an open circuit and the potential at lead 31a can follow the input current of the operational amplifier. For that shown, such an input current tends to drive the output to full negative voltage (or the reverse for transistors of opposite polarity).

When electrode 17a is properly connected to the patient, the resistance across the input (lead 31a) is that of electrode 17a and the patient, of the order of a few thousand ohms. This is a sufficient change from the open circuit condition, whereby a significant and measurable change in the input voltage will occur, by which the input electrode 31a goes from a negative voltage to a nearly zero voltage condition.

The output of amplifier 33a is connected to the input of a transistor amplifier 41a for detecting this change in voltage and for turning off the signal light 21a whenever the negative voltage on lead 31a drops below a predetermined threshold level. For, when the associated electrode is disconnected the full negative voltage is applied to the base 43 of a npn transistor 45. Each respective one of lamps 21a is wired in series in the collector circuit of the transistor. Thus, negative base voltage turns on the transistor, permitting current to flow to the grounded emitter. When the electrode 17a is properly connected the output of the operational amplifier is nearly zero volts and transistor 45 is thereby turned off.

FIGS. 3-8 illustrate another preferred form of circuitry for carrying out the present invention which also incorporates special trace control and centering circuits as well as driven ground circuitry as will be hereinafter explained. Thus, as shown in FIG. 3, the distributor 13 contains a plurality of buffer preamplifiers 102-110, a driven ground circuit 112, and a summing amplifier 114. Each lead from an electrode 16 attached to the patient 19 is brought through the appropriate distributor terminal 14 and passes to an input buffer
preamplifier (102–110), the circuitry of which is illustrated in detail in FIG. 4. It is to be understood that each of the buffer preamplifier circuits could alternately be substituted by the circuit of FIG. 2, if desired.

Each of amplifiers 102–110 is of the circuitry form shown in FIG. 4 and consists of a field effect transistor (FET) first stage followed by a bipolar transistor second stage connected such that the collector of the FET 120 lies in the base circuit of the bipolar transistor 122. This circuit has the property that presents a very high input impedance to the incoming signal and converts the signal to a low output impedance suitable for being carried on an extended cable 12 which connects the low impedance output of the distributor output terminals 17 at the patient to a remote amplifying and recording means to be hereinafter described. Such a cable illustrated within the circle labeled 116 (FIG. 3).

A diode 124 is connected across the input to thereby ground the same through the diode voltage drop so that no long term drift in open circuit operating potentials can appear at the electrode before the same is connected to the patient.

The summing amplifier 114 (FIG. 5) receives the RA, LA and LF outputs representing right arm, left arm and left foot and through matched input resistance, the sum of these signals appears at the input of a differential amplifier 125 from which a common signal is derived via line 115. The common signal on output lead 115 is also connected to the trace and centering control amplifiers, 141–148. This common signal via lead 115 is used as a reference signal against which the signals V_L, V_R are compared in the latter circuits.

The preamplifier section also contains a driven ground circuit 112, including a filter means 113 for sensing induced 60 and 120 cycle voltages induced in the patient and for comparing such induced voltages with a ground potential level supplied by an amplifier having the same offset characteristics as an associated one of the buffer amplifiers 102–110. In this way filter 113 prevents oscillation of circuit 112 while still providing effective operation in the range of interest, that is up to 180 Hz.

Referencing particularly to FIG. 6, there is shown resistances and capacitances as indicated on the drawing and making up a filter circuit 113 upstream of the input 117 to a differential amplifier 118. While any of the various voltages from the patient could be taken as a reference input, the particular input voltage that has been arbitrarily selected to be taken is from the left arm LA via amplifier 103.

An FET amplifier 119 supplies a ground reference signal having the same offset characteristics as the remaining buffer amplifiers 104–110. The output of amplifier 119 is applied to the other input of differential amplifier 118, the output of which is carried through a resistance 121 of the value shown and thence to the electrode attached to the right foot.

In this way, differential amplifier 118 serves to respond to changes in the induced voltages of the patient to supply a compensating voltage which drives the patient through the right foot to a zero potential relative to the ground potentials defined by the outputs of the various FET amplifiers 120. The remaining portion of FIG. 6 corresponds to that of FIG. 4 and need not be again described in detail.

By selecting the values shown for the elements of filter 113, the input to differential amplifier 118 via line 117 is selectively sensitive to low frequency signals, such as 60 cycle voltages, and is relatively insensitive to high frequency signals, such as those produced by the electrical characteristics of the patient.

Referring now to FIGS. 3 and 7, the various outputs of the distributor are connected through the extended cable 116 to the inputs of tracing amplifier and centering control circuits 141–148 as is common in the practice of the electrocardiogram art. Thus, the left arm and right arm inputs (LA, RA) are applied to one differential pair (141) while the left arm and left foot (LA, LF) form another (142). The difference signals being commonly termed as “I” and “II” outputs from which “III” aV_L, aV_R and eV_outputs are derived by standard sum and difference amplification.

Likewise, signals from the various chest electrodes V_1–V_6 and from common 114 are differentially compared to derive six outputs V_1–V_6 as is known in the art. Each of these comparisons is preferably made with differential amplifier circuitry which compares the output of at least two different buffer amplifier and summing circuits to derive an output signal, such as differential amplifiers which consist of suitable integrated circuits as are now commonly available (FIG. 7) and preferably consist of a pair of series connected operational amplifiers 127, 128 having a gain of the order of 20K with a feedback stabilization loop represented by resistances R6 and R7 and R8 in FIG. 7. The overall amplification is approximately 1,000.

Another feed-back loop is connected between the output of amplifier 128 and one input signal lead 129 and consists of resistors R12 and R17 connected in series through an oppositely connected pair of diodes CR1 and CR2 to the high input impedance operational BB3308 amplifier 130. The output of amplifier 130 is taken through R11 to the input 129 of differential amplifier 127 to provide for DC voltage offset as will be described.

The junction of R17 and R12 is bypassed to ground through a “ready” circuit 133 consisting of a 33,000 ohm resistance 131 and a transistor Q3 and is also bypassed directly to ground through a “run” circuit 134 consisting of transistor Q2.

In operation, the sensitivity of the circuit is established by the diode CR1 and CR2 such that whenever the output voltage appearing at junction of R12 and R17 exceeds ± one-half volt, that voltage is impressed upon the integrating amplifier 130 to thereby cause the input circuit 129 to receive a compensating voltage. In this manner, the output 132 is maintained at a DC level somewhere between ± one-half a volt.

When the electrodes have been connected to the patient, and it is desired to begin an electrocardiogram trace, the “ready” circuit 133 is activated by connecting suitable voltage through resistor R15, diode CR3 and to the base electrode of transistor Q3. This causes reduction in the sensitivity of the diode circuit CR1, CR2 because of the low impedance path to ground through Q3 and R9. The value of the resistance R9 is such that the reduction in sensitivity permits the draft voltage to be uncentered by as much as ± one and one-half a volt during the “ready” position.

After “ready” circuit 133 has been utilized, the final trace is taken by actuating the “run” circuit 134 via resistor R14 and transistor Q2. This circuit effectively grounds the input of the feed-back loop which is clamped by the action of the voltage drop across R17
and therefore the offset voltage remains wherever it was between ± one and one-half a volt. A recorder output circuit 136 is also formed by Q1, R13 and CR5 such that whenever run circuit 134 is actuated, the signal output is taken from collector 135 for recording output 137. In this way, any drift in DC potential or from an electrode or anywhere else in the circuit can only drive the tracing off scale after recording is commenced and the EKG attendant or interpreter will have no doubt that there has been no spurious correcting signals applied during the trace in order to maintain circuit centering.

Generally, the operator actuates the "ready" circuit for a little while just before the recording commences, by way of example, for a few heart beats, and during that time the centering action is such as to permit the entire EKG trace to center up on the graph paper. In so doing, it would be realized that the base line is permitted to move anywhere within the range of the ready circuit, i.e., ± one and one-half volt. Thereafter, the "run" circuit 134 is actuated to clamp the setting at a fixed value.

Another embodiment of distributor is shown in FIG. 8 in which a distribution head 20' is formed in a three-dimensional schematic representation of the human body in the form of a doll. The elements 14, 15, 16 and 17 (a-j) of the embodiment of FIG. 8 are of the same type as the corresponding elements described with respect to FIG. 1 and are therefore given the same numbers but with the addition of a double prime mark (""").

I claim:

1. In electrocardiograph apparatus, a distributor having a plurality of input terminals for receiving electrical signals generated at selected positions on a patient under examination, a plurality of input leads terminating in electrodes adapted to be placed into contact with the patient and connected to said terminals, buffer amplifier means associated with said leads for accepting a high input impedance signal from the patient and for converting it to a low output impedance signal, extended cable means for connecting the low output impedance signals from said distributor to remote amplifying and recording means, a driven ground circuit including means for sensing induced voltages in the patient and means responsive to said last named means for introducing a compensating voltage to one patient electrode whereby the voltage of the patient is kept zero relative to ground, and further in which said means for sensing induced voltages in the patient consists of a filter circuit selectively sensitive to low frequency signals and insensitive to high frequency signals, a differential output for receiving signals from said filter circuit, a ground sensing means for providing a second input to said differential amplifier.

2. An electrocardiograph apparatus comprising a distributor having a plurality of input terminals for transmitting electrical signal generated at selected positions on a patient under examination, a plurality of input leads terminating in electrodes adapted to be placed into contact with the patient, buffer amplifier means associated with said leads for accepting high input impedance signals from the patient and for converting them to low impedance output signals, extended cable means for connecting the low impedance output signals from said distributor to a remote amplifying and recording means, a summing circuit for adding certain ones of said output signals to derive a common signal, differential amplifier means connected to at least two different ones of said buffer amplifier means and summing circuit to amplify the output thereof, means forming a DC sensing circuit with respect to the DC level of the patient and including a feed-back loop for supplying a DC bias signal to the input of said differential amplifier, said feed-back loop having means to define a first sensitive condition for controlling base line drift including means for applying DC bias to the input of said differential amplifier, said drift control means being operable within approximately ± one-half volt position, and means for establishing circuit centering in which the total voltage wave form of an incoming signal is sensed and said signal centered within ± one and one-half volt to define a second sensitive condition and means for selectively controlling the operation of said first and second conditions of said feed-back loop.

3. In an electrocardiograph system of the type employing an electrocardiograph having input terminals, apparatus for interconnecting said electrocardiograph to a patient including distributor means, a plurality of first leads coupled between said electrocardiograph input terminals and said distributor means for transmitting thereto electrical signals from said distributor means, said first leads adapted to permit remote location of said distributor means in the immediate proximity of the patient, diagram means formed on said distributor means for forming an outline representation of a human form showing body, arms and legs thereon, a plurality of terminal locations formed on said representation, and including right and left arm, right and left terminal locations and chest terminal locations, at least said arm and leg terminal locations being positioned on the corresponding leg or arm of said representation, a plurality of second leads terminating in electrodes adapted to be placed in contact with the respective examination point on the patient, and including at least right and left arm, right and left leg, and chest leads and connected to the respective ones of said terminal locations, said second leads adapted to extend from the respective terminal locations on said distributor means to the proper examination point of said patient, circuit means within said distributor for connecting said second plurality leads to said plurality of leads, said circuit means including a plurality of identical buffer amplifiers respectively connected to each electrode lead for accepting a high input impedance signal from the patient and for converting the signal to a low output impedance, indicator means responsive to proper contact of any of said electrodes with the patient to give a visual signal thereof, said indicator means being disposed adjacent to each related terminal location on said distributor means, said indicator means including a light source and a means responsive to a shift in impedance caused by contact of an electrode to the patient to de-energize said light source upon proper connection being established to the patient.

4. A device as in claim 3 wherein said distributor means has a shape including essentially flat surface on which said representation is formed.

5. A device as in claim 3 wherein said distributor means itself is formed in a doll-like representation of the human form. * * * * *