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ELECTRODES FOR VENTRICULAR DEFIBRILLATOR

Filed June 25, 1962

2 Sheets-Sheet 1

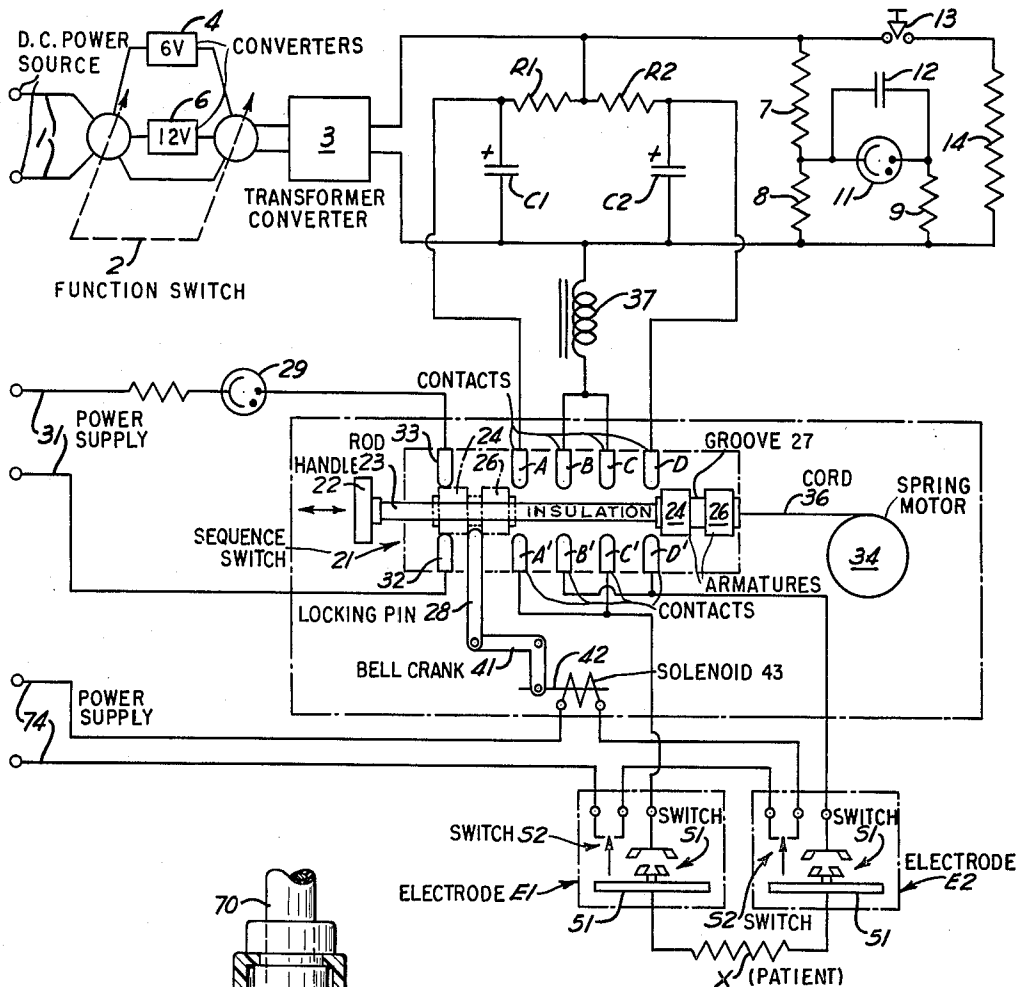


Fig. 1

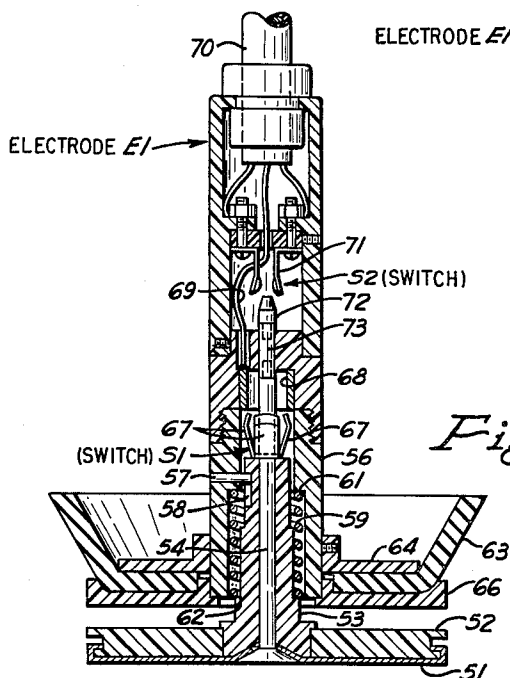


Fig. 2

INVENTORS.
EARL M. BECKER
WILLIAM C. STUCKRATH

BY

Brown, Critchlow, Flick & Peckham.
ATTORNEYS.

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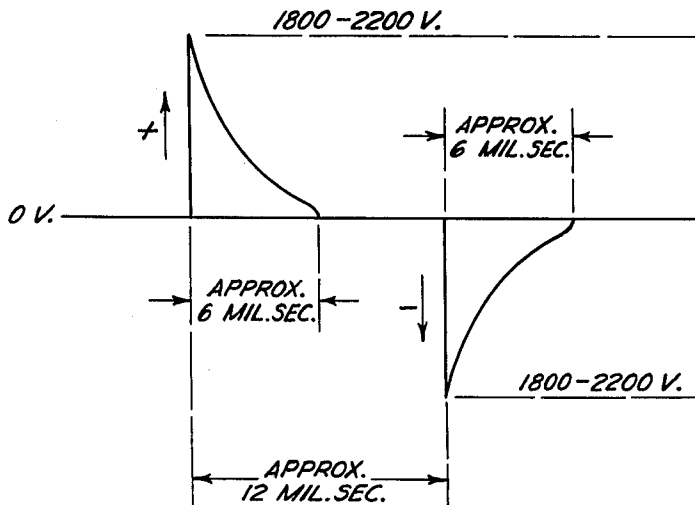


Fig. 3

INVENTORS.
EARL M. BECKER
WILLIAM C. STUCKRATH

BY

Brown, Critchlow, Flick & Peckham
ATTORNEYS.

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ELECTRODES FOR VENTRICULAR DEFIBRILLATOR

Earl Matthew Becker and William Carl Stuckrath,
Pittsburgh, Pa., assignors to Mine Safety Appliances
Company, a corporation of Pennsylvania
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4 Claims. (Cl. 128—421)

This invention relates generally to the electrodes used in a ventricular defibrillator for stopping cardiac fibrillation by the delivery of one or more pulses of high voltage electric current through a patient's body in the region of the heart. More specifically, the invention relates to electrodes that incorporate certain safety features for the protection of the patient and those using the apparatus.

It is accordingly among the objects of this invention to provide a pair of electrodes for use in a cardiac defibrillator, in which the electrodes will incorporate the following safety features, among others: (1) the electrodes will normally disconnect from the high voltage source the electrode surfaces that are adapted to make contact with the patient's body; (2) when, and only when, both electrodes have been pressed with a predetermined force against the patient's body, will the electrode contact surfaces be connected to the high voltage source; (3) where a pulse generator serves as the high voltage source, then when, and only when, both electrodes have been pressed with a still greater force against the patient's body will the electrodes initiate the operation of the pulse generator, i.e., a certain predetermined force will be necessary to connect the pulse generator to the contact surfaces of the electrodes and still greater force will be required to initiate operation of the pulse generator to deliver a rapid series of electric current pulses through the electrodes to the patient's body.

Further objects will be apparent from the following description of the invention, in connection with the attached drawings, in which:

FIG. 1 is a schematic wiring diagram of a defibrillator incorporating the present invention;

FIG. 2 is a sectional elevation of one of the electrodes, showing structural details of the safety switches mounted therein; and

FIG. 3 is a representation of the wave shape of the current pulses produced by the discharge of two capacitors when connected in the circuit of FIG. 1.

In accordance with this invention, which may be used in any type of defibrillator for delivering one or more pulses of electric current from a high voltage source or from a pulse generator through a pair of electrodes to a patient's body, each electrode includes a conducting contact surface, a stem mounted thereon, and a hollow insulated handle slidably receiving the stem. Means are provided for retaining the stem within the handle, but leaving it free for longitudinal reciprocation therein; and spring means urge the stem in a direction out of the handle. Inside the handle, a normally open first switch is adapted to be closed only when the stem is pushed into the handle a predetermined distance against the urging of the spring. When the first switch of each electrode is in its closed position, those switches connect the high voltage source (for example an A.C. transformer, one or more charged capacitors, etc.) to the electrodes. In one application of the invention (and the one described herein), where the electrodes are used with a pulse generator (in the form of a sequence switch for separately and successively discharging a plurality of capacitors), there is additionally provided within each electrode handle a normally open second switch, which is adapted to be closed only when the stem is pushed into the handle a distance further

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than that required to close the first switch. The second switches of the two electrodes are connected together in series with a source of electric current and with electromagnetic means, such as solenoid, for initiating the operation of the pulse generator. Accordingly, the pulse generator is first connected to the electrodes and then its operation is initiated, in each case solely in response to the application of a predetermined pressure on the electrode handles with the contact surfaces of the electrodes resting against some relatively unyielding surface, such as the patient's body.

Referring to the drawings, the general features of a defibrillator, including the electrical connections between its component parts, are shown schematically in FIG. 1. A source of electric current 1, which may be either conventional 115 volt A.C. or batteries providing a lower voltage, such as 6 or 12-volt D.C., is connected through a function switch 2 to a transformer-converter 3, either directly (as when the current source is 115 volts A.C.) or indirectly through a 6-volt converter 4 or a 12-volt converter 6 (depending upon whether the source is 6 or 12 volts D.C.), which changes the 6 or 12 volts D.C. to 115 volts A.C.

In transformer-converter 3, the 115 volt A.C. input is changed to a 2,500 volt D.C. output, which is used to charge two high voltage capacitors C1 and C2, connected in parallel to the voltage source through separate limiting resistors R1 and R2, respectively, as shown in FIG. 1. Connected across the capacitors and their associated resistors is a charge light circuit that includes resistors 7, 8, and 9, and a neon glow discharge tube 11 with a capacitor 12 connected across it, as shown in FIG. 1. When the capacitors C1 and C2 are charged to some predetermined voltage, tube 11 will blink. A shorting switch 13 in series with a resistor 14 is also connected across capacitors C1 and C2, for discharging them otherwise than through the electrodes to be described below.

Capacitors C1 and C2 are connected to a sequence switch generally designated by the numeral 21. The purpose of this switch is to discharge the two capacitors C1 and C2 serially, so that they will deliver two short pulses of current with the second pulse following very quickly after the first one and having a reverse polarity (see FIG. 3). Switch 21 is of the linear plunger type, with a handle 22 at one end of an insulating rod 23 and armatures 24 and 26 at the other end of the rod. The two armatures are of conducting material, but they are insulated from each other and separated by a circumferential groove 27. The switch is cocked by pulling the handle to the left in FIG. 1 until a locking pin 28 drops into groove 27 and holds the armatures in their cocked positions, as shown in broken lines in FIG. 1. A signal light 29 connected to a low voltage source 31 through contacts 32 and 33 lights up when those contacts are bridged by armature 24 to show that switch 21 is in its cocked position. A spring motor 34 exerts a predetermined axial force on the plunger through a nylon cord 36, urging the armatures to the right towards their uncocked position. In moving from their cocked to their uncocked positions, the armatures pass rapidly by and momentarily engage a series of electrical contacts A, B, C, and D, and their diametrically opposed contacts A', B', C', and D'. Contacts A and D are connected to one side (here the positive side) of capacitors C1 and C2, respectively, while contacts B and C are connected to the other sides (here the negative sides) of both capacitors through a choke coil 37. Contacts A' and C' are connected to electrode E1 and contacts B' and D' to electrode E2.

The general circuit referred to above is described more fully and claimed in the copending joint application of William P. Caywood and Robert S. Kush, Serial No.

204,948, filed of even date herewith and assigned to the same assignee. In addition, details of sequence switch 21 are more fully described and claimed in the copending joint application of Earl M. Becker, one of the applicants herein, and John J. Bridge, Serial No. 204,947, filed of even date herewith and assigned to the same assignee.

Contacts A' and C' are connected to a first switch S1 in electrode E1, while contacts B' and D' are connected to a similar switch in electrode E2. Locking pin 28 is connected through a bell crank 41 to the armature 42 of a solenoid 43. This solenoid is energized in a low voltage electrical circuit that includes, in series connection, a second switch S2 in each of the electrodes. It will be apparent from FIG. 1 that electrodes E1 and E2 can receive pulses of current from capacitors C1 and C2 only after (1) the first switches S1 associated with each electrode are closed and (2) the second switches S2 are also closed.

In FIG. 2 are shown the structural details of one of the electrodes (say electrode E1) and of the first and second switches associated therewith, the other electrode E2 having an identical structure. The electrode includes a metal contact surface 51, which may be mounted on a plastic disc 52 of insulating material. A stem 53, also of insulating material, is secured to the plastic disc and is provided with a metal pin 54 extending axially through it, the outer end of this pin making electrical contact with contact surface 51. The stem fits into a hollow insulating handle 56 and is held therein by a pin 57 extending through the wall of the handle into a longitudinal slot 58 on the side of the stem. The stem, with its attached electrode contact surface, is therefore free to move axially of the handle a predetermined distance, but cannot rotate relative to the handle. A coil spring 59, compressed between a shoulder 61 on the inside of the handle and a shoulder 62 on the stem, urges the stem outwards from the handle. The handle preferably has its lower end surrounded by an insulating hand guard, which may be a cup-shaped rubber guard 63, as shown in FIG. 2, held between two insulating discs 64 and 66 mounted on the end of the handle.

Inside the handle, the first electric switch S1 is adapted to be opened and closed by inward axial movement of the stem relative to the handle. One of the many forms that this switch can take is shown in FIG. 2, where one element of the switch consists of spring contacts 67, mounted on the inner end of the stem and connected to the metal pin 54 and thus to the contacting surface 51; and the other switch element is a conducting sleeve 68, mounted inside the handle and connected through a high voltage conductor 69 in an electrical cable 70 to the appropriate sequence switch contacts, A' and C', as shown in FIG. 1. In the normal position of the electrode, with the stem extended outward to its fullest extent under the compulsion of the coil spring, contacts 67 do not engage sleeve 68, and switch S1 is open. However, when the contact surface of the electrode is placed against a patient's body and the handle pressed with sufficient force to overcome the pressure of the spring, the stem will be pushed into the handle until contacts 67 engage sleeve 68 to close the first switch S1. Such closing connects the electrode with the pulse generator, here represented by capacitors C1 and C2 and sequence switch 21 with its associated contacts.

The second switch S2 is also mounted inside the electrode handle. It too may take many forms and, in the example shown, includes two stationary spring contacts 71, adapted to be bridged and electrically interconnected by a metal plunger 72 on the end of an insulating rod 73, which is supported on stem 53. The elements of this second switch, including the length of rod 73, are so dimensioned that switch S2 will close only after the switch S1 has already closed. In other words, after the switch S1 is closed, the stem must be pushed further into the handle in order to close the switch S2. Only upon the closing of the second switches S2 in both electrodes is a series circuit completed between a low voltage current source

74 and solenoid 43 for releasing locking pin 28 to uncock sequence switch 21 to initiate the serial discharge of capacitors C1 and C2.

When switch 21 is released from its cocked position, it moves quickly to the right in FIG. 1. Armature 26 first bridges contacts A and A' (connected to the positive side of capacitor C1), but no circuit is thereby completed. When armature 26 moves farther to the right to bridge contacts B and B' (connected to the negative sides of both capacitors through choke coil 37), it is no longer in engagement with contacts A and A'; but armature 24 now bridges the latter contacts, completing a circuit that permits capacitor C1 to discharge through the two electrodes and the patient's body, here represented by a resistance X. A moment later, when the armatures bridge contacts B-B' and C-C', no current flows through the electrodes. However, as soon as the armatures bridge contacts C-C' and D-D', capacitor C2 discharges through the electrodes and the patient's body, but in the reverse direction to the discharge of capacitor C1.

It is among the advantages of the present invention that it provides a safe, effective, and reliable means for arming the electrodes of a high voltage defibrillator. While the invention can be used with any type of defibrillator, it is especially adapted for use with a defibrillator that includes a pulse generator, such as the capacitors and sequence switch described herein. In this particular defibrillator circuit, the capacitors remain connected to the high voltage source even during their discharge, so that the contacts of the sequence switch would, except for the safety features incorporated in the electrodes, connect those electrodes to the high voltage source during the cocking of the sequence switch as well as during its firing. However, the first switch means S1 associated with each of the electrodes effectively isolate those electrodes from the high voltage source except when the electrodes are intentionally pressed with a predetermined pressure (for example, a pressure on the order of ten pounds) against the patient's body or some other relatively unyielding object. This feature gives assurance of maximum safety to operating personnel and to the patient, regardless of the position of the armatures in the sequence switch.

A further advantage of the electrode structure herein described is that the electrode contact surfaces 51, while axially movable with stems 53 relative to handles 56, are not rotatable relative thereto, so that the usual contact jelly placed on those surfaces may be rubbed into the skin of the patient, by rotating the electrode handles, thereby assuring good electrical contact.

Another feature of the present invention is that the high voltage pulse generator, here represented by capacitors C1 and C2 and by sequence switch 21 with its associated electrical contacts, is first connected to the electrodes before the operation of the pulse generator is initiated. The interval between the two events may be very short, but it is essential for the proper operation of the defibrillator that the electrodes be already connected to the pulse generator when the latter discharges its current pulses.

According to the provisions of the patent statutes, we have explained the principle of our invention and have illustrated and described what we now consider to represent its best embodiment. However, we desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

We claim:

1. In a cardiac defibrillator for delivering pulses of high voltage electric current from a pulse generator through a pair of electrodes to a patient's body, safety means for connecting the pulse generator to the electrodes and for initiating operation of the pulse generator, comprising: separate first switch means associated with each electrode and operable to connect each electrode to the pulse generator when the electrode is pressed with a predetermined

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pressure against the body of the patient, electrically actuated triggering means for initiating operation of the pulse generator, separate second switch means associated with each electrode, an electrical series circuit including a source of electric current and both second switch means and the triggering means, the second switch means being operable to actuate the triggering means for initiating operation of the pulse generator solely in response to a predetermined pressure of both electrodes against the patient's body in excess of the pressure required to operate the first switch means.

2. In a cardiac defibrillator for delivering pulses of high voltage electric current from a pulse generator through a pair of electrodes to a patient's body, safety means for connecting the pulse generator to the electrodes and for initiating operation of that generator, comprising: separate first switch means operable to connect each electrode to the pulse generator when the electrode is pressed with a predetermined pressure against the body of the patient, electromagnetic means for initiating operation of the pulse generator, separate second switch means associated with each electrode, an electrical series circuit including a source of electric current and both second switch means and the electromagnetic means, the second switch means being operable to energize the electromagnetic means in said circuit solely in response to a predetermined pressure of their associated electrode against the patient's body in excess of the pressure required to operate the first switch means.

3. In a cardiac defibrillator for delivering pulses of electric current from a pulse generator through a pair of electrodes to a patient's body, safety means for connecting the pulse generator to the electrodes and for initiating operation of the generator, comprising: a stem

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mounted on each electrode, a hollow handle slidably receiving the stem, means retaining the stem within the handle for reciprocal longitudinal movement therein, spring means urging the stem out of the handle, separate first switch means associated with each electrode and adapted to be closed only when the stem is pushed into the handle a predetermined distance against the pressure of the spring means and operable when closed to connect that electrode with the pulse generator, separate second switch means associated with each electrode and adapted to be closed only when the stem is pushed into the handle a predetermined distance greater than the distance required to close the first switch means, electromagnetic means for initiating operation of the pulse generator, and a source of electric current connected in a series circuit that includes the electromagnetic means and each of the second switch means for energizing the electromagnetic means only when both of the second switch means are closed.

4. Apparatus according to claim 3 that also includes means for preventing rotation of each electrode relative to its handle.

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RICHARD A. GAUDET, *Primary Examiner*.

JORDAN FRANKLIN, *Examiner*.