Oct. 12, 1965 E. M. BECKER ETAL 3,211,154

SEQUENCE SWITCH FOR VENTRICULAR DEFIBRILLATOR

Filed June 25, 1962 2 Sheets-Sheet 1

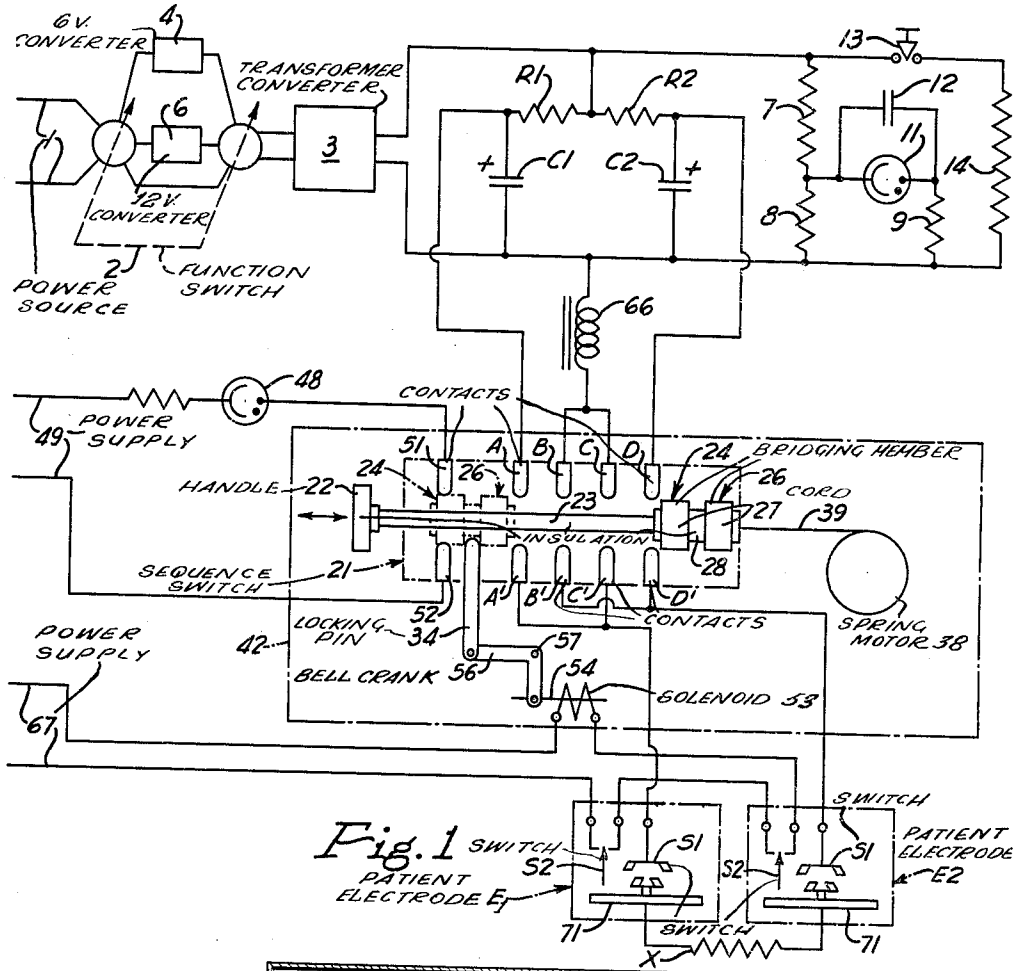

Fig. 1

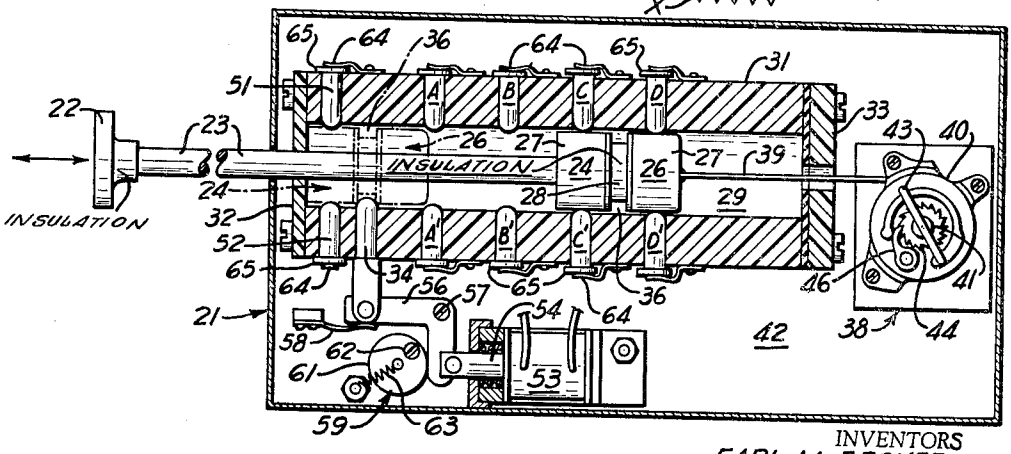

Fig. 2

INVENTORS
EARL M. BECKER
JOHN J. BRIDGE

BY

Brown, Critchlow, Flick & Peckham,
ATTORNEYS.

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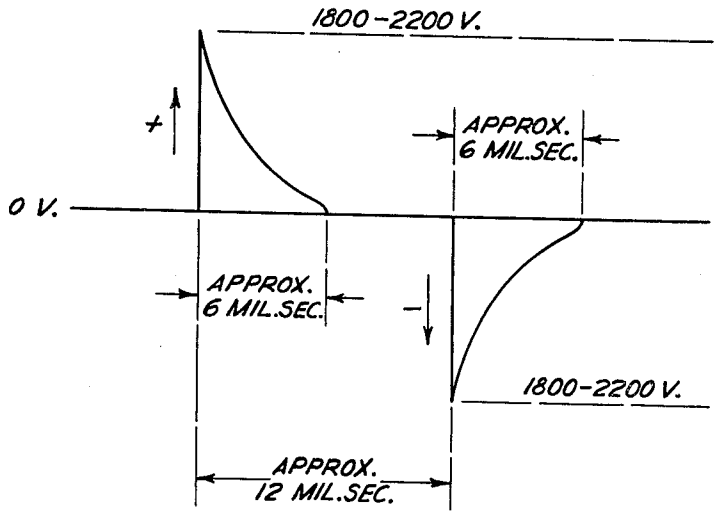

Fig. 3

INVENTORS.
EARL M. BECKER
JOHN J. BRIDGE
BY
Brown, Critchlow, Flick & Peckham
ATTORNEYS.

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SEQUENCE SWITCH FOR VENTRICULAR DEFIBRILLATOR

Earl M. Becker, Pittsburgh, and John J. Bridge, Turtle Creek, Pa., assignors to Mine Safety Appliances Company, a corporation of Pennsylvania

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5 Claims. (Cl. 128—421)

This invention relates to an electrical switch for momentarily closing an electrical circuit to transmit a pulse of current, and is particularly adapted for use as a sequence switch in a ventricular defibrillator for stopping cardiac fibrillation by the delivery of rapid pulses of electric current, represented by sequential discharges of a plurality of capacitors, through a patient's body in the region of the heart.

It is among the objects of this invention to provide a switch of the type referred to that can simply and reliably transmit one or more pulses of electric current, as by initiating the discharge of one or more capacitors charged to a high voltage, so that the duration of a single current pulse, or the duration and spacing of multiple current pulses, can be adjusted within defined limits.

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

FIG. 1 includes a diagrammatic view of the sequence switch of this invention and a schematic wiring diagram of a defibrillator associated therewith;

FIG. 2 is a section of the sequence switch itself, showing its structural details; and

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

Broadly stated, the switch of this invention includes electrically conducting bridging means slidably received in an insulated guide for reciprocal movement therein along a defined straight path. Spring means are provided to move the bridging means rapidly along this path in one direction towards an uncocked position and normally to hold the bridging means in this position. The bridging means can be moved manually in the opposite direction to a cocked position and held there by releasable latch means. When released from the cocked position, the bridging means move rapidly along the defined path toward the uncocked position and, in so doing, momentarily engage electrical contact means disposed in the path of movement and thereby close an electrical circuit for the duration of the engagement between the bridging means and the contact means.

More specifically, as applied to one type of cardiac defibrillator, the switch of this invention includes a pair of electrically conducting bridging members mounted in axially spaced and insulated relation to each other. Means are provided for guiding the bridging members in a linear reciprocal path, and a spring motor normally holds them in an uncocked position at one end of their path. The bridging members are moved manually in the opposite direction to a cocked position, where they are held by releasable latch means. On release of the latch, the bridging members move rapidly under the urging of the spring motor towards their uncocked position and, in so doing, successively engage a plurality of spaced sets of contact members, for example, four such sets. Each set includes two contacts insulated from each other but lying in substantially the same plane at right angles to the axis of travel of the bridging members, and each set is axially spaced from an adjacent set by a distance substantially equal to the axial distance between the leading edge of the contact engaging surface of the first bridging member and the corresponding edge of the second bridging member. As a result, in moving from its cocked to its uncocked position, the first bridging member will momentarily and successively connect together the contacts of the second and fourth sets of contact members at the same time as the second bridging member momentarily and successively connects together the contacts, respectively, of the first and third sets of contact members. Electrical conductors connect the first contact of each set to the capacitors and the second contact of each set to the electrodes in a way that provides two successive pulses of current of opposite polarity.

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 electrical current 1, which may be either conventional 115 volt A.C. or batteries providing either 6- or 12-volt D.C., is connected through a function switch 2 to a transformer-converter 3, either directly (as when source 1 is 115 volts A.C.) or indirectly through a 6-volt converter 4 or a 12-volt converter 6 (depending upon whether source 1 is 6 or 12 volts D.C.), which changes the 6–12 volts D.C. to 115 volts A.C.

In transformer-converter 3, the 115 volt A.C. input is changed to a high voltage D.C. output, for example, 2,500 volts, which is used to charge two high voltage capacitors C1 and C2 connected respectively in series with resistors R1 and R2, 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 condenser 12 connected across it, as shown in FIG. 1. When capacitors C1 and C2 are charged to the desired 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 the sequence switch of this invention, which is designated generally by the numeral 21, and best shown in FIG. 2. 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. Switch 21 is a linear plunger type switch, with a handle 22 at one end of an insulating plunger rod 23 and two separate bridging members 24 and 26 at the other end of the rod. The bridging members may be constructed in various ways, including separated outer surfaces of conducting material, such as metal bands 27, secured to an insulating plastic core 28, so that the bridging members will be axially spaced and insulated from each other. They are slidably received in a bore 29 of a thick-walled body 31 of insulating material, with end closure plates 32 and 33. Plunger rod 23 extends through end plate 32. The switch is cocked by pulling the handle to the left, as shown in the drawings, until a locking pin 34, slidably supported in the wall of body 31, drops into a circumferential groove 36 between the bridging members to hold them in their cocked position (shown in broken lines in the drawings). A spring motor 38 exerts a predetermined axial force on the bridging members through a nylon cord 39, urging the bridging members to the right towards their uncocked position. The spring motor includes a conventional coiled flat spring (not shown) secured at one end to a housing 40 and at the other end to a shaft 41. Both the housing 40 and the body 31 are mounted in spaced relation on the wall of a suitable container 42. The spring motor 38 is wound to the desired tension by a key 43, which is attached to the end of shaft 41, and held in its wound position by the engagement of ratchet 44 with pawl 46. The nylon cord 39 is wrapped around a drum (not shown) attached to the

shaft 42 inside the housing 40; and its free end, passing through the end plate 33 of switch 21, is secured to the bridging member end of plunger rod 23. A signal light 48, connected to a low voltage source 49, through contacts 51 and 52 in the wall of body 31, lights up when those contacts are bridged by bridging member 24, when the latter is in its cocked (broken line) position.

The bridging members are released from their cocked position by energizing (as hereinafter described) a solenoid 53, causing its armature 54 to turn a bell crank 56 on its pivot 57 to withdraw locking pin 34 from groove 36, against the urging of a light spring 58. If desired, the bridging members can be uncocked by a manual release 59, which includes a cam disc 61 mounted on a pivot 62 and rotated by a handle (not shown). When the disc is turned (counter-clockwise in FIG. 2), the cam turns the bell crank 56 to withdraw the locking pin 34. A spring 63 returns the cam to its normal position.

In moving from their cocked to their uncocked position, the bridging members pass rapidly by and momentarily engage a series of electrical contacts A, B, C, and D, and their respectively and diametrically opposed contacts A', B', C', and D'. These contacts, as well as signal light contacts 51 and 52, are slidably received in the wall of body 31 and have rounded ends protruding a short distance into bore 29. The contacts are urged inwards by leaf springs 64 mounted on body 31 and pressing against the enlarged heads 65 of the contacts. Contacts A and D are connected to one side (for example, the positive side) of capacitors C1 and C2, respectively, while contacts B and C are connected to the other side of those capacitors through a choke coil 66. Contacts A' and C' are connected to electrode E1 and contacts B' and D' to electrode E2. It may be found desirable, as a means of reducing contact bounce, to taper the bridging members axially approximately 3°, with their leading edges (to the right in the drawings) having the reduced diameter.

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. Solenoid 53 is energized in a low voltage electrical circuit that also includes, in series connection, a source 67 of electric current and a second switch S2 in each of the electrodes. It will be apparent from FIG. 1 that electrodes E1 and E2 can normally receive pulses of current from capacitors C1 and C2 only after (1) the first electrode switches S1 are closed to connect the electrodes with contacts A', B', C', and D' and (2) the second electrode switches S2 are both in their closed position to release sequence switch 21 from its cocked position. These electrode switches, S1 and S2, are closed in succession by pressing the contact surfaces 71 of the electrodes against the patient's body, so that those surfaces are connected to the contacts of the sequence switch before that switch is fired.

When switch 21 is released from its cocked position, it moves quickly to the right. Bridging member 26 first bridges contacts A and A' (connected to the positive side of capacitor C1), but no circuit is thereby completed. When bridging member 26 moves farther to the right to bridge contacts B and B' (connected to the negative sides of both capacitors through choke coil 66), it will no longer be in engagement with contacts A and A'; but bridging member 24 will now bridge the latter contacts, completing a circuit that discharges capacitor C1 through the two electrodes and the patient's body, represented by the resistance X. When bridging member 26 bridges contacts C and C', bridging member 24 will bridge contacts B and B', but no current flows through the electrodes. A moment later, when bridging members 24 and 26 bridge contacts C—C' and D—D', respectively, capacitor C2 will be discharged through the patient's body, but in the reverse direction to the discharge of capacitor C1.

Portions of the circuit referred to above are 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 the electrodes E1 and E2 are more fully described and claimed in the copending joint application of Earl M. Becker, one of the applicants herein, and William C. Stuckrath, Serial No. 204,949, filed of even date herewith, and assigned to the same assignee.

It is among the advantages of the present invention that it provides simple and reliable means for producing an electrical pulse of defined duration when connected in an electrical circuit. While the switch is especially suited for serially discharging a plurality of high voltage capacitors in the manner described in this application, it will be apparent to those skilled in the art that it is capable of other uses as well. When used as herein described for discharging a pair of high voltage capacitors, the bridging members desirably move from their cocked to their uncocked position in about twenty milliseconds with each capacitor discharge lasting about four milliseconds and with about six milliseconds between successive discharges (see FIG. 3). Of course, these times can be varied within desired limits by suitable adjustments, for example, by adjusting the tension of spring motor 38 or by varying the mass of bridging members 24 and 26. It will also be noted that the duration of each current pulse transmitted by the switch can be made shorter, if desired, than the time required to discharge the capacitors. A further advantage of the switch of this invention resides in the fact that the bridging members are rotatable about the axis of plunger rod 23, so that fresh contact surfaces on the bridging members can be periodically presented to engage the contacts. This is a desirable feature, because under the conditions that occur in discharging high voltage capacitors, there is bound to be some arcing between the bridging members and the contacts they engage, and therefore, relatively large and freshly presentable contact surfaces on the bridging members will tend to reduce wear from arc erosion.

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, in combination with a pair of electrodes, a sequence switch for serially discharging pulses of current from a high voltage source through the electrodes, the sequence switch comprising: a pair of electrically conducting bridging members mounted in fixed axially spaced and insulated relation to each other, means guiding the bridging members for linear axial reciprocation along a defined path, spring means for moving the bridging members rapidly in one direction and for normally holding them in an uncocked position at one end of their path, means for manually moving the bridging members in the opposite direction to a cocked position, releasable latch means for holding the bridging members in their cocked position, means for releasing the latch means to cause the bridging members to move rapidly under the urging of the spring means towards their uncocked position, a plurality of axially spaced sets of contact members adapted to be momentarily and successively engaged by the surfaces of the bridging members when the bridging members are moving from their cocked to their uncocked position, each set of contact members including two contacts separated from each other but lying in substantially the same plane at right angles to the axis of travel of the bridging members, each set of contact members being axially spaced from an adjacent set by a distance substantially equal to the axial distance between the leading edge of the contact engaging surface of the first bridging

member and the corresponding edge of the second bridging member, whereby when the bridging members are moving from their cocked to their uncocked position the first bridging member will momentarily connect together the contacts of one set of contact members at the same time as the second bridging member momentarily connects together the contacts of an adjacent set of contact members, and electrical conductors connecting the first contacts of the sets of contact members to the high voltage source and the second contacts of the sets to the electrodes.

2. In a cardiac defibrillator, in combination with a pair of electrodes, a sequence switch for serially discharging the capacitors through a pair of electrodes, the sequence switch comprising: a pair of electrically conducting bridging members mounted in fixed axially spaced and insulated relation to each other, means guiding the bridging members for linear axial axial reciprocation along a defined path, spring means for moving the bridging members rapidly in one direction and for normally holding them in an uncocked position at one end of their path, means for manually moving the bridging members in the opposite direction to a cocked position, releasable latch means for holding the bridging members in their cocked position, means for releasing the latch means to cause the bridging members to move rapidly under the urging of the spring means towards their uncocked position, at least four axially spaced sets of contact members adapted to be momentarily and successively engaged by peripheral surfaces of the bridging members when moving from their cocked to their uncocked position, each set of contact members including two contacts separated from each other but lying in substantially the same plane at right angles to the axis of travel of the bridging members, each set of contact members being axially spaced from an adjacent set by a distance substantially equal to the axial distance between the leading edge of the contact engaging surface of the first bridging member and the corresponding edge of the second bridging member, whereby while the bridging members are moving from their cocked to their uncocked position the first bridging member will momentarily and successively connect together the contacts of the second and fourth sets of contact members at the same time as the second bridging member momentarily and successively connects together the contacts of the first and third sets of contact members respectively, and electrical conductors connecting the first contacts of the sets of contact members to the capacitors and the second contacts of the sets to the electrodes.

3. Apparatus according to claim 2 that includes means for adjusting the tension of the spring means to change the axial speed of the bridging members in travelling from their cocked to their uncocked position.

4. Apparatus according to claim 2, in which the means for guiding the bridging members includes a body of electrically non-conductive material having a cylindrical bore in which the bridging members travel.

5. Apparatus according to claim 2, in which the latch means includes a locking pin movable radially of the bridging members, the bridging members being separated axially by a circumferential groove into which the locking pin is adapted to be inserted when the bridging members are brought to their cocked position.

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RICHARD A. GAUDET, *Primary Examiner.*

JORDAN FRANKLIN, *Examiner.*