June 11, 1963 P. L. R. LOHR 3,093,136

VENTRICULAR DEFIBRILLATOR

Filed May 25, 1960 3 Sheets-Sheet 1

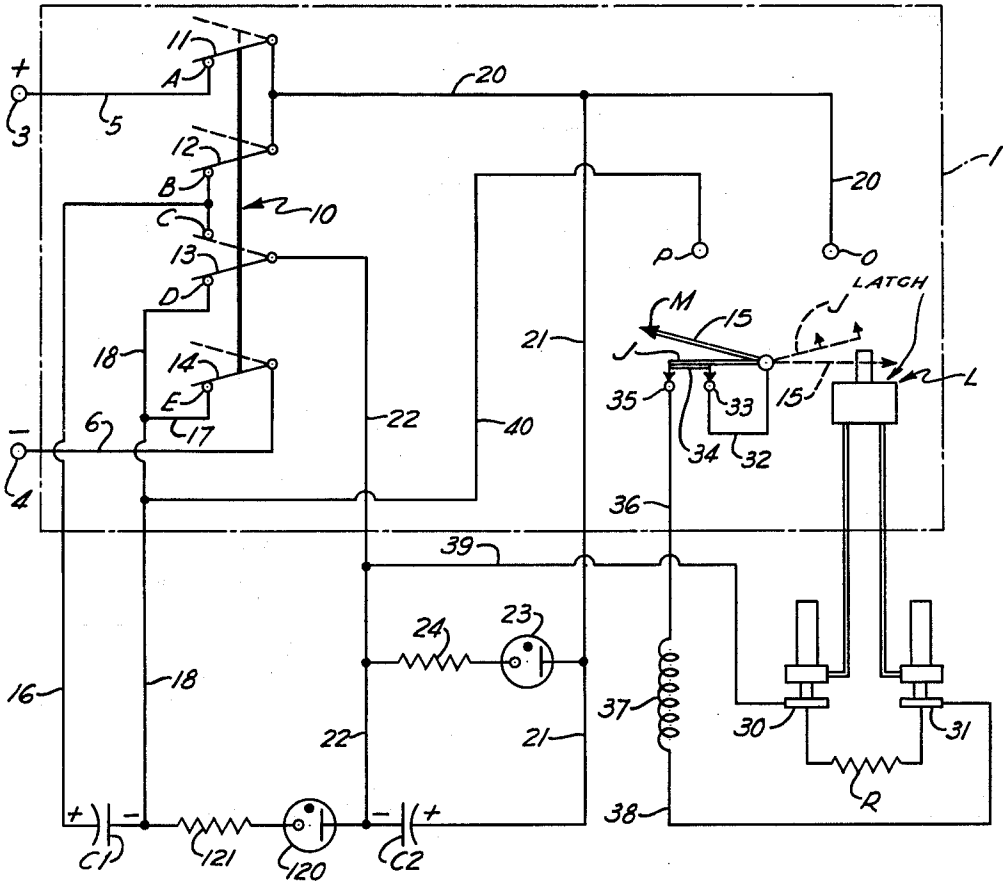

Fig. 1

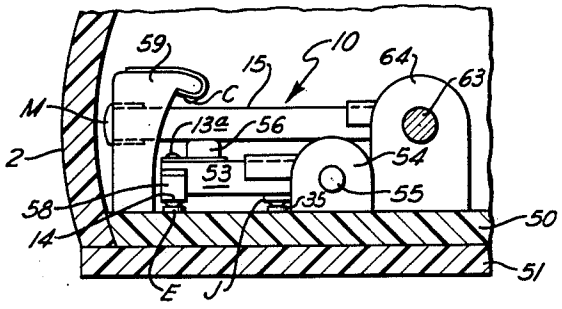

Fig. 2

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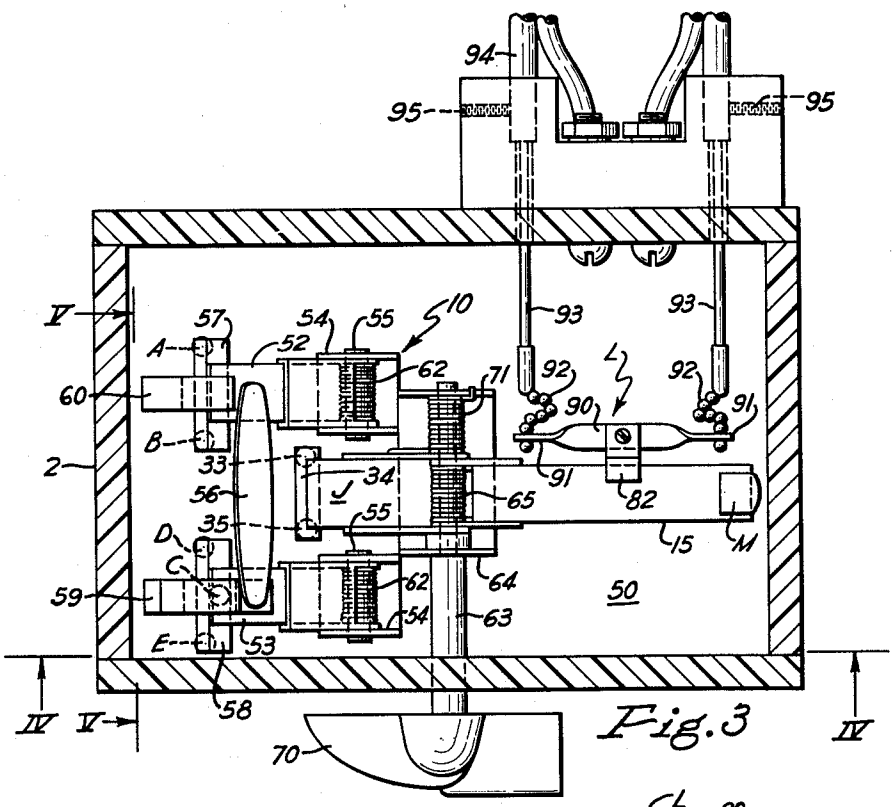

Fig. 3

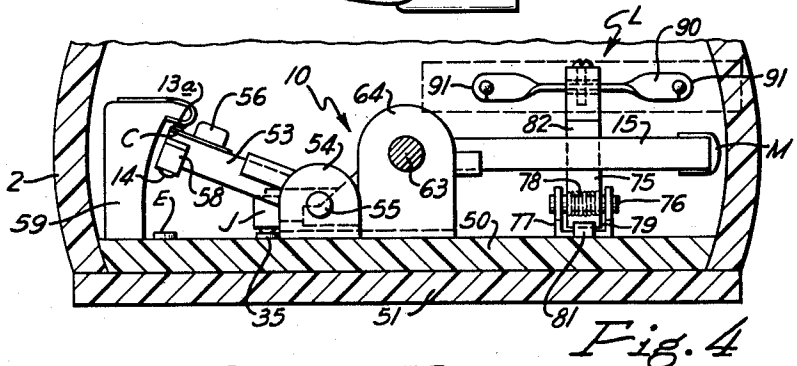

Fig. 4

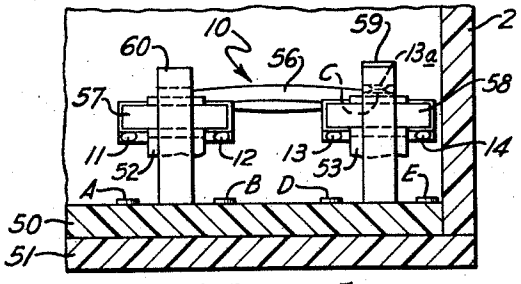

Fig. 5

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VENTRICULAR DEFIBRILLATOR

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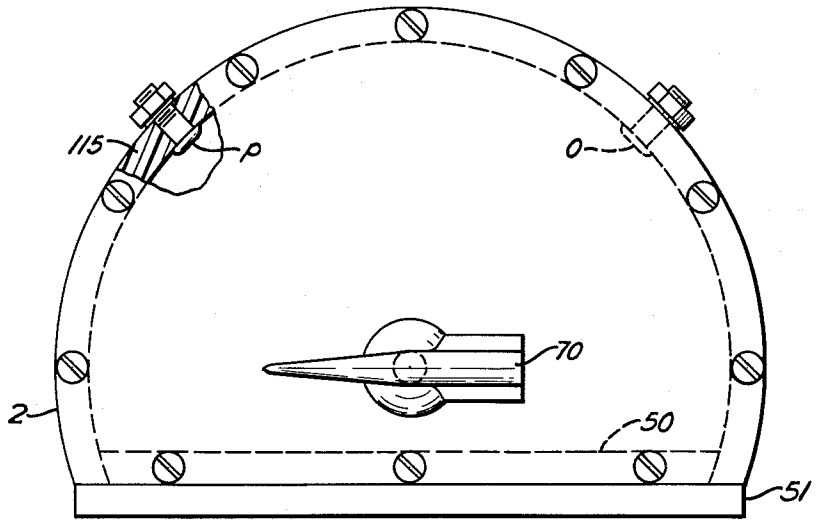

Fig. 6

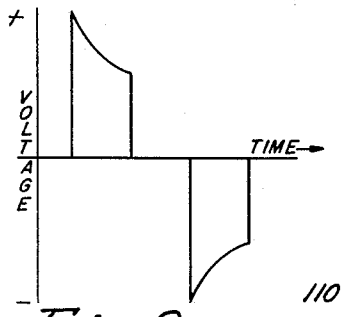

Fig. 9

Fig. 7

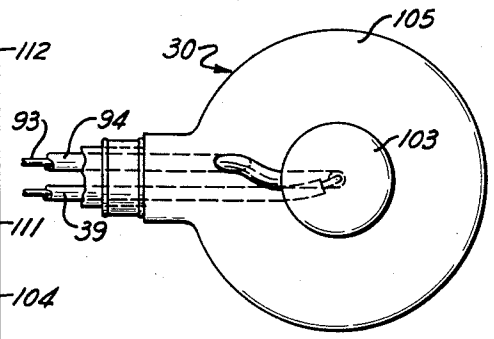

Fig. 8

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United States Patent Office 3,093,136 Patented June 11, 1963

3,093,136

VENTRICULAR DEFIBRILLATOR

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Filed May 25, 1960, Ser. No. 31,776
14 Claims. (Cl. 128—423)

This invention relates generally to a ventricular defibrillator for use in stopping cardiac fibrillation by the rapid serial discharge of a plurality of capacitators into a patient's body in the region of the heart. More specifically, the invention relates to switch means for controlling the charging and discharging operations of the defibrillator.

It is among the objects of this invention to provide switch means of the type referred to that will perform the following functions in the sequence stated: (1) In its normal position, the switch means connect the capacitators in parallel to a charging circuit. (2) In its cocked position, the switch means disconnect the capacitators from the charging circuit and connect them in series with a discharge circuit. (3) In response to a predetermined pressure of both electrodes against the patient's body, and not otherwise, the switch means rapidly discharge the capacitators serially into the patient's body to arrest fibrillation. (4) After firing, the switch means return to their normal position to connect the capacitators in parallel to the charging source in preparation for a second shot if that should be necessary.

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

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

FIG. 2 is a front elevation of a portion of the switch mechanism in its normal or uncocked position;

FIG. 3 is a plan view of the same switch mechanism in its cocked position;

FIG. 4 is a front elevation of the switch mechanism on the line IV—IV of FIG. 3;

FIG. 5 is an end elevation of the switch mechanism, with a portion removed for clarity, on the line V—V of FIG. 3;

FIG. 6 is a front elevation of the switch housing, partly in section, showing the switch cocking handle and the electrical contacts that are connected to the electrodes;

FIG. 7 is a sectional elevation of one of the electrodes mounted in its handle;

FIG. 8 is a plan view of the electrode in FIG. 6; and

FIG. 9 is a diagram showing the wave form of the electrical discharge that is applied to the patient.

In accordance with this invention, the switch means is used with a cardiac defibrillator having a plurality of capacitators, a source of electrical energy for charging the capacitators, and a pair of electrodes adapted to be applied to the patient. The switch means includes a movable spring-loaded switch arm (which controls other spring-loaded elements of the switch means) adapted to move from a cocked position to an uncocked position and, during its movement therebetween, to connect each of the capacitators successively and momentarily to the electrodes. The switch also includes a latch for holding the movable switch arm in its cocked position, this latch being releasable in response to a predetermined pressure of both electrodes against the body of the patient. More specifically, the latch includes a spring-biased latch bar normally held in its latching position. Pivotally mounted on the latch bar is a yoke, to the opposite ends of which are secured by flexible slack connectors the ends of two cables. The yoke is adapted to move the latch bar to its releasing position when both cables are pulled.

If only one of the cables is pulled, the yoke merely turns on its pivot without displacing the latch bar. The other ends of the cables are attached to stems on the electrodes. The stems are received in hollow handles, and pressure on those handles, with the electrodes placed on the body of the patient, actuates the cables to release the latch bar.

Referring to the drawings, the general features of the defibrillator, including the electrical connections between its component parts, are schematically shown in FIG. 1. The broken line **1** outlines those components that are enclosed in a housing **2**, as shown in other figures (FIGS. 2–6). A source of direct current (not shown) is connected to terminals **3** and **4**, which represent, respectively, positive and negative terminals. A multiple gang switch, represented generally by the numeral **10**, includes movable switch points **11**, **12**, **13** and **14** for opening and closing switch contacts A, B, C, D, and E; it also includes a movable switch arm **15** (which controls the positions of the switch points) and a switch cocking lever J. The normal uncocked positions of the various switch elements are shown in solid lines in FIG. 1, their cocked (or cocking, in the case of lever J) positions by broken lines. The mechanical structure and operation of the switch means are described later herein in connection with FIGS. 2–8.

In its normal uncocked position, switch means **10** connects capacitators C1 and C2 in parallel with the power terminals **3** and **4** to charge the capacitators, as follows: Positive terminal **3** is connected through conductor **5**, closed switch contacts A and B, and conductor **16** to the positive side of capacitator C1. Negative terminal **4** is connected through conductor **6**, closed switch contact E, and conductors **17** and **18** to the negative side of that same capacitator. At the same time, capacitator C2 is connected to positive terminal **3** through conductor **5**, closed switch contact A, and conductors **20** and **21**, and to negative terminal **4** through conductor **6**, closed switch contact E, conductors **17** and **18**, closed switch contact D, and conductor **22**. A signal light **23** is connected in series with a resistance **24** between conductors **21** and **22**, and lights up when capacitator C2 is fully charged. Capacitators C1 and C2 have the same capacity; and, when one is fully charged, it is assumed that the other will also be fully charged.

In the normal uncocked position of the switch means, switch arm **15**, and its cocking lever J, occupy their solid line positions in FIG. 1, so that electrode **30** is connected only to the negative terminal **4** of the power source and to the negative sides of capacitators C1 and C2 while electrode **31** is not connected to either of the power terminals or to either of the capacitators. In the uncocked position of the switch means, the apparatus is therefore "safe."

To cock the switch means, cocking lever J is manually turned in a clockwise direction to engage the underside of switch arm **15** and turn the latter in the same direction until arm **15** is latched by a latch means L. Upon the cocking of arm **15**, switch points **11**—**14** move to their broken line positions, opening switch contacts A, B, D, and E and closing switch contact C. Capacitators C1 and C2 are now connected in series and, though disconnected from the power terminals **3** and **4**, are fully charged. Cocking lever J returns to its normal solid line position. Electrode **30** is connected to the negative sides of capacitators C1 and C2, but electrode **31** is not connected to either of the capacitators; and neither electrode is connected to either of the power terminals. The cocked position is still "safe."

When the switch arm **15** is released or fired, by the means described below, it moves quickly from its broken line position under the urging of its spring to its normal solid line position. As it does so, contact M on its outer

end successively wipes contact points O and P to discharge capacitors C2 and C1 in that order through electrodes 30 and 31 and the patient's body (represented in FIG. 1 by the resistance R). The discharge circuit is as follows. As contact M on switch arm 15 momentarily brushes contact O, current from the positive side of capacitator C2 flows through conductors 21 and 20, contacts O and M, switch arm 15, conductor 32, contact 33, conducting strip 34 on cocking lever J, contact 35, conductor 36, inductor 37, conductor 38 and electrode 31 to the body of the patient R. At the same time, current from the negative side of capacitor C2 flows through conductors 22 and 39 to electrode 30, which is also in contact with the patient's body R. The patient thereby receives a strong pulse of current having the wave form depicted in the first half of FIG. 9. This wave form shows the voltage of the current pulse plotted against time, the portion of the wave above the horizontal line representing positive voltage and that below the line representing negative voltage; alternating current pulses having this wave form have been found particularly suitable for arresting fibrillation of the heart.

As switch arm 15 continues to move from its cocked to its uncocked position, its tip M momentarily brushes contact P, which discharges condensers C1 into the body of the patient along the following conducting paths. Current from the positive side of capacitator C1 flows through conductor 16, closed switch contact C, and conductors 22 and 39 to electrode 30. From the negative side of capacitator C1, current flows through conductors 18 and 40, contacts P and M, switch arm 15, conductor 32, contact 33, conducting bar 34 on cocking lever J, contact 35, conductor 36, inductor 37, and conductor 38 to electrode 31. The patient then receives a second pulse of current, flowing in the reverse direction from that of the first pulse and having the wave form shown in the second half of FIG. 9. These two pulses of current are generally sufficient to arrest fibrillation. Switch arm 15, after passing contact P and before returning to its initial position, causes movable switch points 11—14 to return to their normal solid line positions. The capacitators are then reconnected in parallel to the power terminals and are quickly recharged so that the process can be repeated, if necessary.

It should be noted that in cocking switch arm 15, its tip M brushes over contacts P and O in a clockwise direction; but the capacitators cannot be discharged, because cocking lever J has also moved clockwise from its initial position and opened a non-conducting gap between contacts 33 and 35.

The physical structure of the switch means is shown in FIGS. 2–8. Referring first to FIGS. 2–6, the housing 2 is provided with a composite insulated base 50 and 51, between the layers of which are concealed the pertinent wiring circuits shown in FIG. 1. Various mechanical components of switch means 10 are mounted on this base, including movable gang switch arms 52 and 53 pivotally mounted in separate brackets 54 on pins 55 and joined together by a striking bar 56. The switch arms 52 and 53 are provided with switch heads 57 and 58, respectively. On the underside of head 57 are mounted the movable switch points 11 and 12 adapted to make and break connections with contacts A and B, respectively, mounted on base 50. Switch head 58 has switch points 13 and 14 mounted on its underside adapted to make and break connections with contacts D and E, respectively, on the base 50. Switch point 13 is connected to a subsidiary switch point 13*a* (electrically, they are a single switch point, as represented in FIG. 1, with a double throw action) on the upper surface of head 58. Switch point 13*a* is adapted to make and break connection with contact C mounted on the underside of a stop member 59, which is also secured to base 50. A similar stop member 60 (without contacts) is provided for head 57. Accordingly, switch arms 52 and 53 are free to move in a limited arc between contacts A, B, D and E on the base 50 and contact C on stop member 59. Coil springs 62 (FIG. 3) urge these arms towards their elevated position (in which contact C is closed, as shown in FIGS. 3 and 4). This corresponds to the cocked positions of the switch points, as shown in broken lines in FIG. 1.

Switch arms 52 and 53 are normally held, however, in their lower, uncocked positions, shown in FIG. 2, by switch arm 15. The latter is rotatably mounted on a shaft 63 supported in brackets 64 and urged by a strong spring 65 in a counter-clockwise direction against the striker bar 56. Spring 65 is strong enough to overcome the combined opposing torque of springs 62, so that switch arms 52 and 53 normally close contacts A, B, D, and E, as shown by their solid line positions in FIG. 1.

To cock the switch mechanism, knob 70, which is mounted on the end of shaft 63 projecting outside the housing, is turned manually in a clockwise direction to rotate cocking lever J, which is rigidly secured to shaft 63, against the urging of spring 71. Cocking lever J underlies switch arm 15 and, on being turned in a clockwise direction, rotates arm 15 about shaft 63 until the arm is caught by the latching mechanism L and held by the latter in its cocked position. Knob 70 is then released and spring 71 returns the knob and cocking lever J to their initial positions. During the cocking operation, when the striker bar 56 is relieved of the pressure of switch arm 15, switch arms 52 and 53 are urged by their springs 62 into the position shown in FIGS. 4 and 5, in which contacts A, B, D, and E are open and contact C is closed.

The latching mechanism L includes a latch bar 75, which is pivotally mounted on a pin 76 supported in a bracket 77 secured to the base 50. A coil spring 78 urges the latch bar into its latching position, as shown in FIGS. 3 and 4, but not beyond that position due to the engagement of the forwardly projecting foot 79 of the latch bar against the stop 81 on the base 50 (see FIG. 4).

The latch bar is provided with a beveled head 82, so that the latch bar will be displaced to the rear (FIGS. 2 and 3) when arm 15 is pushed against the beveled surface by cocking lever J, to permit the arm to pass below the latch head and to spring against its under side. Pivotally mounted on the latch bar is a yoke 90, which is adapted to turn in a substantially horizontal plane. To its ends 91 are secured by short flexible connectors 92, the ends of two flexible wire cables 93. These cables are slidably received in flexible sheaths 94 that are clamped to the housing 2 by set screws 95. The other ends of the sheathed cables are connected to electrodes 30 and 31, as shown in FIGS. 7 and 8.

The two electrodes, generally identified by the numbers 30 and 31, are identical in form and structure; and one of them is shown in FIGS. 7 and 8. The electrode itself is a metal plate 100, secured to the underside of an insulating disc 101. The disc in turn is mounted concentrically on a tubular stem 102, which is slidably received inside a hollow handle 103. The latter is preferably lined with an anti-friction bearing surface 104, such as a sleeve of Teflon.

The cable sheath 94 is secured to a guard disc 105 mounted on the lower part of the handle 103. The sheath extends, however, through a slot 106 in the handle and an enlarged registering slot 107 in the stem. The end of cable 93 extends beyond its sheath and is anchored to the top of the stem by a plug 110, which is secured to the stem by a screw 111. When the electrode assembly 30 or 31 is grasped by the handle and the electrode plate 100 placed on the chest of the patient and the handle pressed downward, the stem is pushed into the handle against the pressure of a coil spring 112, its movement being limited to the initial spacing between the bottom of the handle 103 and disc 101. At the same time, the end of the cable 93, which is secured to the stem, is pulled away from the adjacent end of the sheath which is attached to the guard disc 105 to restrain it against axial

movement, while the other end of the cable is moved in the opposite direction. The movement of the cable is sufficient to take up the slack in the flexible connector **92**, connecting the cable to the yoke **90**, and to pull one end of the yoke towards the rear of housing **2**. If only one electrode is pressed against the patient's body, the yoke will merely pivot, since there is sufficient slack in the flexible connector **92** connecting the other cable and the yoke to permit limited pivoting of the yoke. However, if both electrodes are pushed down by pressure on their handles both cables will be activated by substantially the same amount and will pull the yoke without appreciable rotation, causing the latching bar to pivot on its pin **76** to release or fire the switch arm **15**. The electrical connection to the electrode plate **100** is obtained by conductor **39** (or conductor **38**) connected to the plate by a terminal screw **113**.

During the firing cycle after switch arm **15** is released from the latching bar, the arm turns rapidly on its shaft **63** in a counter-clockwise direction (see FIG. 4). Contact M on the outer end of this arm accordingly moves in an arc. Arm **15** is of such length that contact M will clear the curved top portion **115** of housing **2**, but will make successive electrical contact with contact O and P secured to this curved portion of the housing (see FIG. 6). These contacts are made in rapid sequence and, as previously described, discharge the capacitators C2 and C1 in that order into the patient's body. After the switch arm **15** has passed contact P, it hits striker bar **56** forcing the gang switch arms **52** and **53** from their elevated positions shown in FIG. 4 to their lowered positions shown in FIG. 2, thereby returning the switch mechanism to its initial, normal position.

If desired, a second indicator circuit may be used to indicate that capacitator C1 is fully charged and that the switch mechanism is in is cocked position. To that end, a signal light **120** (similar to signal light **23**) is connected in series with a resistor **121** between the negative terminals of capacitators C1 and C2, as shown in FIG. 1. In the uncocked position of the switch mechanism, the signal light is not energized (cf.-signal light **23**, which is energized when capacitator C2 is fully charged with the switch mechanism in its uncocked position). However, when the switch mechanism is cocked and capacitator C1 is fully charged, current will flow from the positive terminal of capacitator C1 through conductor **16**, closed contact C, conductor **22**, signal light **120**, and resistor **121** to the negative terminal of capacitator C1.

According to the provisions of the patent statutes, I have explained the principle of my invention and have illustrated and described what I now consider to represent its best embodiment. However, I 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.

I claim:

1. For use in a cardiac defibrillator having a plurality of condensers and a source of electrical energy for charging the condensers and a pair of electrodes adapted to be applied to the body of a patient, switch means for serially discharging the condensers through the electrodes and the patient's body, said switch means comprising: a movable electrical contact adapted to move from a cocked position to an uncocked position, a plurality of fixed electrical contacts disposed in the path of movement of the movable contact and adapted to be successively and momentarily engaged by the movable contact when moving from its cocked to its uncocked position, each of the fixed contacts when so engaged connecting through the movable contact a separate condenser across the electrodes, means for rapidly moving the movable contact from its cocked to its uncocked position, a releasable latch for holding the movable contact in its cocked position, and means for releasing the latch that are operative solely

in response to a predetermined pressure of both electrodes against the body of the patient.

2. Apparatus according to claim 1, in which the means for releasing the latch include a yoke pivotally mounted on the latch for moving the latch into its releasing position when the pivotal axis of the yoke is displaced a predetermined amount in a given direction, and means mounted on each electrode and connected to the ends of the yoke for displacing the pivotal axis of the yoke only when both electrodes are pressed against the patient's body.

3. Apparatus according to claim 1, in which the means for releasing the latch include a yoke pivotally mounted on the latch for moving the latch into its releasing position when the pivotal axis of the yoke is displaced a predetermined amount in a given direction, actuating means mounted on each electrode and movable in response to pressure of the electrode against the patient's body, separate connecting means extending between each electrode and the yoke, the yoke ends of the connecting means being attached to the yoke at points on opposite sides of its pivotal axis and substantially equally spaced therefrom and the electrode ends of the connecting means being attached to the actuating means on the electrodes, whereby when both electrodes are pressed against the patient's body and the actuating means are displaced by substantially equal amounts the pivotal axis of the yoke will be displaced by substantially the same amount to move the latch to its releasing position.

4. Apparatus according to claim 3, in which the actuating means include a stem mounted on each electrode and connected to the electrode end of one of the connecting means, a hollow handle with one end closed and the other end slidably receiving the stem, and a coil spring between the closed end of the handle and the stem.

5. Apparatus according to claim 3, in which the connecting means is a flexible wire slidably received in a flexible sheath, and means for securing the sheath against axial movement.

6. Apparatus according to claim 3, in which each connecting means includes a flexible wire slidably received in a flexible sheath that is secured against axial movement and a normally slack flexible member connecting the yoke end of the wire with the yoke.

7. For use in a cardiac defibrillator having a plurality of condensers, a source of electrical energy for charging the condensers, and a pair of electrodes adapted to be applied to the body of a patient, switch means for charging the condenser and for serially discharging them through the electrodes and the patient's body, said switch means comprising: a gang switch having a first operative position in which it connects the condensers in parallel to the source of electrical energy for charging the condensers and a second operative position in which it disconnects the condensers from said source, first spring means urging the gang switch into its second operative position, a switch arm adapted to occupy cocked and uncocked positions, second spring means urging the switch arm into its uncocked position in which the switch arm engages the gang switch and holds it in its first operative position against the urging of the first spring means, means for cocking the switch arm thereby releasing the gang switch and allowing the latter to assume its second operative position, a latch for holding the switch arm in its cocked position, means for releasing the latch solely in response to a predetermined pressure on both electrodes, a plurality of fixed spaced contacts adapted to be successively and momentarily engaged by the switch arm when the latter moves between its cocked and its uncocked positions, the switch arm when released from its cocked position returning rapidly to its uncocked position and during such return movement successively and momentarily connecting the condensers through the fixed contacts across the electrodes and

finally engaging the gang switch and moving it from its second to its first operative position.

8. Apparatus in accordance with claim 7, in which the means for cocking the switch arm includes a manually rotatable cocking lever adapted when rotated to engage the switch arm and rotate it from its uncocked to its cocked position, and spring means for returning the cocking lever to its initial position.

9. Apparatus according to claim 8, in which the cocking lever when moved from its initial position opens said electrical circuit between the condensers and the electrodes.

10. Apparatus according to claim 7, in which the latch means includes a spring-biased latching bar normally held in its latching position, a yoke pivotally mounted on the latching bar for moving the bar into its releasing position when opposite ends of the yoke are displaced a predetermined amount in the same direction, and means actuated by pressure on both electrodes for displacing the yoke.

11. Apparatus according to claim 7 that also includes indicating means operative when one of the condensers is fully charged and the switch arm is in its uncocked position.

12. Apparatus according to claim 7 that also includes indicating means operative when one of the condensers is fully charged and the switch arm is in its cocked position.

13. Apparatus according to claim 7, in which the means for releasing the latch includes a yoke pivotally mounted on the latch and adapted to move the latch into its releasing position when opposite ends of the yoke are displaced a predetermined amount in the same direction, a stem mounted on each electrode, a hollow handle with one end closed and the other end slidably receiving the stem, a coil spring between the closed end of the handle and the received end of the stem, and flexible means connecting each stem with a different end of the yoke, whereby pressure exerted on the handles of both electrodes urging the electrodes against the body of the patient will cause the flexible means to displace the yoke and disengage the latch from the switch arm.

14. Apparatus according to claim 7, in which the gang switch in its second position connects the positive side of a first charged condenser and the negative side of a second charged condenser to the same electrode, so that one condenser will discharge a pulse of current in one direction across the electrodes and the other condenser will discharge a pulse in the opposite direction.

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