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[54] **PORTABLE DEFIBRILLATORS INCLUDING ROTARY SOLENOID RELAYS FOR ENERGY TRANSFER AND DUMPING**

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[51] **Int. Cl.** **A61n 1/36**

[58] **Field of Search** ..... 128/419 D, 419 R, 421, 128/423; 335/114, 122, 193, 206 B

[56] **References Cited**

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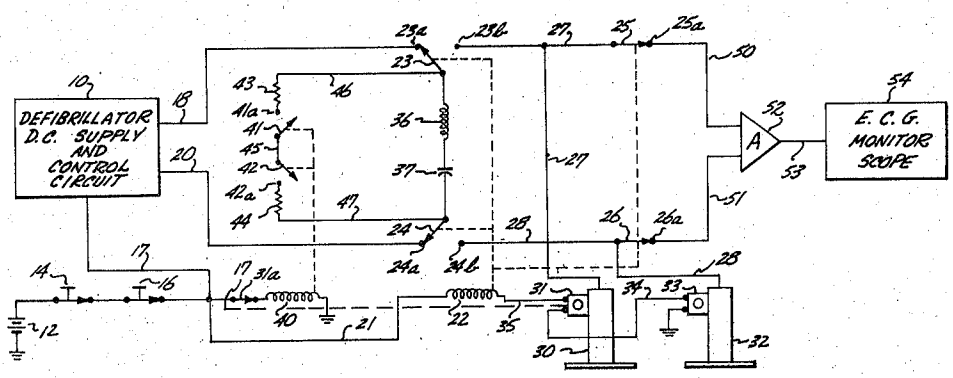
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[57] **ABSTRACT**

A portable defibrillator including at least one open-frame relay is disclosed. The relay combines the functions of previously-used transfer, dump, and ECG protection relays required in portable defibrillator-ECG monitor units. The relay includes at least one rotary solenoid for providing reliable operation while yet resisting accidental operation due to physical shock or the like.

4 Claims, 2 Drawing Figures



E. C. G. MONITOR SCOPE
A
DEFIBRILLATOR D.C. SUPPLY AND CONTROL CIRCUIT

Fig. 1.

Fig. 2.

PORTABLE DEFIBRILLATORS INCLUDING ROTARY SOLENOID RELAYS FOR ENERGY TRANSFER AND DUMPING

FIELD OF THE INVENTION

This invention generally relates to apparatus for monitoring the electrical activity of the heart of a person and selectively applying an electric impulse to the person to stop heart fibrillation, and, more particularly, to an improved relay combining the transfer, dump, and ECG protection relay functions normally required in such devices.

BACKGROUND OF THE INVENTION

By monitoring the heartbeat of a patient, it can be recognized, by a skilled operator, when the heart is fibrillating and hence is in immediate need of a defibrillation signal to terminate fibrillation. Devices such as ECG monitors have long been used in the art to visually display to an operator all information regarding the heartbeat that is necessary to recognize fibrillation. Once the need for a defibrillation signal has been established, a high voltage pulse obtained from a defibrillator may be applied to the patient via appropriate electrodes to momentarily stop the heart and terminate fibrillation.

ECG monitors and defibrillators are now used customarily in intensive care sections of most hospitals and generally comprise stationary units for which considerations of cost, size and weight are not critical. However, portable defibrillators have been used with increasing frequency in ambulances and coronary care vehicles. Considerations of cost, size and ruggedness and reliability under adverse environmental conditions are very important in the construction of portable units. One type of portable unit is that combining a defibrillator and an ECG monitor with a single set of paddle electrodes which are used for both heart monitoring and for the application of a defibrillation pulse, as more completely described and claimed in U.S. Pat. No. 3,547,108, by Stanley V. Seiffert, Dec. 15, 1970, which is also assigned to the assignee of the present invention. Portable combination defibrillator and ECG monitors have typically included two relays for controlling the transfer of a defibrillation pulse to the patient. The first of these relays is commonly known as the transfer relay and operates to transfer a charge from a storage capacitor in the defibrillator to a set of electrodes connected to the patient upon the actuation of a switch by the operator. The second of these relays is commonly known as the dump relay and operates to discharge the defibrillator's storage capacitor whenever the defibrillator is turned off or whenever power supply voltage is lost. In cases where the unit is of the type described and claimed in the aforementioned patent, a third relay is also provided, known as the protection relay, for protecting the ECG monitor from the defibrillation pulse which is applied via the same set of electrodes that are used for the monitor.

In normal cases, the electrodes are continuously attached to the patient. Therefore, it is imperative that a defibrillation signal not be applied unless absolutely needed. The vibrations and shocks to which a portable unit is normally subjected, particularly when placed in a vehicle, are such so as to prohibit the use of ordinary, open-frame relays. Accordingly, the prior art has almost exclusively used, in portable units, vacuum relays

to effect the functions of the transfer and dump relays. Although vacuum relays perform satisfactorily in portable units, they are bulky and their expense is a significant portion of the total cost of a portable defibrillator.

Accordingly, it is an object of this invention to provide an improved portable unit including a defibrillator which does not require separate vacuum relays for the transfer and dump functions thereof.

It is another object of this invention to provide, in a portable unit including a combination defibrillator and ECG monitor with a single set of electrodes, a combination relay for transferring a charge stored in a capacitor to a patient through a set of electrodes upon receipt of a defibrillation signal, for protecting the input an ECG monitor using that set of electrodes when the defibrillation pulse is being applied, and for discharging the capacitor when the defibrillator unit is turned off or when power is removed in any fashion from the portable unit.

It is yet another object of this invention to provide, in a portable unit including a defibrillator, such a combination relay which is inexpensive, simple in construction, and yet resistant to actuation by external shocks and other vibrations.

SUMMARY OF THE INVENTION

These objects and others are achieved, briefly, by using at least one rotary solenoid to actuate a plurality of contacts providing the transfer, dump and ECG protection functions previously requiring separate relays and relay coils in the prior art. In a preferred embodiment, a first rotary solenoid is normally deenergized and actuates the transfer and ECG protection contacts upon actuation of an appropriate first switch, and a second rotary solenoid is normally energized and actuates the dump contacts to discharge the defibrillator's storage capacitor when power to the unit is lost or when the first switch is actuated.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can perhaps best be understood by reference to the following portion of the specification, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a combined block/schematic diagram of a portable unit including a defibrillator and the combination relay of this invention; and

FIG. 2 is a pictorial diagram illustrating a preferred embodiment of the combination relay.

DESCRIPTION OF A PREFERRED EMBODIMENT

While the invention will be hereinafter described with reference to its use in combination with a portable defibrillator and ECG monitoring unit using a single set of paddle electrodes, it is to be clearly understood that the invention has broad applicability to practically any portable unit including a defibrillator.

Now turning to the drawing, a defibrillator DC supply and control circuit **10** is energized from a DC battery **12** when both an on-off switch **14** for the portable unit and an on-off switch **16** for the defibrillator have been closed. The DC signal supplied on line **17** is converted by the circuit **10** into a high voltage signal appearing across leads **18** and **20** which are connected in turn to first stationary contacts **23***a*, **24***a* of a transfer relay **22**.

Second stationary contacts 23*b*, 24*b* of transfer relay 22 have connected thereto leads 27 and 28 which are connected to a set of paddle electrodes 30, 32 and to movable contact arms 25, 26 of transfer relay 22. Stationary contacts 25*a*, 26*a* associated with movable contacts 25, 26 have connected thereto leads 50, 51 which are coupled to the input of an amplifier 52 whose single output 53 drives an ECG monitor scope 54.

As will be described hereinafter, relay 22 is normally de-energized and accordingly movable contacts 23, 24, 25 and 26 thereof appear in the positions illustrated in the drawing. As such, if the paddle electrodes 30, 32 have been placed in appropriate positions on the patient's chest, the ECG monitor space 54 is normally connected thereto and displays information regarding the patient's heartbeat.

During this time, the high voltage appearing on output leads 18 and 20 from circuit 10 is coupled through contacts 23*a*, 23 and 24*a*, 24 across the series connection of a pulse-shaping inductor 36 and storage capacitor 37. Accordingly, storage capacitor 37 is charged and provides a defibrillation pulse, when relay 22 is energized to switch movable contacts 23, 24, into engagement with stationary contacts 23*b*, 24*b*.

Relay 22 is energized in the following manner. DC power is supplied to its coil via lead 21 from lead 17. The other side of the coil is connected by a lead 35 to a first push-button switch 31 placed on the handle of paddle electrode 30, which is in turn connected by a lead 34 to a second push-button switch 33 placed on the handle of paddle electrode 32. Switches 31 and 33 are normally open, and the other side of switch 33 is connected to ground.

When the operator detects fibrillation by observation of the ECG monitor scope 54, he then simultaneously depresses switches 31 and 33 to complete a path to ground for the coil of relay 22. Accordingly, relay 22 is energized to discharge the capacitor 37. Relay 22 is designed so that shortly before movable contacts 23 and 24 engage stationary contacts 23*b* and 24*b*, movable contacts 25 and 26 are moved out of engagement with stationary contacts 25*a*, 26*a* so that the defibrillation pulse applied on common leads 27, 28 will not harm the ECG monitor scope 54.

To discharge the storage capacitor 37 if the portable unit or the defibrillator is turned off without being used, a dump relay 40 is provided whose coil is connected from the lead 17 to ground. Therefore, dump relay 40 is normally energized when power is being supplied to the defibrillator circuit 10. Leads 46 and 47 connect one end of discharge resistors 43, 44 to series network of inductor 36 and capacitor 37. The other ends of resistors 43 and 44 are connected to stationary contacts 41*a*, 42*a* associated with movable contacts 41, 42 of dump relay 40. Movable contacts 41 and 42 are interconnected by a lead 45, and are shown in the drawings in their normal position when relay 40 is energized.

It will be readily appreciated that when power is removed from the coil of relay 40, contacts 41 and 42 move to engage stationary contacts 41*a*, 42*a* to provide a discharge shunt path for capacitor 37 through resistors 43 and 44.

In some cases, it may be desirable to de-energize the dump relay 40 when the defibrillation pulse is to be applied by actuation of relay 22. Accordingly, a set of contacts 31*a*, which are actuated by push-button switch 31, may be interposed in lead 17 to the coil of relay 40. Contacts 31*a* are open when push-button switch 31 is depressed. Therefore, relay 40 is de-energized to provide a shunt path for discharge of capacitor 37 through resistors 43 and 44.

If the resistance of resistors 43 and 45 is chosen to be sufficiently high with respect to the resistance offered by the body of the patient (typically on the order of 70 ohms) then the shunt connection provided thereby will have little or no effect upon the defibrillation pulse if in fact the paddle electrodes 30 and 32 are connected to the patient. If they are not, however, this shunt connection provides an additional safety feature in allowing discharge of capacitor 37 without the possibility of the paddles electrodes 30, 32 later being accidentally touched by the operator or another person.

With reference now to FIG. 2, the relays 22 and 40 are supported on and secured to a base 60 which may be formed from a sheet of transparent plastic stock material. The relays 22 and 40 both comprise rotary solenoids having a pair of terminals for making connections to the coils of the solenoids and additionally having output shafts 82, 64, respectively. In the embodiment shown, shafts 82 and 64 rotate in a clockwise direction when the solenoids are energized. In a working model, the solenoids comprised 24-volt relays obtainable from Ledex, Inc.

The movable contact arm of dump relay 40 is formed by a first machined steel member 62 which is keyed onto shaft 64. The ends of member 62 are recessed at 62*a*, 62*b* to receive, respectively, insulating members 66, 68, which may be secured thereto by appropriate fastening means. Movable contacts 41, 42 comprise standard metallic contact discs which are respectively secured to upper portions of insulating members 66 and 68. As also shown in FIG. 1, contacts 41 and 42 are interconnected by a lead 45.

Support members 70, 72 of insulating material are secured to base 60 adjacent the extremities of members 66, 68 and have attached to their upper ends stationary contacts 41*a*, 42*a*, also of metallic material. The relative positioning of support members 70, 72 is such so that contact pairs 41, 41*a* and 42, 42*a* are in alignment and in engagement when relay 40 is de-energized. With the arrangement of FIG. 2, the shunt resistors 43, 44 may be conveniently positioned adjacent support members 70, 72.

The contact structure of relay 22 is similar to that of relay 40. A second machined steel member 80 is keyed to shaft 82 and supports for rotation first and second insulating members 84, 86. Member 84 in turn has attached thereto movable contacts 23 and 25, and insulating member 86 has attached thereto movable contacts 24 and 26. As best seen with respect to movable contact 24, each of movable contacts 23 and 24 includes a metallic contact disc on opposite sides of its insulating member.

A first insulating support member 90 is secured to base 60 and positions stationary contacts 24*a*, 26*a* so that they are aligned with and in contact with movable contacts 24, 26 when relay 22 is de-energized. A second insulating support member 96 is identical and supports contacts 23*a*, 25*a* for engagement with movable contacts 23 and 25. Third and fourth insulating support members 92, 94 are also secured to base 60 and support stationary contacts 24*b*, 23*b* for engagement with movable contacts 24, 23 when relay 22 is energized.

Although interconnection between the components illustrated in FIG. 2 is made by wire leads, it is also contemplated that a portion of base 60 comprise a printed circuit board substrate with a printed circuit placed thereon for providing the necessary interconnections. In a working model, the entire assembly illustrated in FIG. 2 was provided with a dust-proof, transparent casing, not illustrated, of a plastic material similar to that used for base 60.

As a matter of design, the stationary contacts illustrated in FIG. 2 may be supported from their respective support members by leaf springs so as to provide resilient contact engagement and dampening of contact "bounce," or the stationary members themselves may be made of a resilient material.

The design illustrated in FIG. 2 accordingly combines, into one combination relay, the transfer, dump and ECG protection functions previously provided by three separate relays in the prior art. Since the stationary ECG protection contacts 25*a*, 26*a* are placed on support members 90, 96, the circuit path from the electrodes to the ECG monitor scope 54 will be broken before the defibrillation pulse is applied via contacts 23, 23*a*, 24, 24*a*. In addition, the relay contacts are actuated by rotary solenoids which are virtually impervious to actuation by external shocks or vibrations.

Although the invention has been described with respect to a preferred embodiment thereof, it is to be clearly understood by those skilled in the art that the invention is not limited thereto, but rather is to be bounded only by the limits of the appended claims.

What is claimed is:

1. A portable defibrillator for operation from a source of power, said defibrillator comprising:
   1. a source of defibrillation energy;
   2. an electrical network means for storing said defibrillation energy;
   3. a pair of electrodes engagable with a patient; and,
   4. circuit means for controlling the selective application of said defibrillation energy to said patient via said electrodes, said circuit means including:
      a. a first switch;
      b. a first relay including a first set of contacts normally connecting said defibrillation energy source to said electrical network means, and a second set of contacts for connecting said electrical network means to said electrodes to selectively apply said stored defibrillation energy to said electrodes, said first relay further including a first rotary solenoid having a shaft rotatable upon energization thereof and means responsive to the rotation of said shaft for sequentially opening said first set of contacts and closing said second set of contacts; and,
      c. means interconnecting the source of power, said first switch and said first rotary solenoid to energize said first rotary solenoid upon actuation of said first switch; and,
   5. means for automatically shunting said electrical network means whenever power is removed from said portable defibrillator, said shunting means including:
      a. a second relay including a set of contacts, a second rotary solenoid having a shaft rotatable upon energization thereof and means responsive to the rotation of said shaft for opening said set of contacts;
      b. a resistance means;
      c. means connecting said set of contacts and said resistance means in series across said electrical network means;
      d. means for connecting said second rotary solenoid to the source of power; and,
      e. a set of contacts forming part of said first switch and connected to said second rotary solenoid for removing power from said second rotary solenoid when said first switch is actuated.

2. A portable defibrillator for operation from a source of power in combination with a heart signal monitoring means for displaying the heart signals of a patient, said combination comprising:
   1. a source of defibrillation energy;
   2. an electrical network means for storing said defibrillation energy;
   3. a pair of electrodes engagable with a patient; and,
   4. circuit means for controlling the selective application of said defibrillation energy to said patient via said electrodes, said circuit means including:
      a. a first switch;
      b. a first relay including a first set of contacts normally connecting said defibrillation energy source to said electrical network means, and a second set of contacts for connecting said electrical network means to said electrodes to selectively apply said stored defibrillation energy to said electrodes, said first relay further including a first rotary solenoid having a shaft rotatable upon energization thereof and means responsive to the rotation of said shaft for sequentially opening said first set of contacts and closing said second set of contacts; and,
      c. means interconnecting the source of power, said first switch and said first rotary solenoid to energize said first rotary solenoid upon actuation of said first switch;
   5. means for automatically shunting said electrical network means whenever power is removed from said portable defibrillator, said shunting means including:
      a. a second relay including a set of contacts, a second rotary solenoid having a shaft rotatable upon energization thereof and means responsive to the rotation of said shaft for opening said set of contacts;
      b. a resistance means;
      c. means connecting said set of contacts and said resistance means in series across said electrical network means; and,
      d. means for connecting said second rotary solenoid to the source of power; and,
   6. means for protecting said heart signal monitoring means from receiving any of said defibrillation energy, said protection means comprising:
      a. a third set of contacts connected between said heart signal monitoring means and said patient; and,
      b. means responsive to the rotation of the shaft of said first rotary solenoid for opening said third set of contacts prior to the closure of said second set of contacts.

3. The combination recited in claim 2 wherein said third set of contacts normally connects said heart signal monitor means to said electrodes, and wherein said means responsive to the rotation of the shaft of said first rotary solenoid opens said third set of contacts so as to disconnect said heart signal monitoring means from said electrodes prior to closure of the second set of contacts and the application of defibrillation energy to said electrodes.

4. A portable defibrillator for operation from a source of power in combination with a heart signal monitoring means for displaying the heart signals of a patient, said combination comprising:

1. a source of defibrillation energy;
2. an electrical network means for storing said defibrillation energy;
3. a pair of electrodes engagable with a patient; and,
4. circuit means for controlling the selective application of said defibrillation energy to said patient via said electrodes, said circuit means including:
   a. a first switch;
   b. a first relay including a first set of contacts normally connecting said defibrillation energy source to said electrical network means, and a second set of contacts for connecting said electrical network means to said electrodes to selectively apply said stored defibrillation energy to said electrodes, said first relay further including a first rotary solenoid having a shaft rotatable upon energization thereof and means responsive to the rotation of said shaft for sequentially opening said first set of contacts and closing said second set of contacts; and,
   c. means interconnecting the source of power, said first switch and said first rotary solenoid to energize said first rotary solenoid upon actuation of said first switch; and,
5. means for protecting said heart signal monitoring means from receiving any of said defibrillation energy, said protection means comprising:
   a. a third set of contacts connected between said heart signal monitoring means and said patient; and,
   b. means responsive to the rotation of the shaft of said first rotary solenoid for opening said third set of contacts prior to the closure of said second set of contacts.

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