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Groenke et al.

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(54) **AED WITH FORCE SENSOR**

(75) Inventors: **Allen W. Groenke**, Bloomington, MN (US); **James E. Brewer**, Cottage Grove, MN (US)

(73) Assignee: **Cardiac Science, Inc.**, Bothell, WA (US)

(21) Appl. No.: **10/255,988**

(22) Filed: **Sep. 25, 2002**

Related U.S. Patent Documents

Reissue of:

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Filed: **Oct. 29, 1998**

(51) **Int. Cl.**
A61N 1/39 (2006.01)
A61H 31/00 (2006.01)

(52) **U.S. Cl.** **607/6**; 607/3; 607/5; 600/16

(58) **Field of Classification Search** 607/5–6, 607/3

See application file for complete search history.

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Primary Examiner—Carl Layno

(74) *Attorney, Agent, or Firm*—Patterson, Thuente, Skaar & Christensen, PA

(57) **ABSTRACT**

A force sensor, for use in combination with an automated electronic defibrillator (AED), includes a first conductive layer. A second conductive layer is spaced apart from the first conductive layer such that no electrical communication occurs between the first and second conductive layers. An electrical communication device is provided for establishing electrical communication between the first and second conductive layers responsive to the application of a force to said electrical communication means. A method of prompting a rescuer in the application of cardiopulmonary resuscitation to a victim includes the steps of:

sensing a force applied by the rescuer to the victim's sternum;

sensing an interval between successive applications of force to the victim's sternum;

comparing the force applied by the rescuer to the victim's sternum to a standard of force known to effect resuscitation;

providing a prompt to the rescuer that prompts the rescuer to vary the force delivered to approximate the force that is known to effect resuscitation,

comparing the interval between successive applications of force to the victim's sternum to a standard interval known to effect resuscitation; and

providing a prompt to the rescuer that prompts the rescuer to vary the interval of force application to approximate the interval that is known to effect resuscitation.

45 Claims, 19 Drawing Sheets

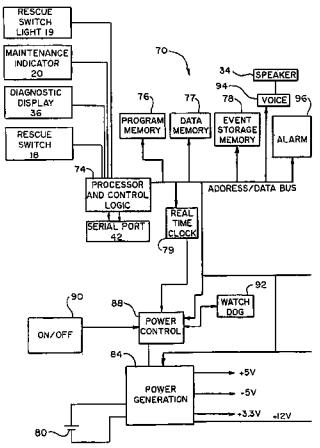

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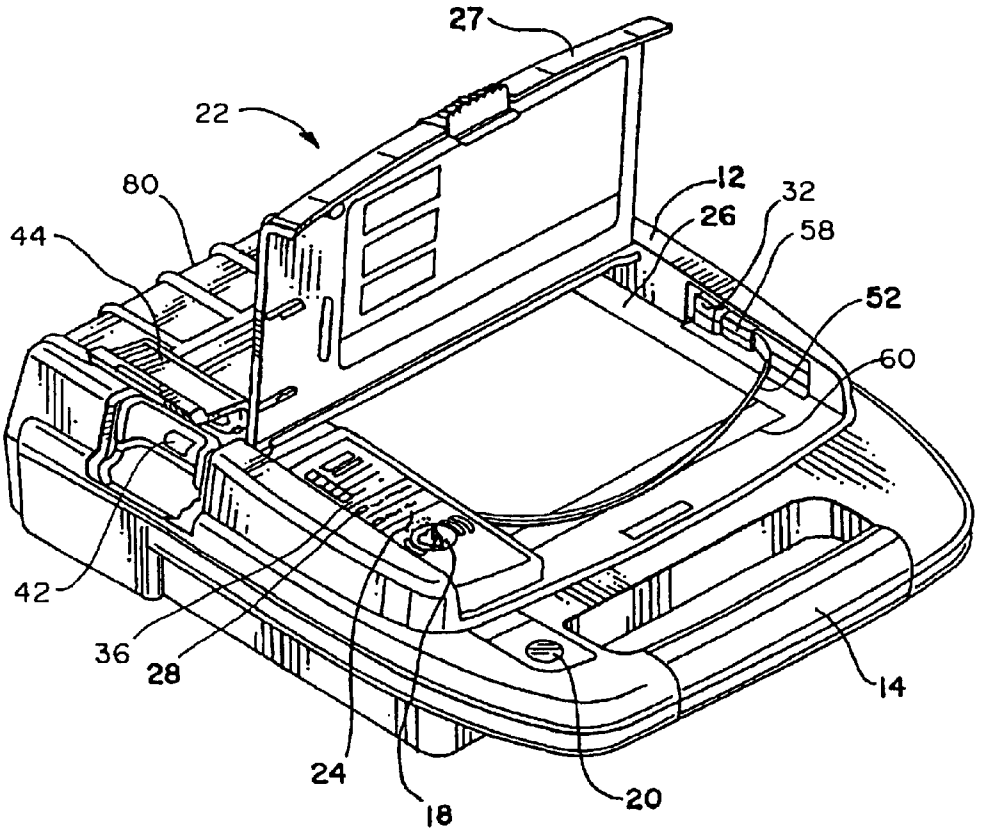
Fig. 1
PRIOR ART



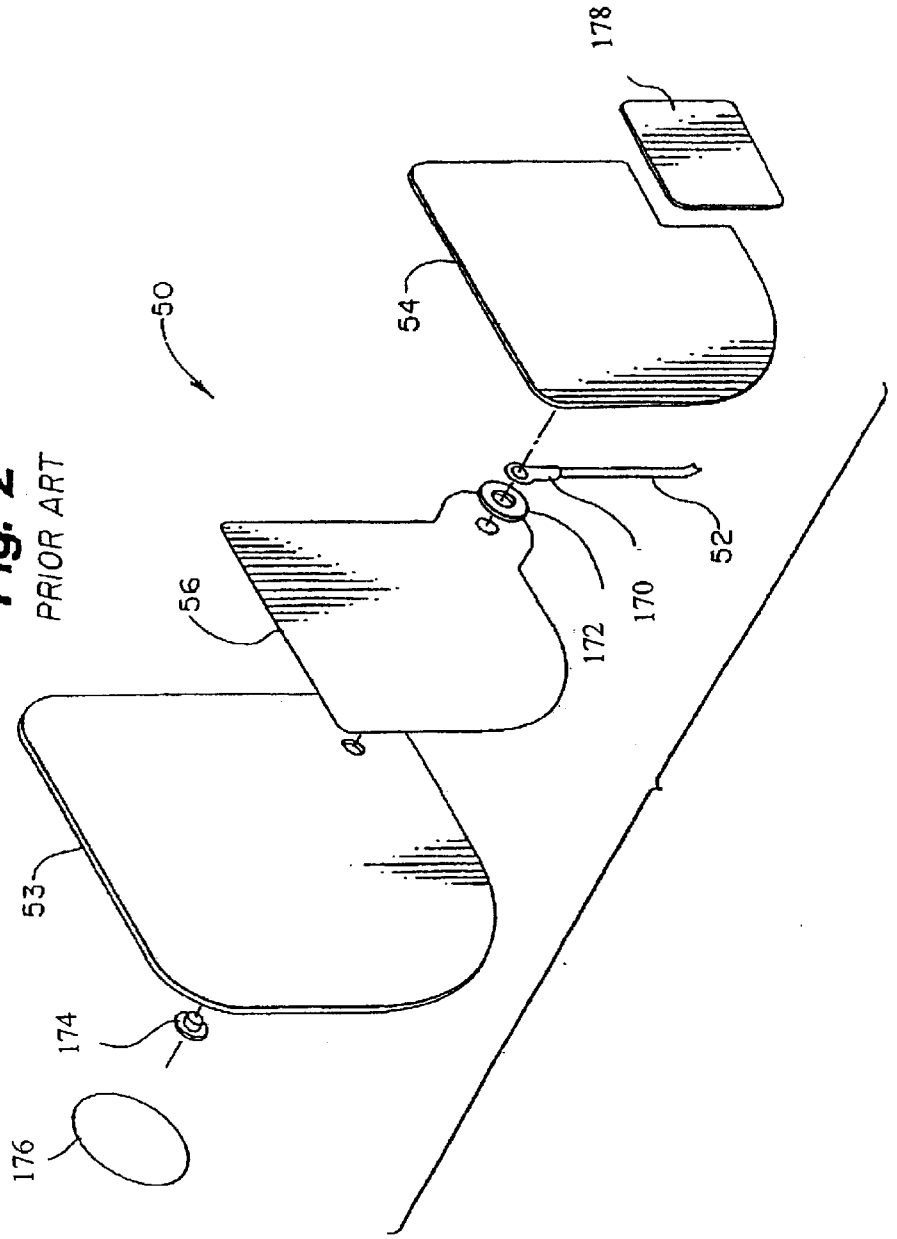
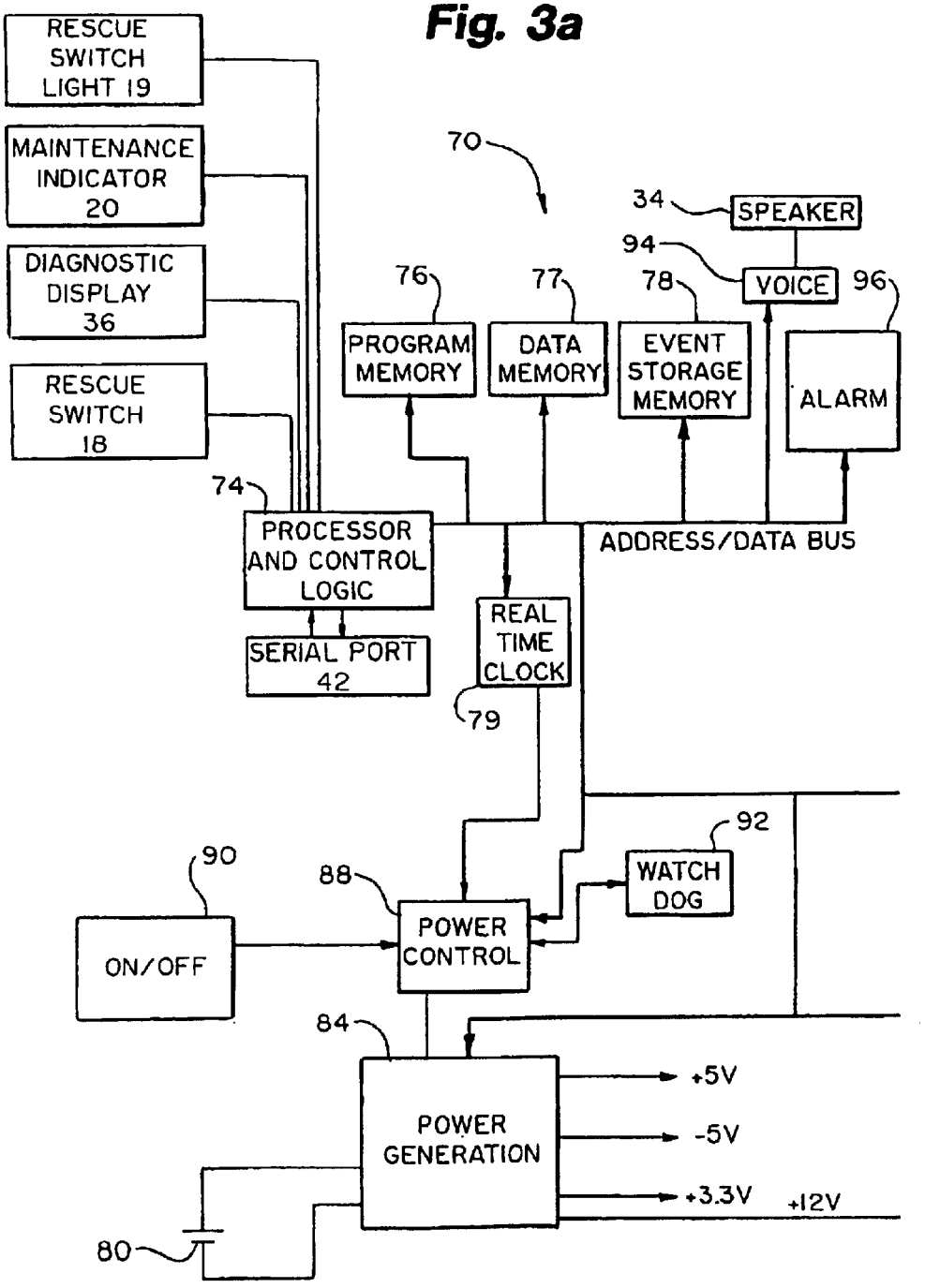


Fig. 2
PRIOR ART

(Amended)

Fig. 3a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MAINTENANCE INDICATOR 20
DIAGNOSTIC DISPLAY 36
RESCUE SWITCH 18
70
34
SPEAKER
94
VOICE
96
76
77
78
PROGRAM MEMORY
DATA MEMORY
EVENT STORAGE MEMORY
ALARM
74
PROCESSOR AND CONTROL LOGIC
ADDRESS/DATA BUS
SERIAL PORT 42
REAL TIME CLOCK
79
92
90
88
WATCH DOG
ON/OFF
POWER CONTROL
84
POWER GENERATION
+5V
-5V
+3.3V
+12V
80

Fig. 3

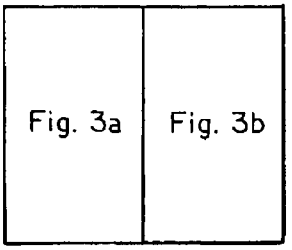
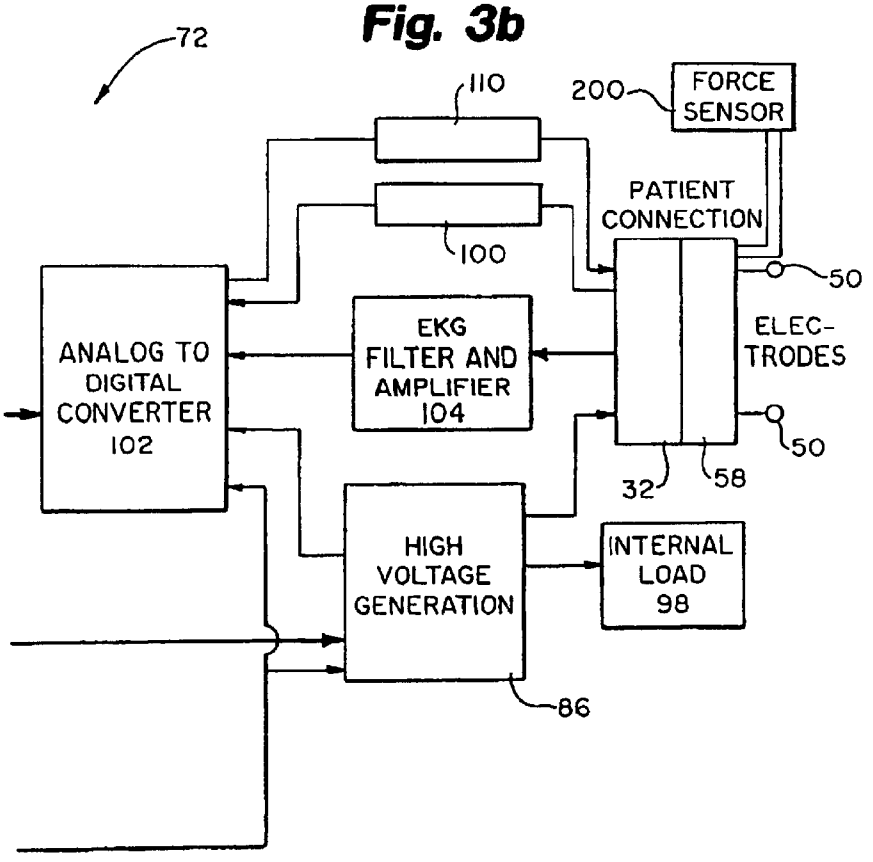


Fig. 3a
Fig. 3b

Fig. 3b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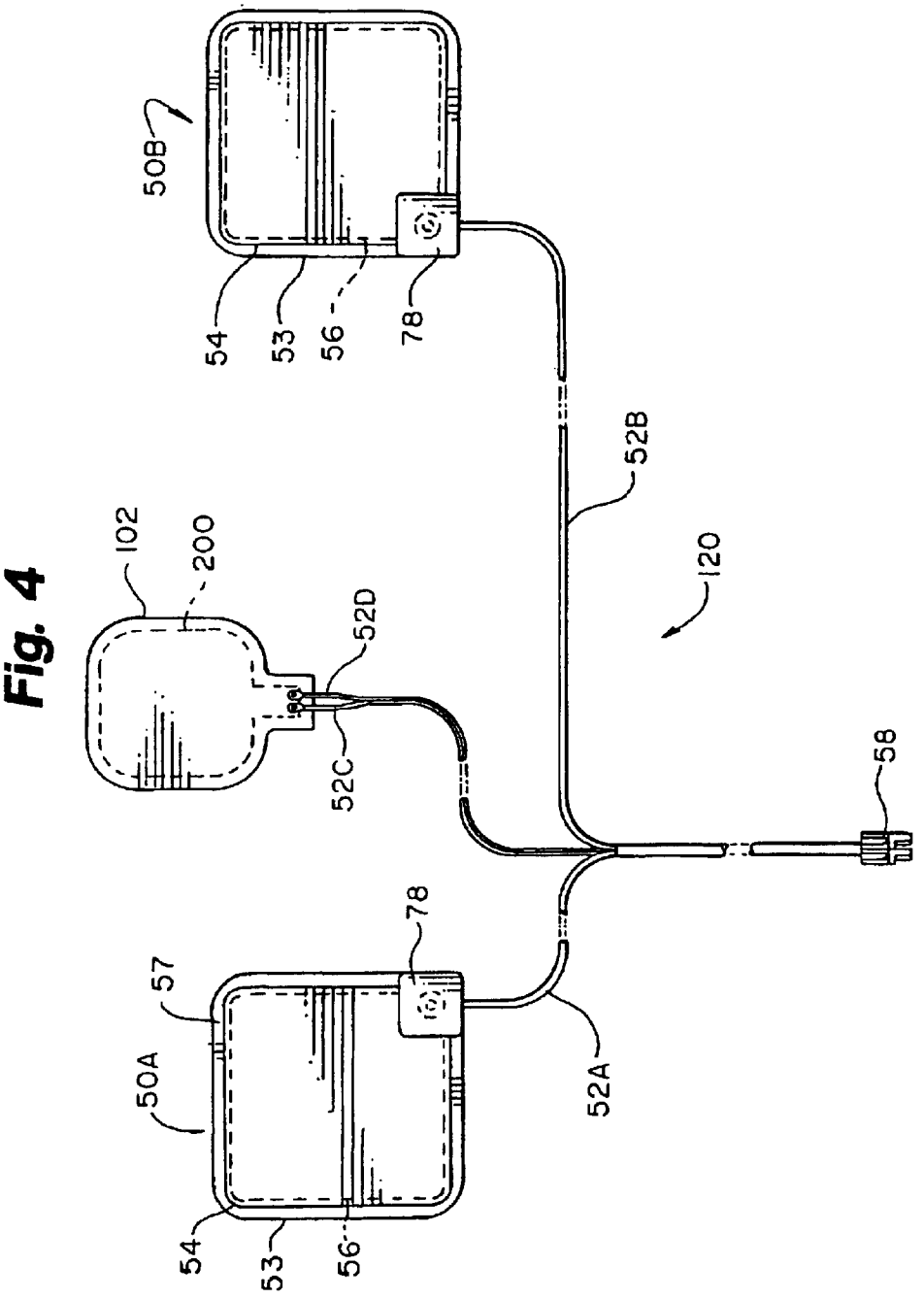
110
200
FORCE SENSOR
PATIENT CONNECTION
100
50
ANALOG TO DIGITAL CONVERTER 102
EKG FILTER AND AMPLIFIER 104
ELEC-TRODES
50
32
58
HIGH VOLTAGE GENERATION
INTERNAL LOAD 98
86

Fig. 4



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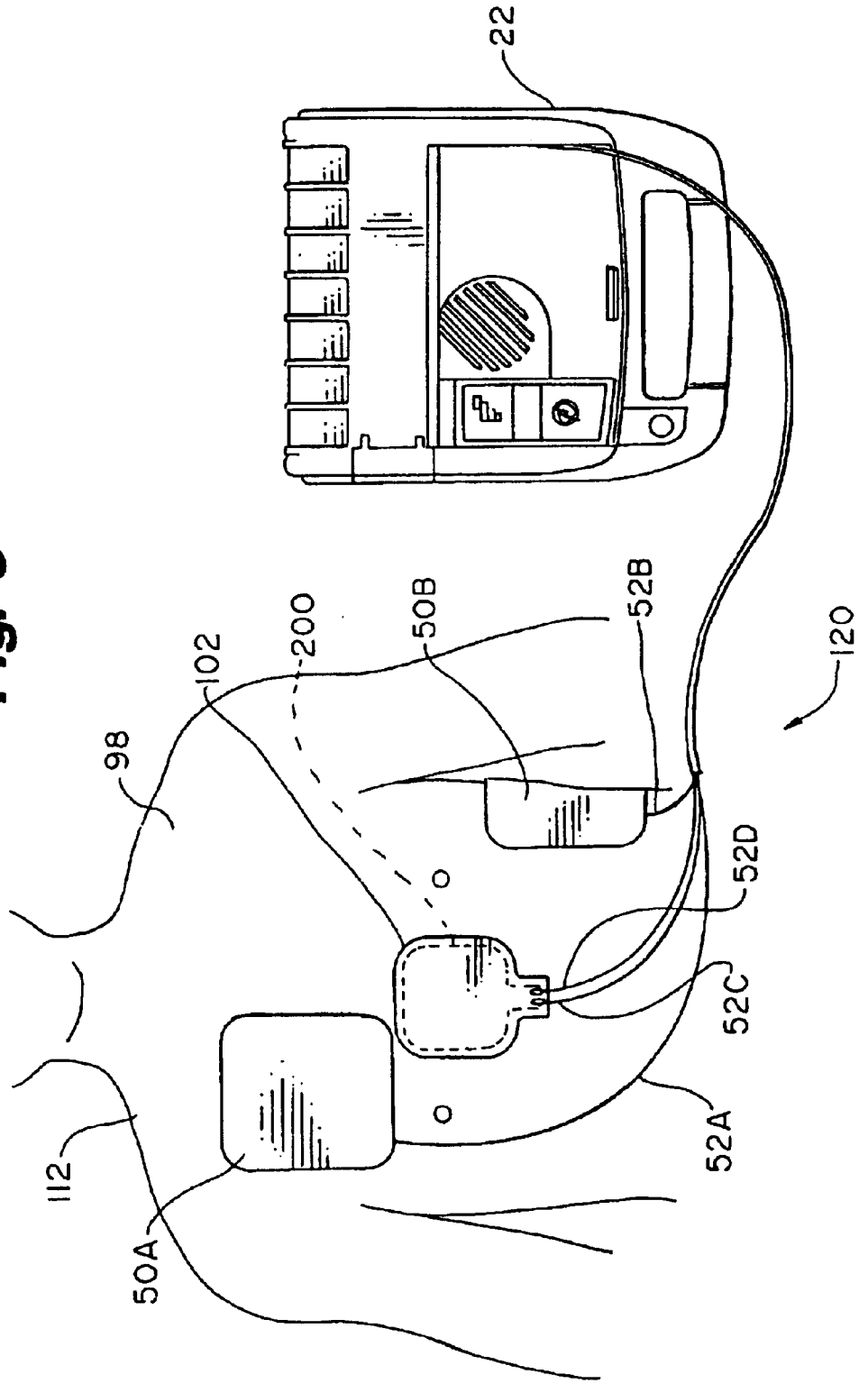

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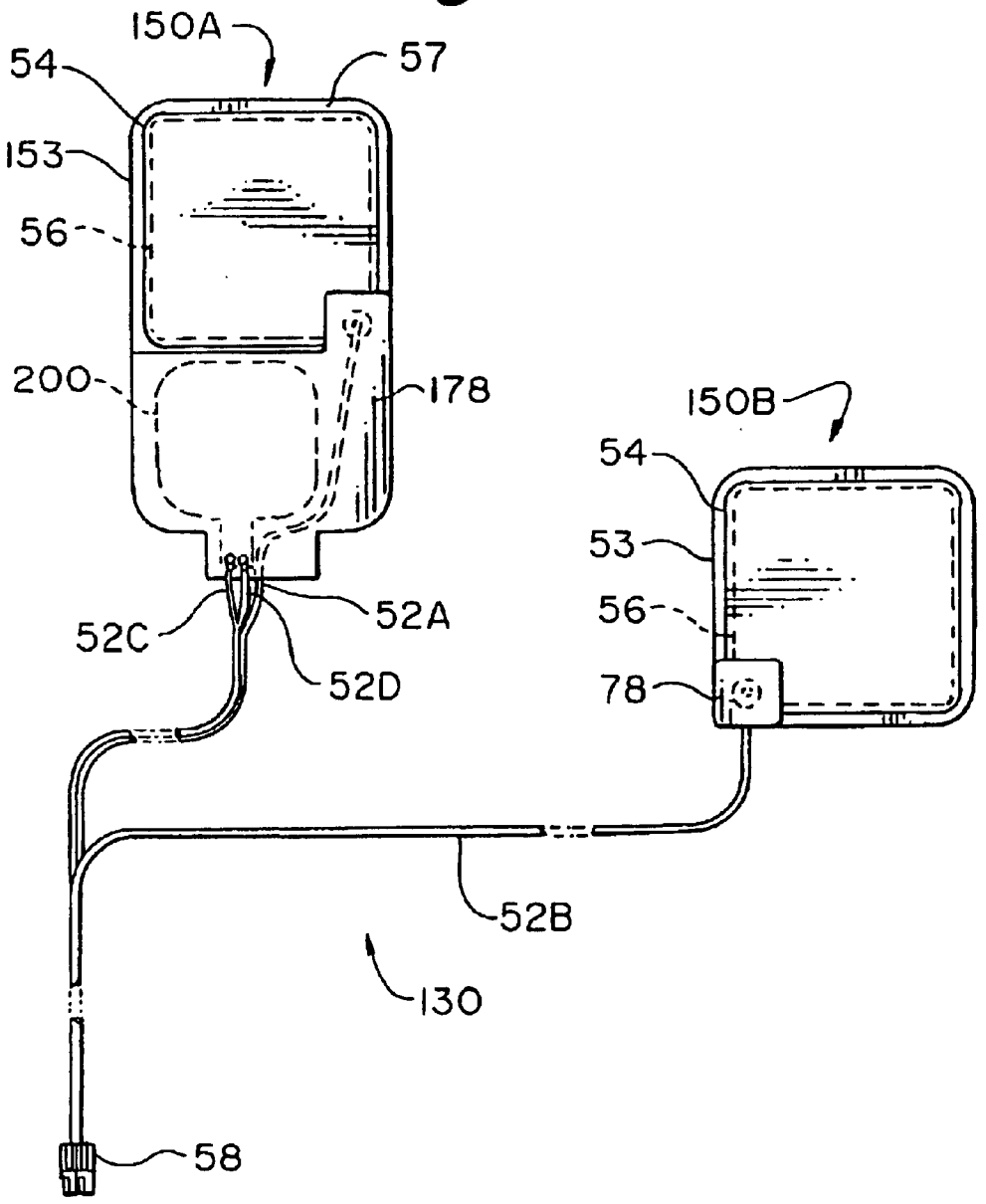

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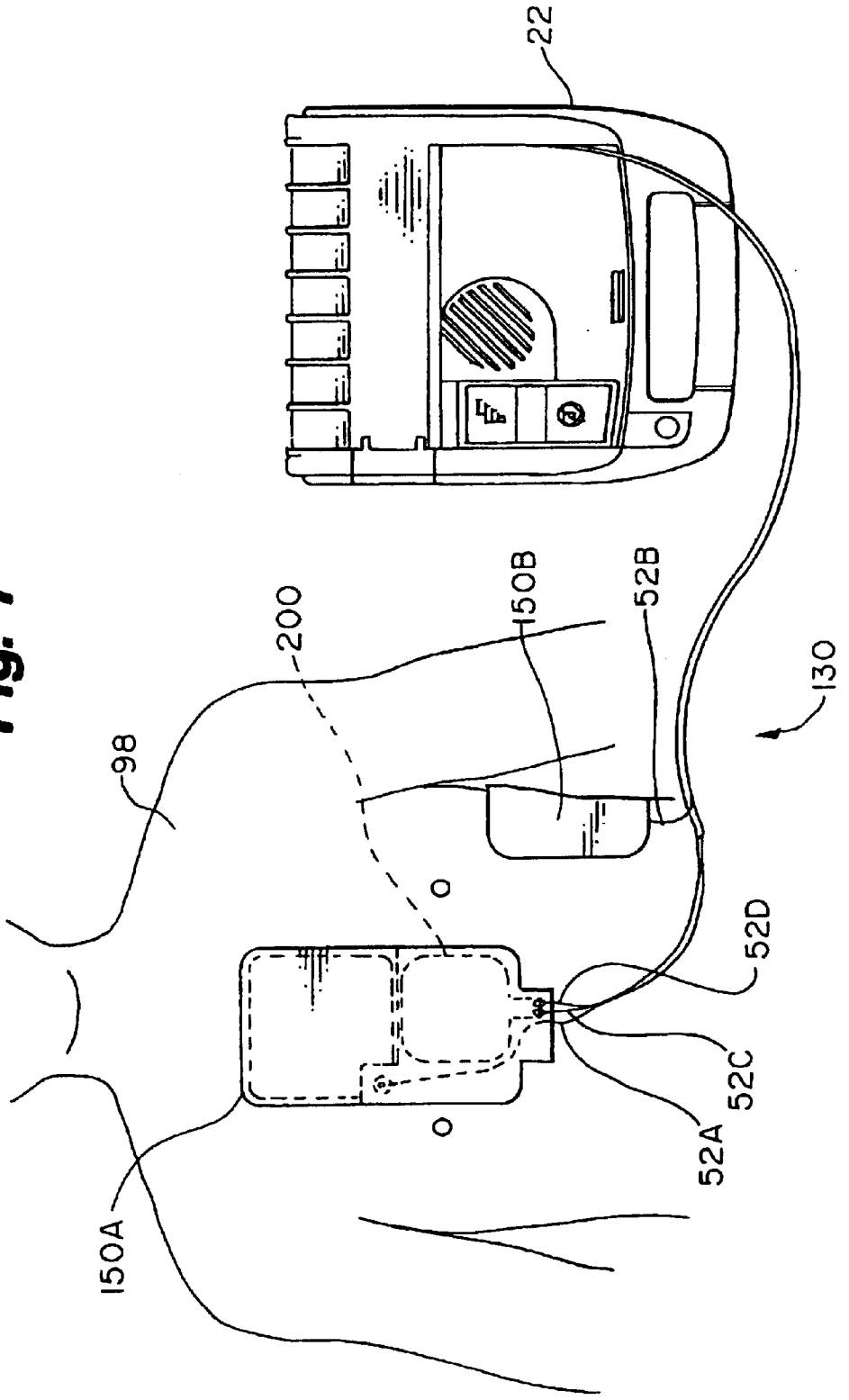


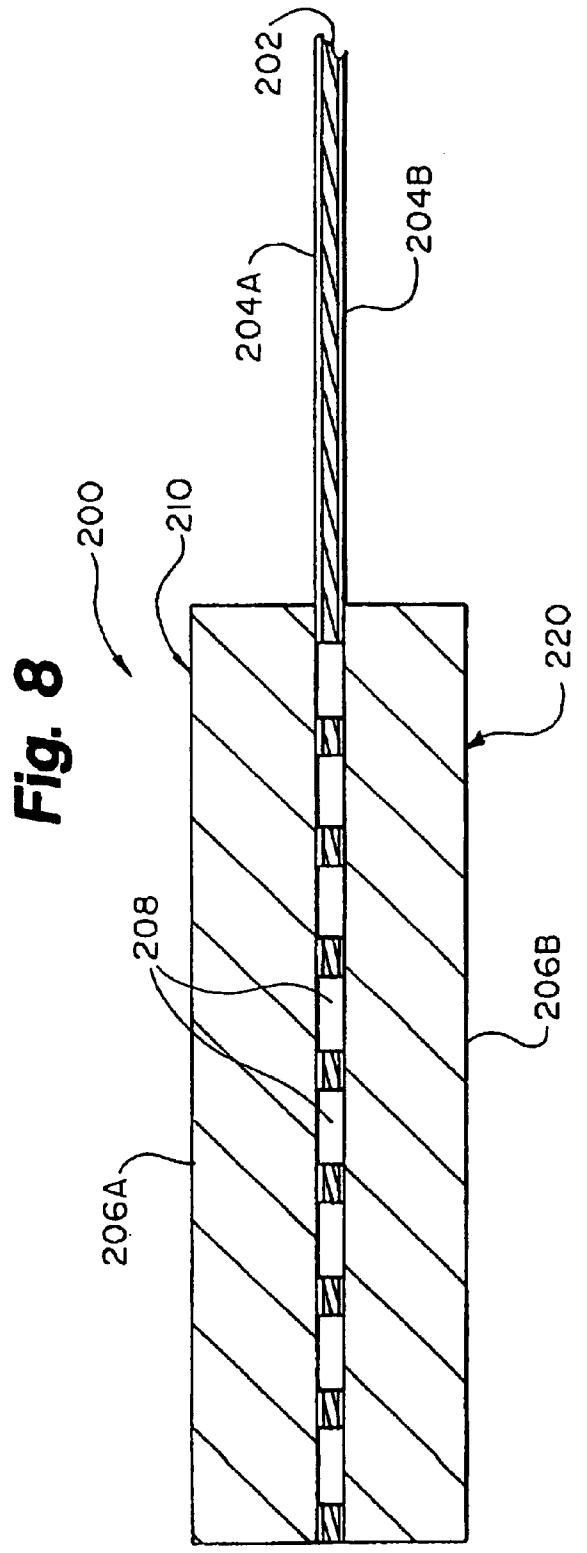
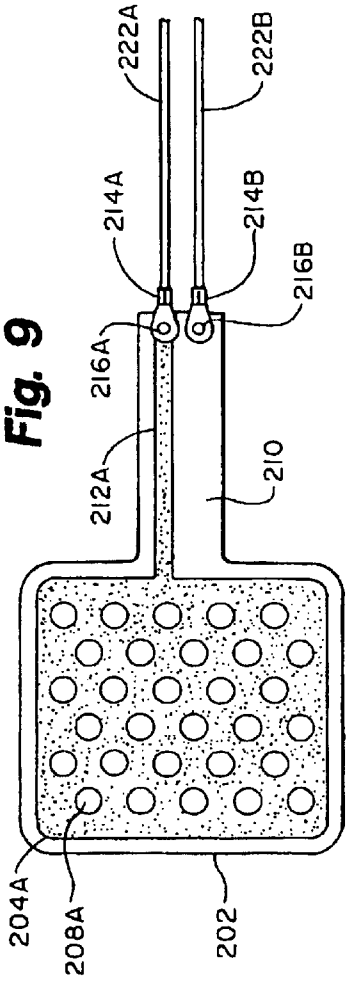


Fig. 8

Fig. 9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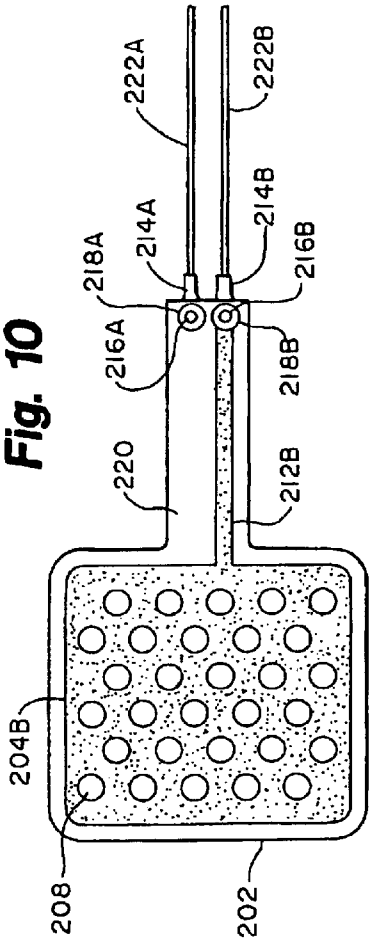
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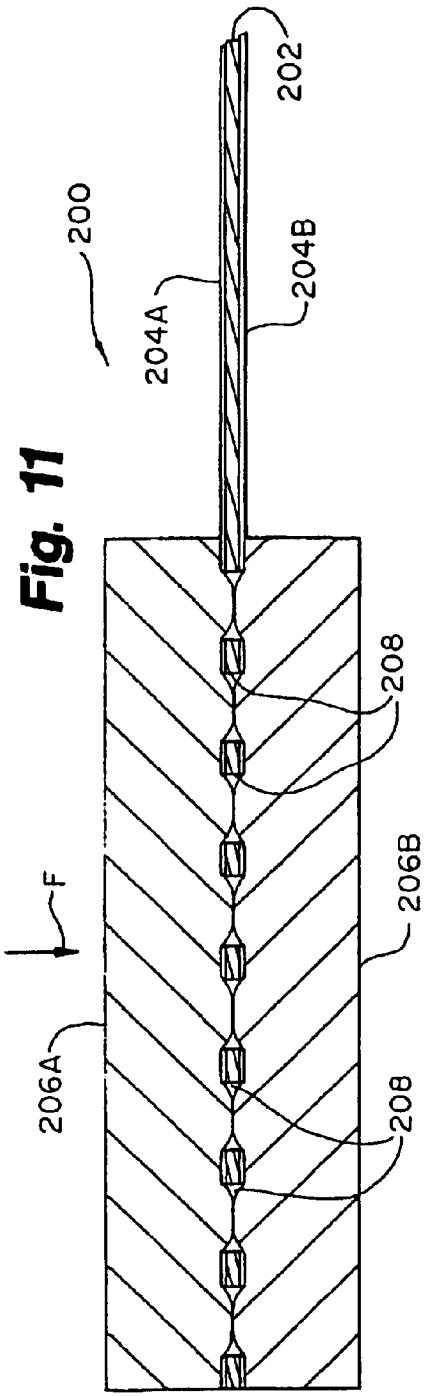
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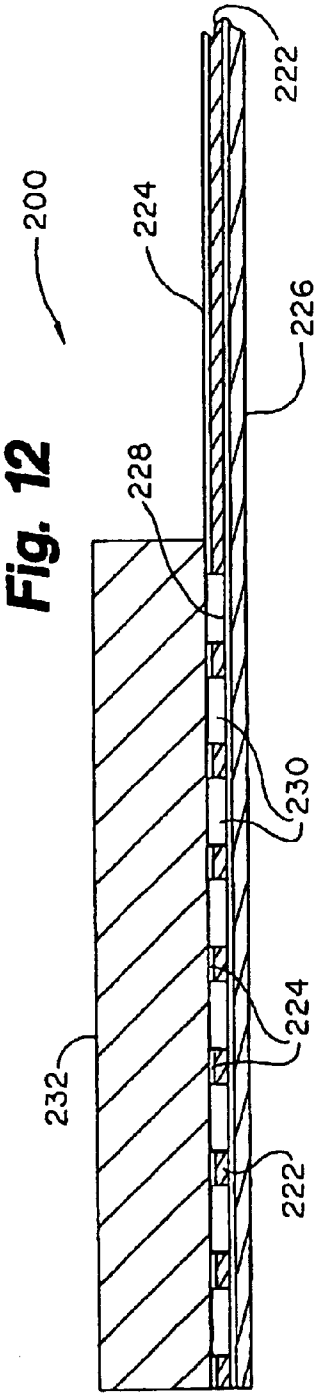
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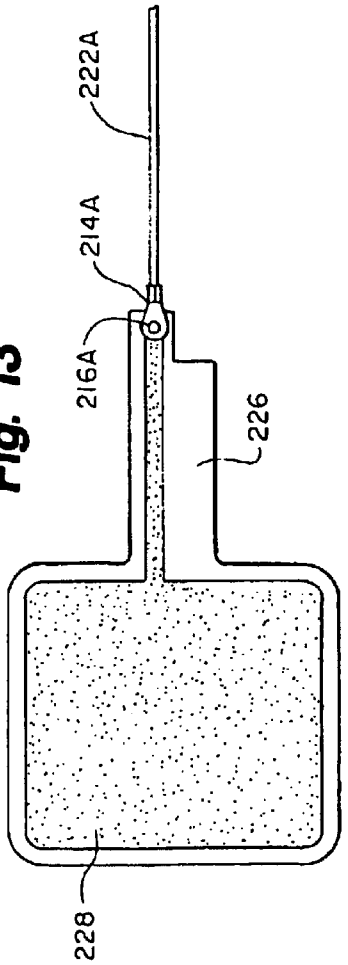
Fig. 12

Fig. 13



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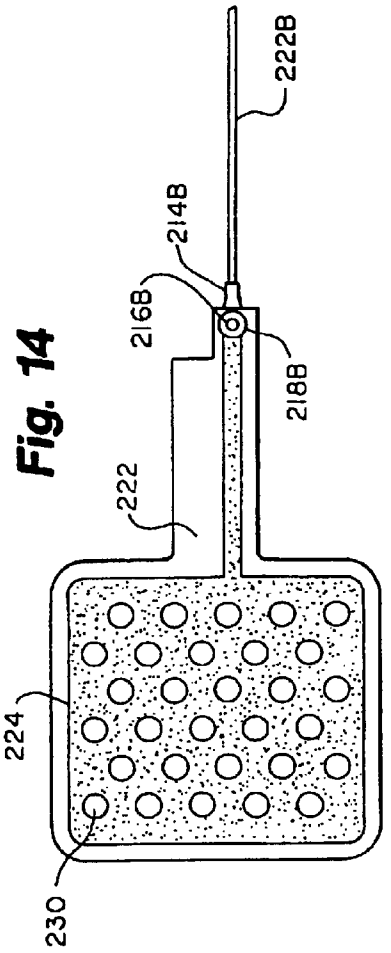

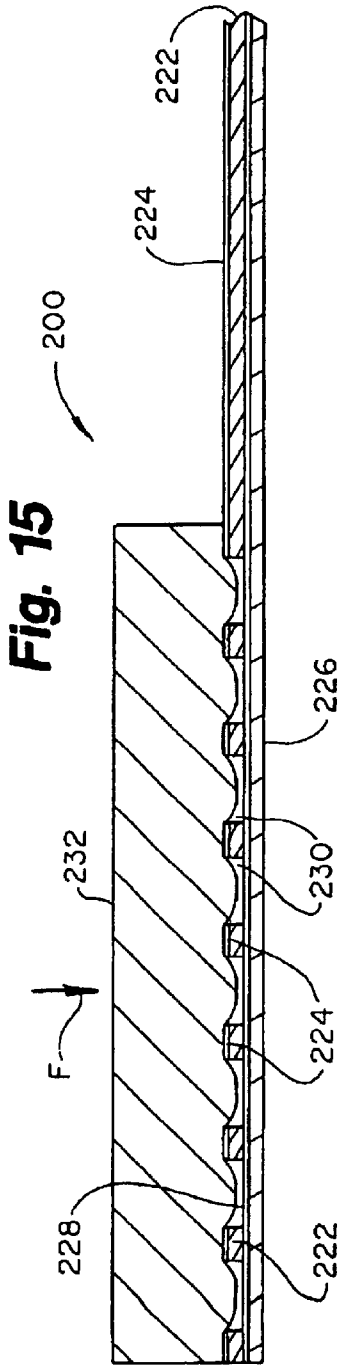
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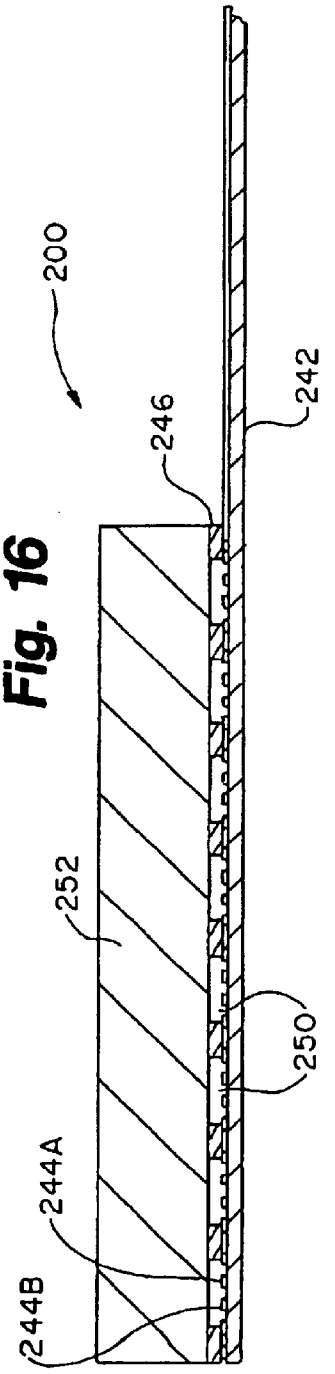
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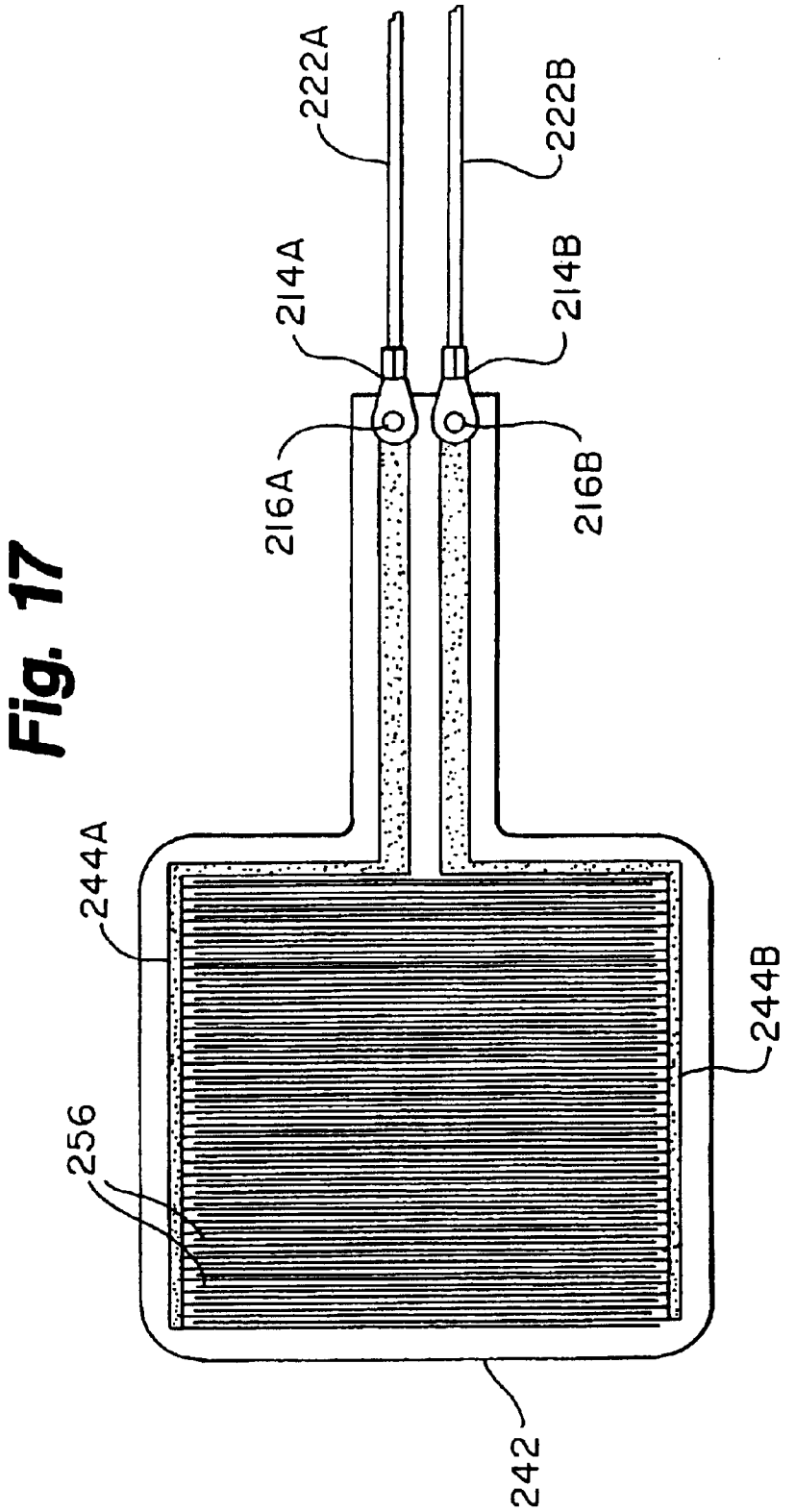

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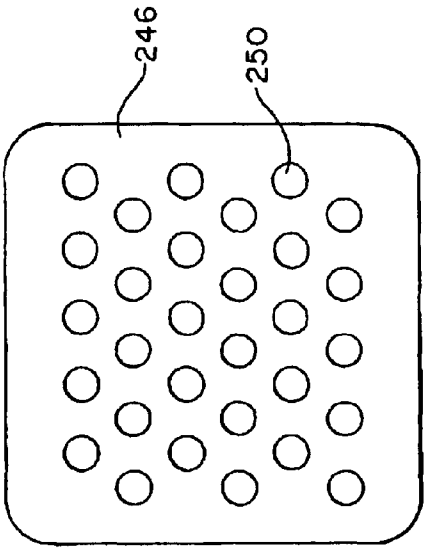

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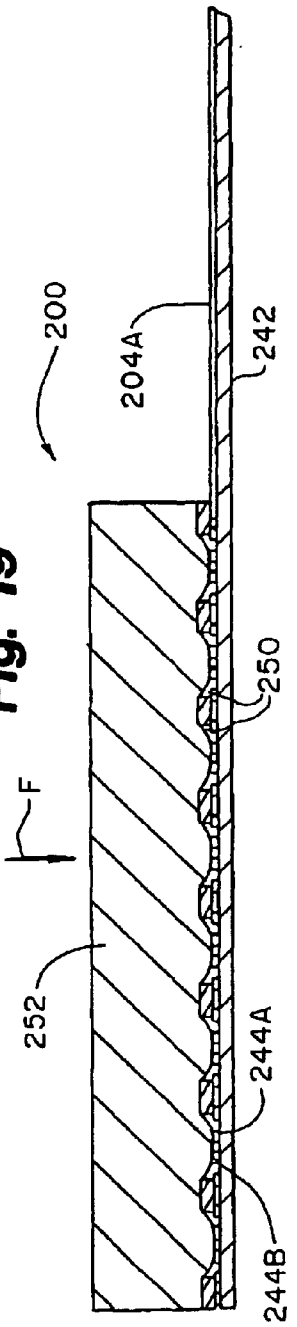

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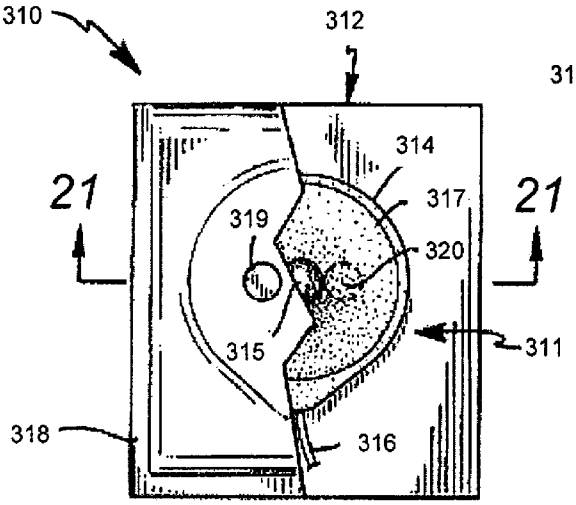

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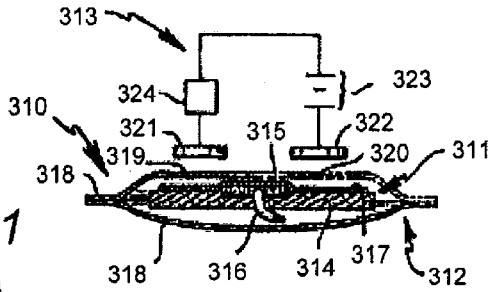

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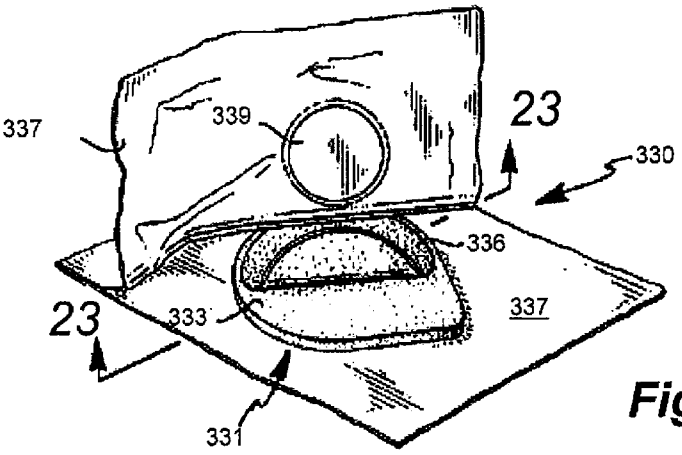

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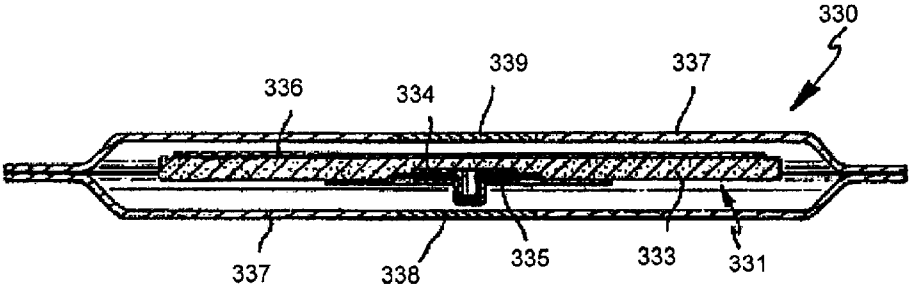

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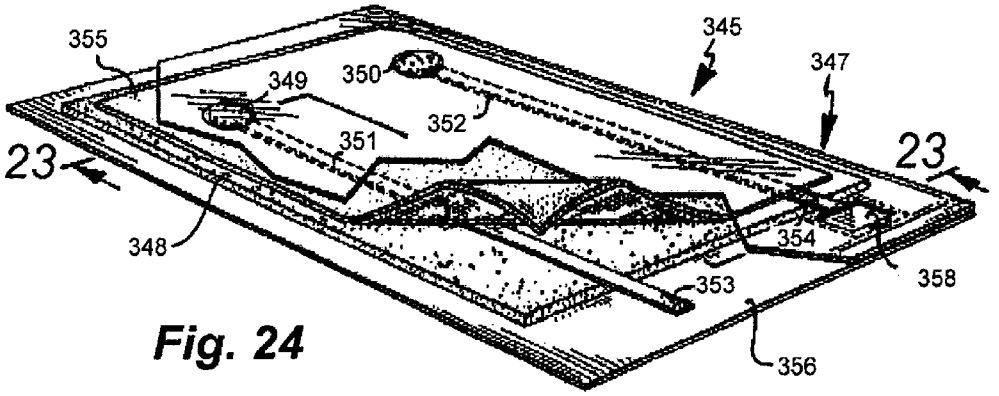

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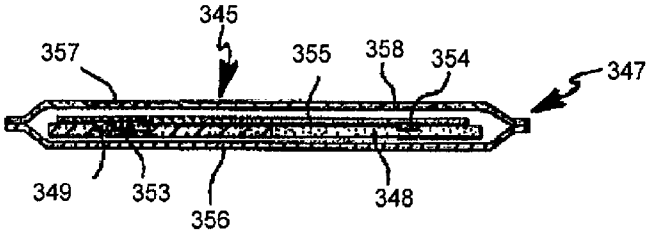

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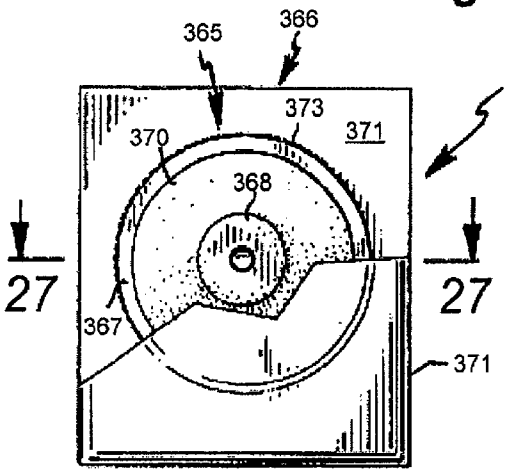

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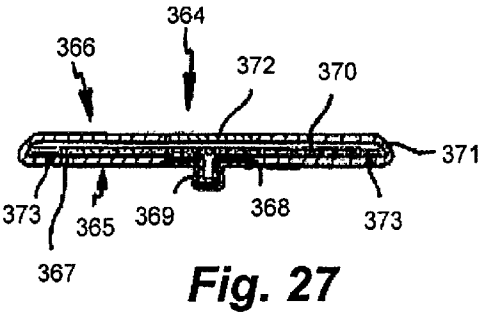

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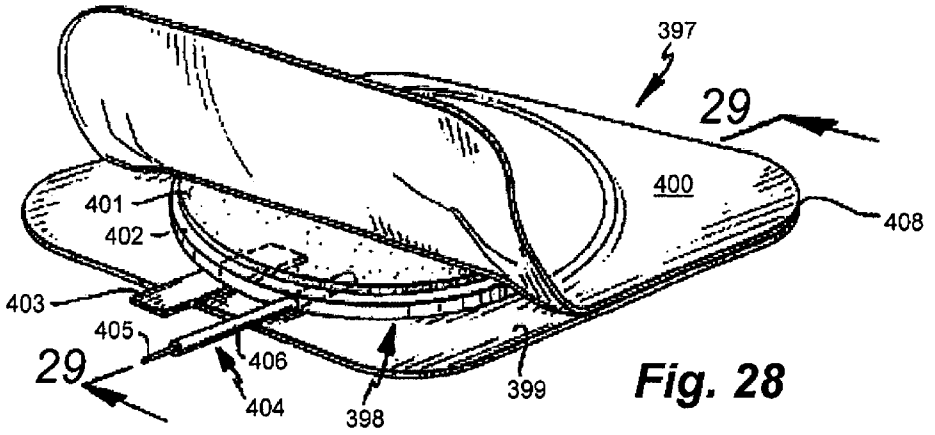

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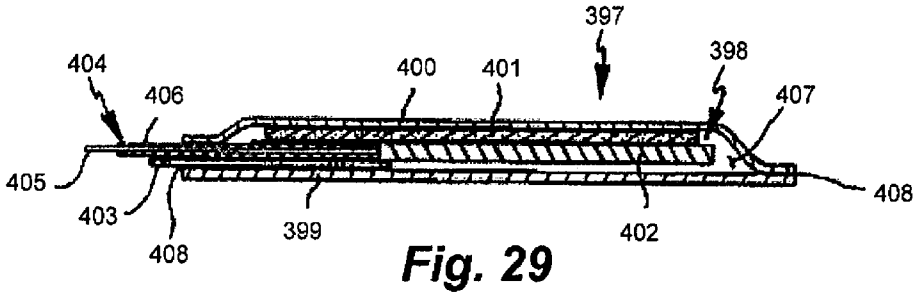

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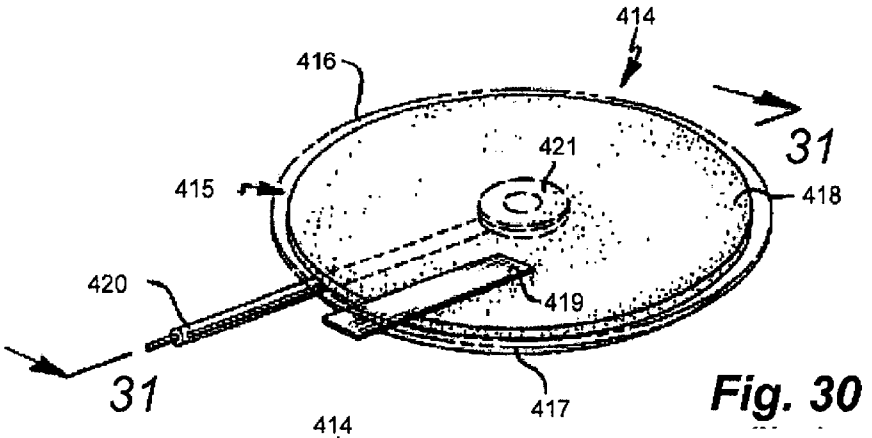

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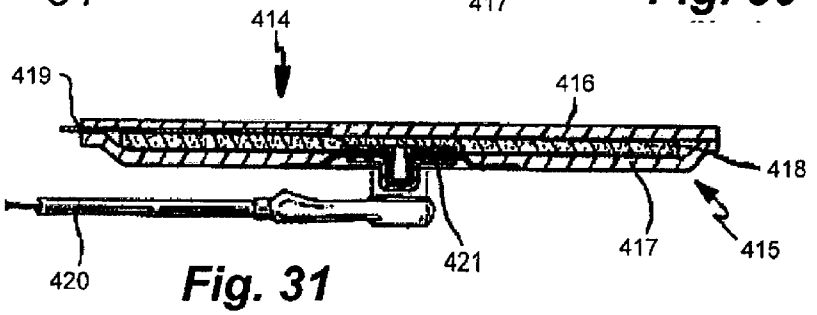

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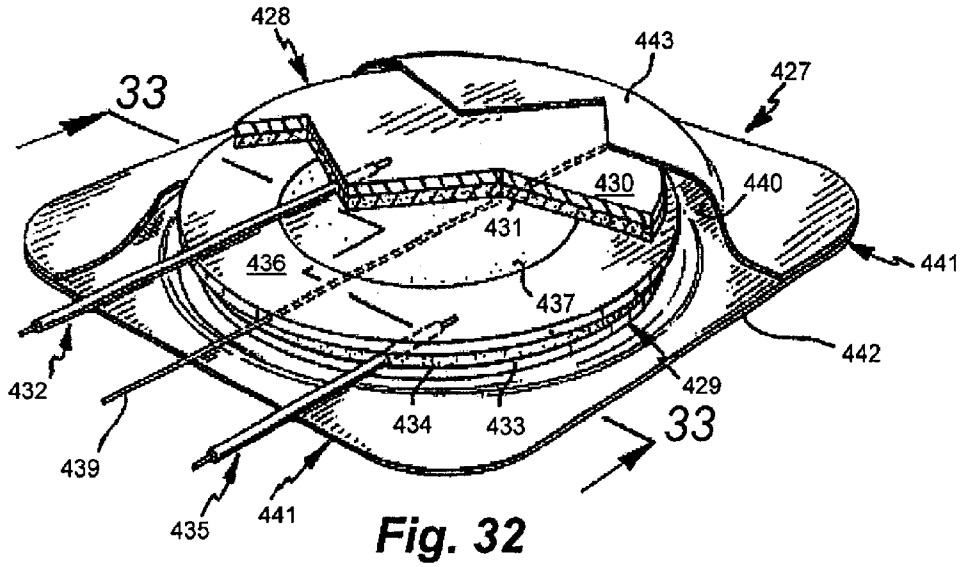

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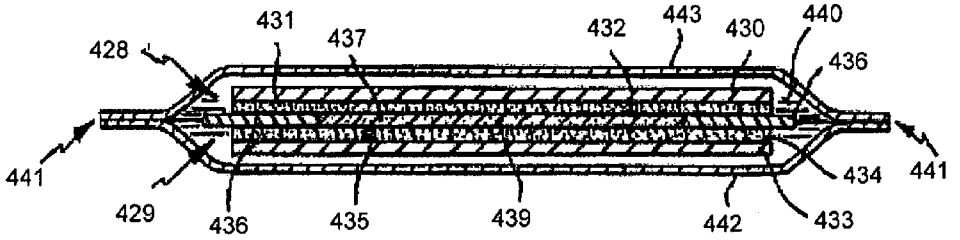

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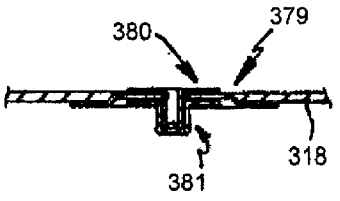

Fig. 34

Fig. 35

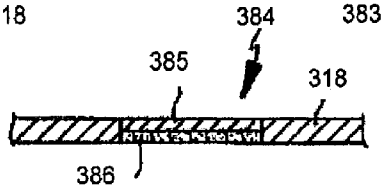

Fig. 36

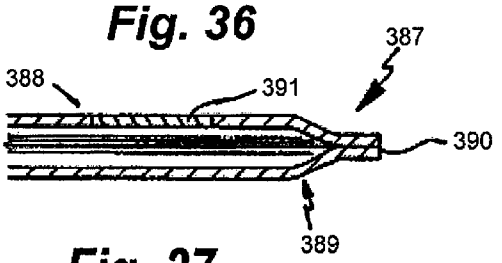

Fig. 37

AED WITH FORCE SENSOR

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

TECHNICAL FIELD

The present invention relates to devices useful for assisting in the administration of cardiopulmonary resuscitation (CPR). More particularly, the present invention relates to a sensor for being disposed on the body of a victim to measure parameters related to the CPR.

BACKGROUND OF THE INVENTION

CPR is a technique used by a rescuer in an emergency situation to get oxygen into a victims blood when that persons heart has stopped beating and/or they are not breathing spontaneously. When performing CPR the rescuer creates blood circulation in the victims body by periodically compressing the victims chest.

The American Heart Association (AHA) recommends that the rescuer press down on the sternum with a force sufficient to depress it between 4 and 5 cm. The recommended rate for these periodic depressions is 100 times a minute (ILCOR Advisory Statement for Single-Rescuer Adult Basic Life Support). Chest compressions produce blood circulation as the result of a generalized increase in intrathoracic pressure and/or direct compression of the heart. The guidelines state "Blood circulated to the lungs by chest compressions will likely receive enough oxygen to maintain life when the compressions are accompanied by properly performed rescue breathing." A victim can be kept alive using CPR provided the rescuer(s) are able to continue delivering properly performed chest compressions and rescue breaths.

Administering chest compressions and rescue breaths is a very physically demanding task. The quality of chest compressions and rescue breaths delivered can degrade as rescuers become fatigued. When a rescuer is fatigued they may not realize that they are compressing the chest with inadequate force.

Administering CPR is a very physically demanding procedure which is performed under stressful (i.e. life and death) circumstances. Under these circumstances, the rescuer is given the difficult tasks of estimating the time between compression's, and the distance which the chest is being compressed. Much of the difficulty in estimating the distance which the chest is being compressed stems from the relative position of the rescuer and the victim. When performing chest compression's, the rescuer positions his or her shoulders directly above the victim's chest, and pushes straight down on the sternum. In this position, the rescuer's line of sight is straight down at the victim's chest. With this line of sight, the rescuer has no visual reference point to use as a basis for estimating the distance that he or she is compressing the chest.

For this reason, there is a need in the art for a practical device which provides the rescuer with feedback to indicate that the rescuer is using proper compression force and that the rate of compressions is correct. A device of this type will provide rescuers with coaching which will enable them to deliver chest compressions consistently and beneficently. To be practical, this device should be one which is already at the rescue scene so that the rescuer is not required to bring an additional piece of equipment to the scene.

Because AEDs are being widely deployed, they are often present at a rescue scene. Prior art AEDs are only capable of defibrillation. There is a need in the industry for an AED which is capable of aiding a rescuer in administering proper chest compressions to a victim.

SUMMARY OF THE INVENTION

The present invention is an AED which is capable of detecting when a rescuer is performing CPR on a victim. This AED is also capable of providing a rescuer with helpful voice prompts to coach them through a CPR procedure. Rescuers who are trained in the use of AEDs are also trained in cardiopulmonary resuscitation (CPR) and will be able to make ready use of the AED of the present invention. AEDs are presently being widely deployed, and they are often on the scene when CPR is administered.

The present invention substantially meets the aforementioned needs. The present invention provides a sensor for sensing both the force applied to the victim's chest and the frequency with which the compressions are applied in order to assist a rescuer in resuscitating a stricken victim. Feedback, preferably by means of voice prompts, is provided to the rescuer by an emergency electronic device in communication with the sensor in order to optimally time the administration of chest compressions and to deliver a chest compression that provides an optimal amount of compression of the chest.

The present invention is a force sensor, for use in combination with an automated electronic defibrillator (AED), includes a first conductive layer. A second conductive layer is spaced apart from the first conductive layer such that no electrical communication occurs between the first and second conductive layers. Electrical communication means are provided for establishing an electrical communication path between the first and second conductive layers responsive to the application of a force to said electrical communication means.

The present invention includes a method of prompting a rescuer in the application of cardiopulmonary resuscitation to a victim having the steps of:

- sensing a force applied by the rescuer to the victim's sternum;
- sensing an interval between successive applications of force to the victim's sternum;
- comparing the force applied by the rescuer to the victim's sternum in a standard of force known to effect resuscitation;
- providing a prompt to the rescuer that prompts the rescuer to vary the force delivered to approximate the force that is known to effect resuscitation;
- comparing the interval between successive applications of force to the victim's sternum to a standard interval known to effect resuscitation; and
- providing a prompt to the rescuer that prompts the rescuer to vary the interval of force application to approximate the interval that is known to effect resuscitation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an automated external defibrillator;

FIG. **2** is an exploded view of an electrode having the force sensor of the present invention;

FIG. **3** is a block diagram of an electrical system of the AED,

FIG. **4** is a perspective view of the force sensor used in conjunction with a pair of electrodes;

FIG. **5** is a perspective view of the force sensor of the present invention applied to a patent;

FIG. **6** is a perspective view of an electrode with the force sensor of the present invention disposed therein,

FIG. **7** is a perspective view of the force sensor of FIG. **6** applied to the chest of a victim;

FIG. **8** is a cross sectional side view of the electrode of the present invention;

FIG. **9** is a top plan view of a further embodiment of the force sensor of the present invention;

FIG. **10** is a bottom plan view of the force sensor depicted in FIG. **9**;

FIG. **11** is a cross sectional side view of the electrode of the present invention;

FIG. **12** is a cross sectional side view of the electrode of the present invention;

FIG. **13** is a top plan view of a further embodiment of the force sensor of the present invention;

FIG. **14** is a bottom plan view of the force sensor depicted in FIG. **13**;

FIG. **15** is a cross sectional side view of the electrode of the present invention;

FIG. **16** is a cross sectional side view of the electrode of the present invention;

FIG. **17** is a top plan view of a further embodiment of the force sensor of the present invention;

FIG. **18** is a bottom plan view of the force sensor depicted in FIG. **17**; and

FIG. **19** is a cross sectional side view of the electrode of the present invention;

FIG. **20** is a partial cut-away view of an embodiment of a packaged electrode system;

FIG. **21** is a cross-sectional view of an embodiment of a packaged electrode system and test apparatus;

FIG. **22** is a perspective assembly view an embodiment of a packaged electrode system;

FIG. **23** is a cross sectional view of an embodiment of a packaged electrode system;

FIG. **24** is an partial cut-away view of an embodiment of a packaged electrode system;

FIG. **25** is cross sectional view of an embodiment of a packaged electrode system;

FIG. **26** is partial cut-away view of an embodiment of a packaged electrode system;

FIG. **27** is a cross-sectional view of an embodiment of a packaged electrode system;

FIG. **28** is perspective assembly view an embodiment of a packaged electrode system;

FIG. **29** is a cross-sectional view of an embodiment of a packaged electrode system;

FIG. **30** is a perspective view of an embodiment of a packaged electrode system;

FIG. **31** is a cross-sectional view of an embodiment of a packaged electrode system;

FIG. **32** is a partial cut-away view of an embodiment of a packaged electrode systsem;

FIG. **33** is a cross-sectional view of an embodiment of a packaged electrode system;

FIG. **34** is a cross-sectional view of a partial embodiment of a packaged electrode system;

FIG. **35** is a cross-sectional view of a partial embodiment of a packaged electrode system;

FIG. **36** is a cross-sectional view of a partial embodiment of a packaged electrode system; and

FIG. **37** is a cross-sectional view of a partial embodiment of a packaged electrode system.

DETAILED DESCRIPTION OF THE DRAWINGS

An AED is shown generally at **22** in FIG. **1**. AED **22** is used for emergency treatment of victims of cardiac arrest and is typically used by first responders. AED **22** automatically analyzes a patient's cardiac electrical signal and advises the user to shock a patient upon detection of (1) ventricular fibrillation; (2) ventricular tachycardia; (3) other cardiac rhythms with ventricular rates exceeding 180 beats per minute and having amplitudes of at **[**lease**]** *least* 0.15 millivolts. When such a condition is detected, AED **22** will build up an electrical charge for delivery to the patient to defibrillate the patient with a defibrillation shock. The operator of AED **22** is guided by voice prompts and an illuminated rescue (shock) button. Olson, et al. U.S. Pat. No. 5,645,571, incorporated herein by reference, discloses the general construction and manner of use of an AED.

AED **22** includes case **12** with carrying handle **14** and battery **80**, the battery **80** being removably disposed within a battery compartment (not shown) defined in case **12**. Battery **80** functions as an energy source for AED **22**. Visual maintenance indicator **20** and data access door **44** are located on the outside of case **12** to facilitate access by the operator. A data communication serial port **42** is situated behind data access door **44**. Case **12** also includes panel **24** and electrode compartment **26** defined in a top portion thereof. Panel **24** includes illuminable rescue switch **18** and diagnostic display panel **36** with "electrodes" indicator light **28**. Panel **24** and electrode compartment **26** are enclosed by selectively closeable lid **27**.

Electrode compartment **26** contains connector **32** and electrode package **60**. Electrode compartment **26** hermetically encloses a patient interface which includes a pair of electrodes **50** depicted in FIG. **2**, and a force sensor **200**, FIGS. **4**–**16**. Electrodes **50** and force sensor **200** are removably connected to connector **32** by lead wires **52** and lead wire connector **58**. Electrodes **50** are attachable to a patient prior to a rescue intervention procedure with AED **22**.

AED **22** also includes a digital microprocessor-based electrical control system (see the block diagram of FIG. **3**) for controlling overall operation of AED **22** and for delivering a defibrillation shock pulse through electrodes **50** via connector **32** and lead wires **52**. The electrical control system further includes an impedance measuring circuit for testing the interconnection and operability of electrodes **50** to detect several faults. For example, if the conductive hydrogel adhesive on electrodes **50** is too dry or if electrodes **50** are not properly connected to connector **32** a relatively high impedance (e.g. greater than about 20 ohms) will be present across connector **32**. However, when fresh electrodes **50** are properly connected, the impedance across connector **32** will be between about 2 and 10 ohms.

To insure operable electrodes **50**, an electrode self-test is conducted (e.g., daily or upon opening lid **27**) in which the interconnection and operability of electrodes **50** are checked with the impedance measuring circuit. If electrodes **50** are missing or unplugged from connector **32**, if electrodes **50** are damaged, or if the conductive hydrogel adhesive on electrodes **50** is too dry, the control system of AED **22** will illuminate "Electrodes" indicator light **28** on diagnostic display panel **36**.

Defibrillator 22 also includes electrocardiogram (EKG) filter and amplifier 104 which is connected between elec-

trode connector 32 and A/D converter 102. The EKG or cardiac rhythm of the patient is processed by filter and amplifier 104 in a conventional manner, and digitized by A/D converter 102 before being coupled to processor 74.

The rescue mode operation of defibrillator 22 is initiated when an operator opens lid 27 to access the electrode package 60. The opening of the lid 27 is detected by lid switch 90, which effectively functions as an on/off switch. In response to this action, power control circuit 88 activates power generation circuit 84 and initiates rescue mode operation of processor 74. Processor 74 then begins its rescue mode operation and initiates the generation of an audible voice prompt "To attempt a rescue, disconnect charger." if a charger is connected when lid 27 is opened.

If the lid-opened self-test is successfully completed, processor 74 initiates the generation of an audible "Place electrodes." voice prompt. In response to this voice prompt, and following the instructions on the inside of lid 27, the operator should remove electrode package 60 from compartment 26, open the package, peel electrodes 50 from the release liner and place the electrodes on the patient's chest. While this action is being performed, processor 74 monitors the impedance signals received through A/D converter 102 to determine whether the impedance across the electrodes indicates that they have been properly positioned on the patient. If the correct impedance is not measured, processor 74 initiates the generation of a "Check electrodes." voice prompt.

After detecting an impedance indicating the proper placement of electrodes 50, and without further action by the operator (i.e., automatically), processor 74 begins a first analyze sequence by initiating the generation of a "Do not touch patient. Analyzing rhythm." voice prompt, and analyzing the patient's cardiac rhythm. In one embodiment, processor 74 collects and analyzes a nine second segment of the patient's cardiac rhythm. The cardiac rhythm analysis program executed by processor 74 is stored in program memory 76. Algorithms of the type implemented by the rhythm analysis program are generally known and disclosed, for example, in the W. A. Tacker Jr. book Defibrillation of the Heart, 1994. If the processor 74 determines that the patient has a nonshockable cardiac rhythm that is not susceptible to treatment by defibrillation pulses (e.g., no pulse rather than a fibrillating rhythm), it initiates the generation of a "Check pulse. If no pulse, give CPR." voice prompt. One minute after this voice prompt, processor 74 repeats the initiation of the "Do not touch patient. Analyzing rhythm." voice prompt and the associated cardiac rhythm analysis.

When a shockable cardiac rhythm is detected, processor 74 begins a first charge sequence by initiating the generation of a "Charging." voice prompt, and causes high voltage generation circuit 86 to operate in the charge mode. When the high voltage generation circuit 86 is charged, processor 74 begins a first shock sequence by initiating the generation of a "Stand clear. Push flashing button to rescue." voice prompt, and the flashing illumination of rescue switch 18. The operator actuation of rescue switch 18 will then cause processor 74 to operate high voltage generation circuit 86 in the discharge mode, and results in the application of a defibrillation pulse to the patient to complete the first series of analyze/charge/shock sequences. In one embodiment, the first defibrillation pulse delivered by defibrillator 22 has an energy content of about two hundred joules.

Following the first series of analyze/charge/shock sequences, processor 74 times out a short pause of about five seconds to allow the heart to reestablish its cardiac rhythm before beginning a second series of analyze/charge/shock sequences. The second series of analyze/charge/shock sequences is identical to the first series described above, except the energy content of the defibrillation pulse can be about two hundred joules or three hundred joules. If the second series of analyze/charge/shock sequences ends with the delivery of a defibrillation pulse, processor 74 again times out a short pause of about five seconds before beginning a third analyze/charge/shock sequence. The third series is also identical to the first series, but processor 74 controls the high voltage generation circuit 86 in such a manner as to cause the defibrillation pulse delivered upon the actuation of the rescue switch 18 to have an energy content of about three hundred and sixty joules.

Following the delivery of a defibrillation pulse at the end of the third series of analyze/charge/shock sequences, or after identifying a nonshockable cardiac rhythm, processor 74 initiates the generation of a "Check Pulse. If no pulse, give CPR." voice prompt. Processor 74 then times a one minute CPR period to complete a first set of three series of analyze/charge/shock sequences. Rescue mode operation then continues with additional sets of three series of analyze/charge/shock sequences of the type described above (all with three hundred and sixty joule pulses). Processor 74 ends rescue mode operation of defibrillator 22 when a total of nine series of analyze/charge/shock sequences have been performed, or lid 27 is closed.

Throughout the analyze, charge and shock sequences, processor 74 monitors the impedance present across connector 32 to determine whether electrodes 50 remain properly positioned on the patient. If the monitored impedance is out of range (e.g., too high if the electrodes have come off the patient, or too low is shortened), processor 74 initiates the generation of a "Check Electrodes." voice prompt, and causes high voltage generation circuit 86 to discharge any charge that may be present through internal load 98. Rescue mode operation will resume when processor 74 determines that the electrodes have been properly repositioned on the patient.

FIG. **2** is an exploded view of a prior art electrode **50**. Electrode **50** includes flexible, adhesive coated backing layer **53** (preferably a polymeric foam), and patient engaging layer **54**. Patient engaging layer **54** is preferably a hydrogel material which has adhesive properties and which is electrically conductive. Hydrogel adhesive of this type is commercially available from LecTec Corporation (Minnetonka, Minn.) and Tyco International Ltd. (Hamilton, Bermuda). Current disbursing flexible conductive portion **56** is preferably located between backing layer **53** and patient-engaging hydrogel layer **54**. Conductive portion **56**, as shown, need not be the same size as backing layer **53** and is preferably a homogeneous, solid, thinly deposited metallic substance, or a conductive ink.

Insulated lead wire **52** is terminated with a wire terminal *1*70. Wire terminal *1*70 is electrically connected to conductive portion **56** via conductive rivet *1*74 and washer *1*72. Conductive rivet *1*74 is covered on a first side with insulating disk *1*76. Conductive rivet *1*74, washer *1*72, and wire terminal *1*70 are all covered on a second side with insulating pad *1*78. Further examples of electrode pad construction for use with AED **22** are described and shown in U.S. Pat. Nos. 5,697,955, 5,579,919, and 5,402,884, all hereby incorporated by reference.

For example, referring to FIGS. 20 and 21 an embodiment of a packaged electrode system 310 is shown to comprise an electrode 311 and a package or enclosure 312. Also shown in FIG. 21 is a test apparatus 313. The electrode 311 is

shown to comprise a non-conductive base or backing layer 314, a conductor or conductive layer 315, a lead 316, and a conductive contact layer 317. The base layer 314 is preferably constructed of a thin, flexible polymeric substance such as a urethane foam, or a polyester or polyolefin laminate which provides structural base and insulative properties. Although the base layer 314 is shown to have a surface area which is substantially coextensive with the surface of the contact layer 317, it alternatively may be slightly larger. In such larger configurations, the base layer 314 may have a pressure sensitive adhesive disposed on its patient contact side for increased adhesion to the patient body.

The conductive layer 315 is shown to be disposed on the first or patient side of base layer 314. It functions to transfer (disperse) current or voltage from the lead 316 (or to the lead in a sensing application) to the patient contact layer 317. Although the conductive layer 315 is shown to have a surface area which is smaller than that of the base layer 314 or contact layer 317, it may alternatively have a dimension which is larger than that shown, or even on which is coextensive with the base and contact layers 314 and 317. The conductive layer 315 is preferably a homogeneous, solid, thinly deposited metallic substance, or a conductive ink material. Alternatively, the conductive layer 315 may be formed of a flexible mesh material, a conductive adhesive or a deposited ink pattern. Flexible conductive ink compounds known in the art have a conductive filler of Gold, Silver, Aluminum or other conductive materials.

The lead 316 is preferably an insulated wire conductor which extends from a mating point with the conductive layer 315, through the base layer 314, and then has a freely movable end. Various alternatives of this lead 316 design exist and are useable consistent with the general teachings of the invention, including but not limited to uninsulated wire conductors and conductive strips or traces deposited between the contact layer 317 and the base 314 or conductive layers 315. Such a trace or strip may also extend just beyond the base layer 314 for connection with an ancillary connection means such as a wiring harness including conductive clip means.

The conductive contact layer 317 is preferably a thin layer of semi-liquid gel material. The gel maintains direct electrical contact with the skin, to reduce variations in conductance, and it permits such contact for long periods of time. The gel is a conductive, gelatinous compound which is also flexible for contoured adhesion to the body of a patient. The gel also preferably has a pressure sensitive, moisture resistant adhesive property. Compounds having these characteristics have been developed by Minnesota Mining and Manufacturing, Medtronic, and Lec Tec (Synkara TM), Corporations, all of Minnesota, U.S.A. Generally, these compounds have low resistivities. The contact layer 317 is for direct contact with the patient's body to transfer current or voltage thereto or therefrom. Overall, although the electrode 311 and its constituent elements are shown to have circular configurations, they may alternatively be formed in various other shapes such as rectangular or square patches.

The package structure 312 is shown to have an envelope-like structure formed of a substantially continuous thin, homogeneous layer 318 of a polymeric, preferably non-gas permeable, material. Alternatively, as shown in FIG. 38, the package 387 embodiment may have a pouch-like structure formed of a pair of thin, flat homogeneous layers 388 and 389 which are sealed or otherwise merged together at their peripheries or outer edges 390. And, although the package 312 is shown to have a rectangular configuration various other configurations and shapes are also useable.

The package further comprises a pair of conductive connectors 319 and 320 which are separated a predetermined distance from one another for contact with separate areas of the contact layer 317 of the enclosed electrode 311. The connectors 319 and 320 are conductive areas which are shown to have a unitary construction with the package layer 318. The contacts 319 and 320 may alternatively be formed of thin layer strips of conductive material, or a printed conductive ink, disposed on the interior side of the package layer 318, extending from contact nodes to peripheral contact areas on the exterior of the package 318. Yet another snap-type embodiment 379 is shown in FIGS. 35 and 36 including a connective member 380 disposed on one side of the base layer 318, and a current dispersion member 381 disposed on the opposite side and being connected to the upper member 380 via an aperture in the base 318. The upper member 380 is shown 360 have a base 382 and a mating notch 383 for coupling the lower member 381.

Referring to FIG. 21, the system 310 may also include a test apparatus 313. The test apparatus 313 includes a current source 323, preferably a battery, test circuitry 324, preferably including measurement components and status indication components such as an analog meter, LCD digital display or light emitting diodes, and connectors 321 and 322 for coupling with the package 312 connectors 319 and 320. In use, the test apparatus 313 is connected to the package connectors 319 and 320. The test circuitry 324 is then activated to form a closed current loop to determine whether continuity exists with respect to the enclosed electrode 311, thereby indicating whether the electrode 311 is still functional. Additionally, a load 386 formed of for example a conductive and semi-conductive material layers 385 and 386, may be added to the current loop as for example is shown in FIG. 37, for purposes of measuring the magnitude of current flow for more precise measurement of electrode 311 condition.

In the case of the electrode system 310, a current loop is formed including the connector 319, the gel of the contact layer 317 (along a substantially horizontal plane), and the connector 320 which is located at a remote location on the contact layer 314 with respect to the connector 319. Current conducts easily in fresh, semi-liquid gel of the contact layer 317. In contrast, no current conducts, or current conduction is attenuated, in stale, dried gel. This is indicative of the need to dispose of the stored electrode without using it. And, this condition is determinable without the need to open the package 312 and thereby risk compromising the freshness or sterility of a viable electrode 311.

Referring to FIGS. 22 and 23, another packaged electrode system 330 is shown to comprise an electrode 331 and a package or enclosure 332. The electrode 331 is shown to comprise a non-conductive base layer 333, and a conductive gel layer 336. A conductive snap-type connector having a connection member 335 disposed on one side and a current dispersion member 334 disposed on the second side is also shown. The package 332 is shown to have at least one body layer 337 with a pair of contacts 338 and 339 disposed at predetermined locations to electrically connect with the gel layer 336 and contact 335. In a test mode, a current loop is formed between the connector 339, gel layer 336, connector portions 334 and 335 and connector 338.

Referring to FIGS. 24 and 25, another packaged electrode system 345 is shown to comprise an electrode 346 and an enclosure 347. The electrode 346 is shown to comprise a non-conductive base layer 348, a conductive gel layer 355, and a pair of separate conductive layers 349 and 350, each of which are shown to have a lead 351 and 352 extending

therefrom and terminating in a connective node 353 and 354. The lead pair 351 and 352 (and layer pair 349 and 350) provide a redundant circuit path for increased reliability of use in emergency settings. The package 347 is shown to have at least one body layer 356 with a pair of contacts 357 and 358 disposed at predetermined locations to electrically couple with connective nodes 353 and 354. In a test mode, a current loop is formed between a connector 357 or 358, it's respective connective node 353 or 354 and lead 351 or 352, and its respective conductive layer 349 or 350. In a properly functioning electrode 346, current conducts through the gel 355 from one conductive layer 349 to the other 350, and then back to the test apparatus through the above-mentioned path.

Referring to FIGS. 26 and 27, another packaged electrode system 364 is shown to comprise an electrode 365 and a unitary package 366. The electrode 365 is shown to compromise a non-conductive base layer 367, and a conductive gel layer 370. A snap-type connector with members 368 and 369 electrically couples the gel layer 370.

The package 366 is shown to have at least one body layer 371 which is coupled to the electrode 365 base layer 367 at tear-away perforated lines 373. A connector 372 is shown disposed for contact with the electrode 365 gel layer 370. In a test mode, a current loop is formed between the connector 372, the gel layer 370, and the connector members 368 and 369.

Referring to FIGS. 28 and 29, another packaged electrode system 397 is shown to comprise an electrode 398 and a package. The electrode 398 is shown to comprise a non-conductive base layer 401, a conductive gel layer 402, and a lead 404 having a conductor 405 and an insulator 406, which is shown to be embedded directly in the gel layer 402. Alternatively, the lead may be connected to a conductive current dispersion layer (not shown). A conductive test strip 403 is also shown to be adhered to the surface of the gel 402 at a location remote from the lead 404 for test purposes, and which is designed to release from the gel 402 upon removal of the package layer 399.

The package is shown to have a pair of layers 399 and 400 which overlap to form an interior cavity 407 and area sealingly connected at their peripheries 408. In a test mode, a current loop is formed between the lead 404, the gel layer 402 and the test strip 403, which like the lead 404 is shown extended through the package periphery 408 for contact with an external test apparatus.

Referring to FIGS. 31 and 32, another packaged electrode system 414 is shown to comprise an electrode 415 and an enclosure. The electrode 415 is shown to comprise a non-conductive base layer 417, and a conductive adhesive gel layer 418 which is connected to a snap-type connection node 421 or the like, and an associated lead 420. The package is shown to comprise a single top layer of non-conductive material 416 which is laminated or adhesively mated to the electrode base layer 417. In use the gel layer 418 is removable from the package layer 416. A test strip 419 is disposed on the interior of the package, adhesively connected to the gel layer 418, and extending to the package exterior. In a test mode, a current loop is formed between the lead 420, node 421, gel layer 418 and the test strip 419.

Referring to FIGS. 33 and 34, another packaged electrode system 427 is shown to comprise a pair of electrodes 428 and 429 and a package. The electrodes 428 and 429 are shown to comprise non-conductive base layers 430 and 433, and conductive gel layers 431 and 434. Leads 432 and 435 extend from the respective gel layers 431 and 434. The package is shown to have a pair of overlapping layers 442 and 443 which are sealed at their peripheries 441 to form an enclosure 440 housing the electrodes 428 and 429. Importantly, the electrodes 428 and 429 are oriented with their respective gel layers 431 and 434 mating with a resistive layer 437 (and an optional separator layer 436) formed of a conductive/resistive material as known in the art. A conductive lead 439 or strip extends from the resistive layer through the package periphery 441, as do the electrode leads 432 and 435.

In a test mode, a current loop is formed between, for example, a lead 432, a gel layer 431, the resistive layer 437, and the remaining gel layer 434 and lead 435. The circuit can be altered to include the lead 439.

FIG. **3** is a block diagram of electrical system **70** of AED **22**. The overall operation of AED **22** is controlled by a digital microprocessor-based control system **72** which includes a processor **74** interfaced to program memory **76**, data memory **77**, event memory **78** and real time clock **79**. The operating program executed by processor **74** is stored in program memory **76**. Electrical power is provided by the battery **80** which is removably positioned within the battery compartment of AED **22** and is connected to power generation circuit **84**.

Power generation circuit **84** is also connected to lid switch **90**, watch dog timer **92**, real time clock **79** and processor **74**. Lid switch **90** is a magnetic read relay switch in one embodiment, and provides signals to processor **74** indicating whether lid **27** is open or closed. Data communication port **42** is coupled to processor **74** for two-way serial data transfer using an RS-232 protocol. Rescue switch **18**, maintenance indicator **20**, the indicator lights of diagnostic display panel **36**, the voice circuit **94** and piezoelectric audible alarm **96** are also connected to processor **74**. Voice circuit **94** is connected to speaker **34**. In response to voice prompt control signals from processor **74**, circuit **94** and speaker **34** generate audible voice prompts for consideration by a rescuer.

High voltage generation circuit **86** is also connected to and controlled by processor **74**. Circuits such as high voltage generation circuit **86** are generally known, and disclosed, for example, in the commonly assigned Persson **[**et al.**]** U.S. Pat. No. 5,405,361, which is hereby incorporated by reference. In response to charge control signals provided by processor **74**, high voltage generation circuit **86** is operated in a charge mode during which one set of semiconductor switches (not separately shown) cause a plurality of capacitors (also not shown), to be charged in parallel to the 12V potential supplied by power generation circuit **84**. Once charged, and in response to discharge control signals provided by processor **74**, high voltage generation circuit **86** is operated in a discharge mode during which the capacitors are discharged in series by another set of semiconductor switches (not separately shown) to produce the high voltage defibrillation pulses. The defibrillation pulses are applied to the patient by electrodes **50** through connector **32** connected to the high voltage generation circuit **86**.

Impedance measuring circuit **100** is connected to both connector **32** and real time clock **79**. Impedance measuring circuit **100** is interfaced to processor **74** through analog-to-digital (A/D) converter **102**. Impedance measuring circuit **100** receives a clock signal having a predetermined magnitude from clock **79**, and applies the signal to electrodes **50** through connector **32**. The magnitude of the clock signal received back from electrodes **50** through connector **32** is monitored by impedance measuring circuit **100**. An impedance signal representative of the impedance present across

electrodes **50** is then generated by circuit **100** as a function of the ratio of the magnitudes of the applied and received clock signals (i.e., the attenuation of the applied signal).

For example, if electrodes **50** within an unopened package **60** are connected by lead wires **52** and connector **58** is properly connected to connector **32** on AED **22**, a relatively low resistance (e.g., less than about 10 ohms) is present across electrodes **50**. If the hydrogel adhesive **54** on electrodes **50** is too dry, or the electrodes **50** are not properly positioned on the patient, a relatively high resistance (e.g., greater than about two hundred fifty ohms) will be present across the electrodes **50**. The resistance across electrodes **50** will then be between about twenty-five and two hundred fifty ohms when fresh electrodes **50** are properly positioned on the patient with good electrical contacts. It should be noted that these resistance values are given as exemplary ranges and are not meant to be absolute ranges. The impedance signal representative of the impedance measured by circuit **100** is digitized by A/D converter **102** and provided to processor **74**.

Impedance measuring circuit **110** is connected to connector **32** and real time clock **79**, and is interfaced to processor **74** through analog-to-digital (A/D) converter **102**. Impedance measuring circuit **110** receives a clock signal having a predetermined magnitude from clock **79**, and applies the signal to force sensor **200** through connector **32**. The magnitude of the clock signal received back from force sensor **200** through connector **32** is monitored by impedance measuring circuit **110**. An impedance signal representative of the impedance present across force sensor **200** is then generated by circuit **110** as a function of the ratio of the magnitudes of the applied and received clock signals (i.e., the attenuation of the applied signal). The impedance signal representative of the impedance measured by circuit **110** is digitized by A/D converter **102** and provided to processor **74**.

FIG. **4** is a plan view of a patient interface **120** for use with AED **22**. Patient interface **120** includes connector **58** which is adapted to releasably mate with connector **32** of AED **22**. Four lead wires **52**A, **52**B, **52**C, and **52**D are all terminated with connector **58**. Patient interface **120** also includes a force sensing pad **102** which includes a force sensor **200**. Lead wires **52**C and **52**D are electrically connected to force sensor **200**. Electrodes **50**A and **50**B each include backing layer **53**, patient engaging hydrogel layer **54**, conductive portion **56**, and insulating pad **78**.

FIG. **5** is a plan view illustrating patient interface **120** applied to human torso **98** of the victim **112**. Force sensing pad **102** is applied over the sternum of torso **98**. Force sensing pad **102** may be adhered with pressure sensitive adhesive. Force sensing pad **102** includes force sensor **200** which is electrically connected to lead wires **52**C and **52**D.

Electrode **50**A is shown applied to the upper right chest of torso **98**. Electrode **50**A is electrically connected to lead wire **52**A. Electrode **50**B is applied to the lower left side of torso **98** and is electrically connected to lead wire **52**B. Lead wires **52**A, **52**B, **52**C, and **52**D are terminated with connector **58**. Connector **58** is adapted to make releasable, electrical contact with connector **32** of AED **22**.

Those skilled in the art will readily recognize that electrodes **50**A, **50**B and force sensing pad **102** may be placed in locations on torso **98** other than those shown in FIG. **5** without deviating from the spirit or scope of this invention.

FIG. **6** is a plan view of a patient interface **130** for use with AED **22**. Interface **130** includes a second preferred embodiment of force sensor **200**. Patient interface **130** includes connector **58** which is adapted to releasably mate with connector **32** of AED **22**. Four lead wires **52**A, **52**B, **52**C, and **52**D are all terminated with connector **58**. Patient interface **130** also includes force sensor **200** which is positioned between backing layer **153** and insulating pad **178** of electrode **150**A. Lead wires **52**C and **52**D are electrically connected to force sensor **200**. Electrodes **150**A and **150**B each include patient engaging hydrogel layer **54**, and conductive portion **56**.

FIG. **7** is a plan view illustrating patient interface **130** applied to torso **98**. Force sensor **200** is positioned over the sternum of torso **98**. Force sensor **200** is electrically connected to lead wires **52**C and **52**D. Electrode **150**A is shown applied to torso **98**. Electrode **150**A is electrically connected to lead wire **52**A. Electrode **150**B is applied to the lower left side of torso **98** and is electrically connected to lead wire **52**B. Lead wires **52**A, **52**B, **52**C, and **52**D are terminated with connector **58** (not shown). Connector **58** is adapted to make releasable, electrical contact with connector **32** (not shown) of AED **22**.

FIG. **8** is a cross section illustrating an embodiment of a force sensor **200**. Force sensor **200** has a first side **210** and a second side **220**. Force sensor **200** includes a substrate **202**. A conductive pattern **204**A, **204**B is situated on each side of the substrate layer. Substrate **202** may be any thin (e.g. about 0.002" to 0.020") nonconductive sheet of material. Plastic film materials such as polyester, polycarbonate, PVC, etc. have been found to work well as substrate **202**. Conductive patterns **204**A, **204**B may be any conductive material such as copper foil, nickel foil, or conductive ink. In a preferred embodiment substrate **202** is 5 mil polyester and conductive patterns **204**A, **204**B are silver conductive ink.

Substrate **202** includes apertures **208**. Conductive pads **206**A and **206**B are situated on each side of substrate **202** as shown in FIG. **8**. Conductive pads **206**A, **206**B are preferably made of a deformable, conductive material. Materials which have been found suitable include conductive silicone rubber, conductive foam rubber, and conductive urethane rubber.

FIG. **9** is a plan view illustrating first side **210** of force sensor **200** with conductive pads **206**A, **206**B removed. Conductive pattern **204**A is seen situated on substrate **202**. Apertures **208** are cut through conductive pattern **204**A, substrate **202**, and conductive pattern **204**B, underlying substrate **202**.

FIG. **10** is a plan view illustrating second side **220** of force sensor **200** with conductive pads **206**A, **206**B removed. Conductive pattern **204**B is seen situated on substrate **202**. As also shown in FIG. **9**, apertures **208** are cut through conductive pattern **204**B, substrate **202**, and conductive pattern **204**A, underlying substrate **202**.

Referring now to both FIG. **9** and FIG. **10**, conductive patterns **204**A, **204**B each include conductive traces **212**A, **212**B. Wire terminals **214**A, **214**B are arranged make electrical contact with conductive traces **212**A, **212**B respectively. Wire terminals **214**A, **214**B are attached to substrate **202** with rivets **216**A, **216**B and washers **218**A, **218**B. Lead wires **222**A, **222**B are terminated with wire terminals **214**A, **214**B.

Those with skill in the art will recognize that other methods may be used to attach lead wires **222**A, **222**B to conductive traces **212**A, **212**B. Possible methods include soldering, the use of a connector designed to mate with flexible circuits, and the use of conductive adhesive.

FIG. **11** is a section view of force sensor **200** with a compressive force F applied. When force sensor **200** is used, it is placed between two objects, such as the sternum of a cardiac arrest victim and the heel of a rescuer's hand. When the rescuer presses down with the heel of his or her hand, the

force results in pressure distributed across the area of the heel of his or her hand.

When pressure is applied to force sensor **200**, conductive pads **206**A, **206**B extrude through apertures **208**. When pads **206**A, **206**B contact each other, they complete an electrical circuit between conductive layer **204**A and conductive layer **204**B. Increasing the force F applied to force sensor **200** increases the surface area of the electrical connection between conductive pads **206**A, **206**B, thereby decreasing the electrical resistance between pads **206**A, **206**B. The electrical resistance of the circuit between conductive layer **204**A and conductive layer **204**B is therefore indicative of the magnitude of the force F applied to force sensor **200**.

FIGS. **12**–**14** illustrate a further preferred embodiment of force sensor **200**. Force sensor **200** includes a first substrate **222**. A conductive pattern **224** is situated on first substrate **222**. As in the previous embodiment, substrate **222** may be any thin (e.g. about 0.002" to 0.010") nonconductive sheet of material. Plastic film materials such as polyester, polycarbonate, PVC, etc. have been found to work well as substrate **222**. Conductive pattern **224** may be any conductive material such as copper foil, nickel foil, or conductive ink. In a preferred embodiment substrate layer **222** is 5 mil polyester and conductive pattern **224** is silver conductive ink.

Force sensor **200** includes second substrate **226**. A conductive pattern **228** is situated on second substrate **226**. Second substrate **226** is situated on first substrate **222**. First substrate **222** and second substrate **226** may be held together with a layer of pressure sensitive adhesive (not shown).

Substrate **222** includes apertures **230**. A conductive pad **232** is situated on, and makes electrical contact with conductive pattern **224** as shown in FIG. **14**. Conductive pad **232** is preferably made of a deformable, conductive material. Materials which have been found suitable include conductive silicone rubber, conductive foam rubber, and conductive urethane rubber.

FIG. **13** is a plan view illustrating second substrate **226** and conductive pattern **228**.

FIG. **14** is a plan view illustrating first substrate **222** and conductive pattern **224**.

FIG. **15** is a section view of the force sensor **200** of FIG. **12** with a force F applied. When force sensor **200** is used, it is placed between two objects, such as the sternum of a cardiac arrest victim and the heel of a rescuers hand. When the rescuer presses down with the heel of his or her hand, the force results in pressure distributed across the area of the heel of his or her hand.

When a force F is applied to force sensor **200**, conductive pad **232** extrudes through apertures **230**. When conductive pad **232** contacts conductive pattern **228** it completes an electrical circuit between conductive pattern **224** and conductive pattern **228**. Increasing the force F applied to force sensor **200** increases the surface area of the electrical connection between conductive pads **232** and conductive pattern **228**, thereby reducing the electrical resistance between pad **232** and pattern **228**. Accordingly, change in contact area creates a change in electrical resistance which is indicative of the force applied to force sensor **200**.

FIGS. **16**–**18** illustrate another third embodiment of force sensor **200**. In this embodiment force sensor **200** includes a first substrate **242**. Two conductive patterns **244**A, **244**B are situated on first substrate **242**.

Force sensor **200** includes second substrate **246** which includes apertures **250**. Second substrate **246** is comprised of a non-conductive material. Polyester, polyethylene, and polypropylene have been found to be suitable materials for second substrate **246**. A conductive pad **252** is situated on second substrate **246**. As in the previous embodiments, conductive pad **232** is preferably made of a deformable, conductive material.

FIG. **17** is a plan view illustrating first substrate **242** and conductive patterns **244**A, **244**B. The conductive patterns **244**A, **244**B are arranged so that they are in close proximity to each other. Small gaps **256** are left between conductive paths **244**A, **244**B so that there is no direct electrical contact between conductive paths **244**A, **244**B.

FIG **18** is a plan view illustrating second substrate **246** and apertures **250**.

FIG. **19** is a section view of the force sensor **200** of FIGS. **16**–**18** with a force F applied. When force sensor **200** is used, it is placed between two objects, such as the sternum of a cardiac arrest victim and the heel of a rescuers hand. When the rescuer presses down with the heel of his or her hand, the force F results in pressure distributed across the area of the heel of his or her hand.

When pressure is applied to force sensor **200**, conductive pad **252** extrudes through apparatus **250**. When conductive pad **252** contacts conductive patterns **244**A, **244**B it completes an electrical circuit between conductive pattern **244**A and conductive pattern **244**B. Increasing the force applied to force sensor **200** increases the surface area of the electrical connection between conductive pad **252** and conductive patterns **244**A, **244**B. This change in contact area creates a change in electrical resistance which is indicative of the force applied to force sensor **200**.

Referring to FIGS. **4** and **5** in operation force sensor **200** is positioned on the sternum of a victim **112**. The rescuer places the heel of his or her hand onto force sensor **200** and delivers chest compressions to the chest of the victim **112**. Force sensor **200** and impedance measuring circuit **110** produce an electrical signal proportional to the force applied to the victim's chest. This signal indicates to processor **74** the rate and magnitude of the chest compressions which the victim **112** is receiving. This signal also allows processor **74** to determine the precise time that a rescuer has begun (or stopped) CPR.

Processor **74** compares the measured rate of chest compressions to a range of desired values.

If the current chest compression rate value delivered by the rescuer is less than the desired range, processor **74** will produce a control signal which causes voice circuit **94** and speaker **34** to generate an appropriate voice prompt such as "faster". If the current chest compression rate value is greater than the desired range, processor **74** will produce a control signal which causes voice circuit **94** and speaker **34** to generate an appropriate voice prompt such as "slower".

Processor **74** also compares the measured chest compression force to a range of desired values. If the chest compression force delivered by the rescuer is less than the desired range, processor **74** will produce a control signal which causes voice circuit **94** and speaker **34** to generate an appropriate voice prompt such as "harder". If the chest compression force is greater than the desired range, processor will produce a control signal which causes voice circuit **94** and speaker **34** to generate an appropriate voice prompt such as "softer".

AED **22** may also provide other types of audible feedback to the rescuer. For example, AED **22** may give an audible signal each time the force measured using force sensor **200** reaches a desired value.

The present invention may be embodied in other specific forms without departing from the spirit of the essential attributes thereof. Therefore, the illustrated embodiments should be considered in all respects as illustrative and not restrictive, reference being made to the appended claims rather than to the foregoing description to indicate the scope of the invention.

What is claimed is:

1. An automated electronic defibrillator (AED) for use by an operator in assisting in resuscitating a victim, comprising:

a force sensor applicable to a skin surface of the victim and being responsive to the application of a force to said force sensor,

an AED control system being in electrical communication with the force sensor, the AED control system processing a signal communicated from the force sensor related to the magnitude of force applied thereto and to the frequency of application of the force thereto; and

AED prompting means operably coupled to the AED control system for receiving communication signals from the AED control system and for communicating prompts to the operator for use by the operator in resuscitating the victim, the prompts being related to the signal communicated to the AED control system by the force sensor related to the magnitude of force applied to the force sensor and to the frequency of application of the force to the force sensor.

2. The AED of claim **1** wherein the force sensor is responsive to the relative magnitude of the force applied thereto and communicates a signal related to said force magnitude to the AED control system.

3. The AED of claim **2** wherein the AED control system communicates signals relating to the relative magnitude of force applied to the force sensor to the AED prompting means for transmission as a prompt to the rescuer.

4. The AED of claim **1** wherein the AED control system determines the interval between a succession of force applications applied to the force sensor.

5. The AED of claim **4** wherein the AED control system communicates signals relating to the interval between a succession of force applications applied to the force sensor to the AED prompting means for transmission as a prompt to the rescuer.

6. The AED of claim **1** wherein the force sensor comprises:

a first conductive layer;

a second conductive layer being spaced apart from the first conductive layer, the first and second conductive layers being electrically isolated from one another; and

electrical communication means for establishing electrical communication between the first and second conductive layers responsive to the application of a force to said electrical communication means.

7. The AED of claim **6** wherein at least a part of the electrical communication means of the force sensor are formed of an extrudable, electrically conductive material, the electrical communication means being extruded by the application of a force to said electrical communication means, at least one extrusion thereof establishing a path of electrical communication between the first and second conductive layers responsive to the application of said force.

8. The AED of claim **7**, the force sensor further including a flexible, nonconductive layer being disposed between the first and second conductive layers.

9. The AED of claim **8** wherein the first and second conductive layers of the force sensor are formed of conductive ink printed on opposed sides of the nonconductive layer.

10. The AED of claim **9**, the force sensor further including a plurality of holes defined through the nonconductive layer and through the first and second conductive layers printed thereon.

11. The AED of claim **10**, the force sensor further including a first extrudable, conductive layer disposed on the first conductive layer and a second extrudable, conductive layer disposed on the second conductive layer, the first and second extrudable, conductive layers being extrudable into the plurality of holes defined through the nonconductive layer and through the first and second conductive layers responsive to a force applied thereto to form an electrically communicative connection between the first and second conductive layers.

12. The AED of claim **6** wherein the first and second conductive layers of the force sensor are formed of conductive, metallic foil.

13. The AED of claim **1** wherein the force sensor is disposed in a hole defined in an electrode.

14. The AED of claim **6** wherein the magnitude of the force applied to the force sensor is inversely proportional to the impedance existing between the first and second conductive layers.

15. The AED of claim **6** wherein the impedance existing between the first and second conductive layers of the force sensor is related to the magnitude of the force applied to the force sensor.

16. A method of prompting a rescuer in the application of cardiopulmonary resuscitation to a victim comprising the steps of:

sensing a force applied by the rescuer to the victim by means of a force sensor;

sensing an interval between successive applications of force to the victim's sternum; by means of a processor operably coupled to the force sensor,

the processor comparing the force applied by the rescuer to the victim's sternum to a standard of force known to effect resuscitation;

the processor providing a prompt to the rescuer that prompts the rescuer to vary the force delivered to approximate the force that is known to effect resuscitation;

the processor comparing the interval between successive applications of force to the victim's sternum to a standard interval known to effect resuscitation; and

the processor providing a prompt to the rescuer that prompts the rescuer to vary the interval of force application to approximate the interval that is known to effect resuscitation.

[17. An automated electronic defibrillator (AED) for use by an operator in assisting in resuscitating a victim, having a charging circuit for developing a high voltage charge, at least two electrodes for application to the person of a victim, the at least two electrodes being in electrical communication with the charging circuit, a control circuit communicatively coupled to the charging circuit and the electrodes for detecting certain biological parameters of the victim and for controlling the delivery of a voltage charge from the charging circuit through the at least two electrodes to the victim, comprising:

means for prompting a rescuer in the delivery of cardiopulmonary resuscitation (CPR) to the victim, the means for prompting a rescuer further including the control system being in electrical communication with a force sensor, the AED control circuit processing a signal communicated from the force sensor related to the

magnitude of force applied thereto and to a frequency of application of the force thereto.]

18. The AED of claim **17** wherein the means for prompting a rescuer includes a force sensor applicable to a skin surface of the victim and being responsive to the application of a force to said force sensor.

19. [The AED of claim **17** wherein the means for prompting a rescuer] *An automated electronic defibrillator (AED) for use by operator in assisting in resuscitating a victim, having a charging circuit for developing a high voltage charge, at least two electrodes for application to the person of a victim, the at least two electrodes being in electrical communication with the charging circuit, a control circuit communicatively coupled to the charging circuit and the electrodes for detecting certain biological parameters of the victim and for controlling the delivery of a voltage charge from the charging circuit through the at least two electrodes to the victim, comprising:*

means for prompting a rescuer in the delivery of cardiopulmonary resuscitation (CPR) to the victim, the means for prompting a rescuer including the control system being in electrical communication with a force sensor, the AED control circuit processing a signal communicated from the force sensor related to the magnitude of force applied thereto and to a frequency of application of the force thereto and further includ[es]*ing* prompting means operably coupled to the AED control circuit for receiving communication signals from the AED control circuit and for communicating prompts to the rescuer for use by the rescuer in resuscitating the victim, the prompts being related to the signal communicated to the AED control circuit by a force sensor related to the magnitude of force applied to the force sensor and to the frequency of application of the force to the force sensor.

20. The AED of claim **19** wherein the force sensor is responsive to the relative magnitude of the force applied thereto and communicates a signal related to said force magnitude to the AED control system.

21. The AED of claim **20** wherein the AED control circuit communicates signals relating to the relative magnitude of force applied to the force sensor to the AED prompting means for transmission as a prompt to the rescuer.

22. The AED of claim **21** wherein the AED control system determines the interval between a succession of force applications applied to the force sensor.

23. The AED of claim **22** wherein the AED control circuit communicates signals relating to the interval between a succession of force applications applied to the force sensor to the AED prompting means for transmission as a prompt to the rescuer.

24. An automated electronic defibrillator (AED) for use by an operator in assisting in resuscitating a victim, having a charging circuit for developing a high voltage charge, at least two electrodes for application to the person of a victim, the at least two electrodes being in electrical communication with the charging circuit, a control circuit communicatively coupled to the charging circuit and the electrodes for detecting certain biological parameters of the victim and for controlling the delivery of a voltage charge from the charging circuit through the at least two electrodes to the victim, comprising:

means for prompting a rescuer in the delivery of cardiopulmonary resuscitation (CPR) to the victim, the means for prompting a rescuer including a force sensor applicable to a skin surface of the victim and being responsive to the application of a force to said force sensor, the force sensor having,

a first conductive layer;

a second conductive layer being spaced apart from the first conductive layer, the first and second conductive layers being electrically isolated from one another; and

electrical communication means for establishing electrical communication between the first and second conductive layers responsive to the application of a force to said electrical communication means.

25. The AED of claim **24** wherein at least a part of the electrical communication means of the force sensor are formed of an extrudable, electrically conductive material, the electrical communication means being extruded by the application of a force to said electrical communication means, at least one extrusion thereof establishing a path of electrical communication between the first and second conductive layers responsive to the application of said force.

26. The AED of claim **25**, the force sensor further including a flexible, nonconductive layer being disposed between the first and second conductive layers.

27. The AED of claim **26** wherein the first and second conductive layers of the force sensor are formed of conductive ink printed on opposed sides of the nonconductive layer.

28. A patient interface for use with an automated electronic defibrillator (AED) comprising:

a patient connection interface adapted to be positioned externally on a victim and operably connected to the AED, the patient connection interface including:

means for selectively delivering a signal to the AED representative of the victim's cardiac electrical signal;

means for selectively delivering a defibrillation shock pulse from the AED to the victim; and

means for selectively delivering a signal to the AED indicative of a magnitude of chest compression when the victim is receiving cardiopulmonary resuscitation (CPR).

29. The patient connection of claim 28, wherein the means for selectively delivering a signal to the AED comprises at least one sensor having at least one lead wire attached to the sensor.

30. The patient connection of claim 29, wherein the sensor is a force sensor, and the signal delivered to the AED is related to a force applied to the sensor.

31. A method of interfacing an automated electronic defibrillator (AED) with a victim comprising the steps of:

positioning a patient interface externally on the victim, the patient interface having at least two electrodes and at least one sensor;

connecting the patient interface to the AED;

using the AED to sense a signal representative of the victim's cardiac electrical signal from the at least two electrodes;

using the AED to sense a signal from the sensor indicative of a magnitude of chest compression when the victim is receiving cardiopulmonary resuscitation (CPR);

determining if the magnitude of chest compressions received by the victim during CPR is effective for resuscitation by using the AED to analyze the signal from the sensor;

prompting the rescuer in response to the step of determining if the magnitude of chest compressions received by the victim during CPR is effective; and

using the AED to selectively deliver a defibrillation shock pulse from the AED to the victim through the at least two electrodes.

32. The patient connection of claim 29, wherein the sensor senses a force applied to the sensor, and wherein the signal from the sensor is proportional to the force applied to the sensor.

33. The method of claim 31, wherein the step of determining if the magnitude of chest compressions received by the victim during CPR is effective determines whether the rescuer effectively depressed the sternum between about 4 and 5 cm.

34. An automated external defibrillation system for use by a rescuer to resuscitate a victim comprising:

a patient connection interface adapted to be positioned externally on a victim, the patient connection interface including:

at least two electrodes, each having at least one lead wire attached to the electrode that selectively delivers a signal representative of the victim's cardiac electrical signal (EKG) and that selectively delivers a defibrillation shock pulse to the victim; and

at least one sensor having at least one lead wire attached to the sensor that selectively delivers a signal indicative of a magnitude of chest compression when the victim is receiving cardiopulmonary resuscitation (CPR); and

an automatic external defibrillator (AED) having:

charging circuitry that is in electrical communication with the at least two electrodes via the lead wires and selectively develops a high voltage charge for defibrillation of the victim;

EKG cardiac sensing circuitry that is in electrical communication with the at least two electrodes via the lead wires and selectively receives the signal representative of the victim's cardiac electrical signal;

CPR sensing circuitry that is in electrical communication with the at least one sensor via the lead wires and selectively receives the signal indicative of the magnitude of chest compressions;

voice circuitry that selectively generates audio prompts for the rescuer; and

a processor and associated memory and control logic operably connected to the charging circuitry, the EKG sensing circuitry, the CPR sensing circuitry and the voice circuitry that executes programmed instructions to selectively perform the steps comprising:

automatically analyzing the victim's cardiac electrical signal;

automatically analyzing the signal indicative of the magnitude of chest compression;

generating audio prompts to instruct the rescuer on appropriate instructions to perform both CPR and defibrillation based on the steps of analyzing the magnitude of chest compression and the victim's cardiac electrical signal; and

controlling delivery of the high voltage charge from the charging circuitry to the victim via the at least two electrodes at a time coordinated with audio prompts that instruct the rescuer.

35. The system of claim 34 wherein the processor analyzes the signal indicative of the magnitude of chest compression to determine if the indicated magnitude of chest compression is within a desired range.

36. The system of claim 35 wherein the desired range is based on a force and the sensor senses a force applied to the sensor.

37. The system of claim 35 wherein the desired range is based on a chest compression and the processor analyzes the signal indicative of the magnitude of chest compression to determine whether the rescuer effectively depressed the sternum between about 4 and 5 cm.

38. The system of claim 35 wherein the desired range is based on a rate and the processor analyzes the signal indicative of the magnitude of chest compression to determine a rate of chest compressions.

39. An automated external defibrillation system for use by a rescuer to resuscitate a victim comprising:

a patient connection interface adapted to be positioned externally on a victim, the patient connection interface including:

means for selectively sensing and delivering a signal representative of the victim's cardiac electrical signal (EKG) and for selectively delivering a defibrillation shock pulse to the victim; and

means for selectively sensing and delivering a signal indicative of at least one parameter associated with the victim receiving cardiopulmonary resuscitation (CPR); and

an automatic external defibrillator (AED) having:

means for selectively developing a high voltage charge for defibrillation of the victim in electrical communication with the patient interface;

means for selectively generating audio prompts for the rescuer; and

means operably connected to the means for selectively developing a high voltage charge and the means for selectively generating audio prompts for the rescuer for selectively controlling operation of the AED, including:

means for automatically analyzing the victim's EKG signal;

means for automatically analyzing the CPR signal;

means for generating audio prompts to instruct the rescuer on appropriate instructions to perform both CPR and defibrillation in response to the means for automatically analyzing the EKG signal and the means for automatically analyzing the CPR signal; and

means for selectively delivering the high voltage charge from the means for selectively developing a high voltage charge at a time coordinated with audio prompts generated by the means for generating audio prompts.

40. The system of claim 39, wherein the means for selectively sensing and delivering a signal representative of the victim's cardiac electrical signal (EKG) and for selectively delivering a defibrillation shock pulse to the victim comprises a pair of electrodes, each electrode having at least one lead wire attached thereto.

41. The system of claim 39, wherein the means for selectively sensing and delivering a signal indicative of at least one parameter associated with the victim receiving CPR comprises a sensor having at least one lead wire attached thereto.

42. The system of claim 41, wherein the CPR signal includes a signal indicative of the magnitude of chest compression and the means for automatically analyzing the CPR signal analyzes the signal indicative of the magnitude of chest compression to determine if the magnitude of chest compression is within a desired range.

43. The system of claim 42, wherein the desired range is based on a force.

44. The system of claim 42, wherein the desired range is based on a rate.

45. The system of claim 42 wherein the desired range is based on a chest compression and the means for selectively controlling operation of the AED analyzes the signal indicative of the magnitude of chest compression to determine whether the rescuer effectively depressed the sternum between about 4 and 5 cm.

46. A method of prompting a rescuer in the resuscitation of a victim comprising the steps of:

positioning a patient connection interface externally on a victim, the patient connection interface including at least two electrodes and at least one sensor;

connecting the patient connection interface to an automatic external defibrillator (AED);

using the AED and the at least two electrodes to selectively sense and automatically analyze a signal representative of the victim's cardiac electrical signal (EKG);

using the AED and the at least one sensor to selectively sense and automatically analyze a signal indicative of a magnitude of chest compression when the victim is receiving cardiopulmonary resuscitation (CPR);

automatically causing voice circuitry in the AED to generate audio prompts to instruct the rescuer on appropriate instructions to perform both CPR and defibrillation based on the steps of automatically analyzing the victim's EKG and automatically analyzing the signal indicative of a magnitude of chest compression when the victim is receiving CPR; and

automatically causing the AED to selectively deliver a high voltage charge from a charging circuitry to the victim via the at least two electrodes at a time coordinated with audio prompts generated by the voice circuitry.

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