United States Patent

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[54] **MONITORING SYSTEM FOR HEART RATE, RESPIRATION RATE AND BLOOD PRESSURE**
28 Claims, 5 Drawing Figs.

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[51] Int. Cl. A61l 5/02
[50] Field of Search .... 128/2.05, 2.06, 2.1, 2.15(digest); 330/191

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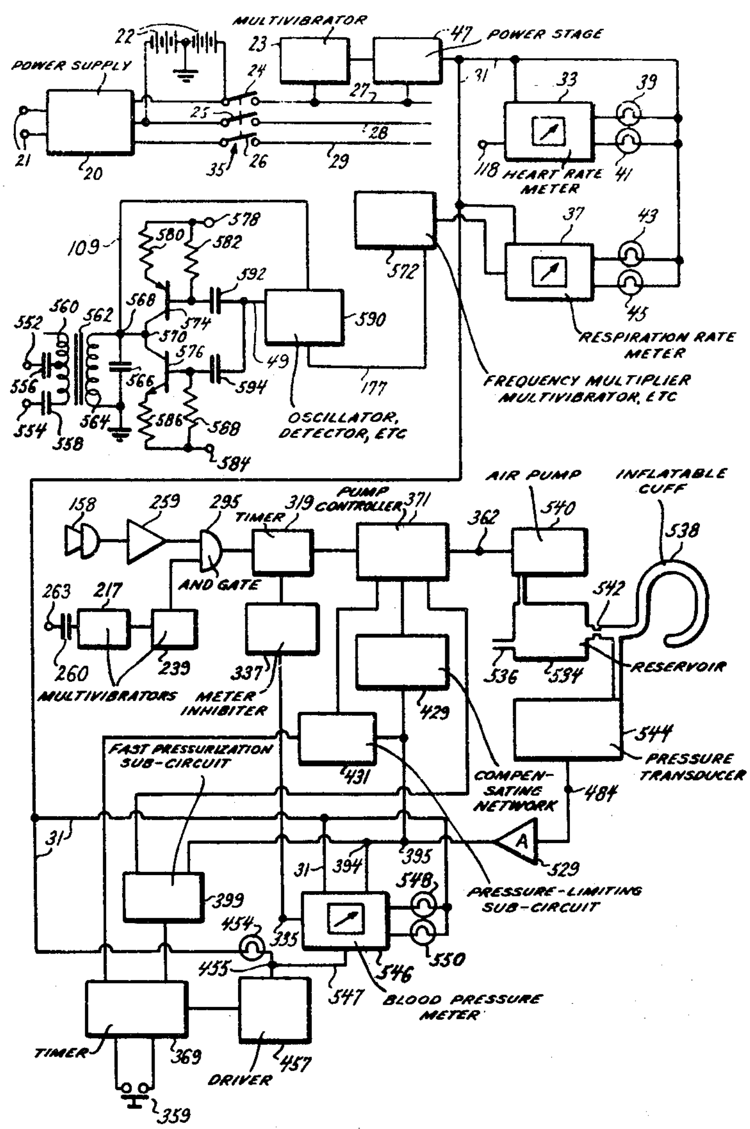
Attorneys—Samuel L. Welt, Jon S. Saxe, Bernard S. Leon and Jacob Frank

ABSTRACT: A solid-state control system simultaneously and substantially continuously monitors the blood pressure, heart rate and respiration rate of a person providing variable length pulses to an electromagnetically operated, variable-length stroke, air pump to control the pressurization and depressurization of an artery-occluding inflatable cuff, using a signal from a heart rate circuit to "gate" a blood pressure circuit, using AC coupling of a respiration rate circuit to the body of the person to avoid grounding of that person's body and to avoid impedance matching adjustments, and using just one pair of electrodes, maintained in good electrical contact with that person's body by an electrolyte, for both the heart rate circuit and the respiration rate circuit to enable a high frequency signal from that respiration rate circuit to depolarize that electrolyte.



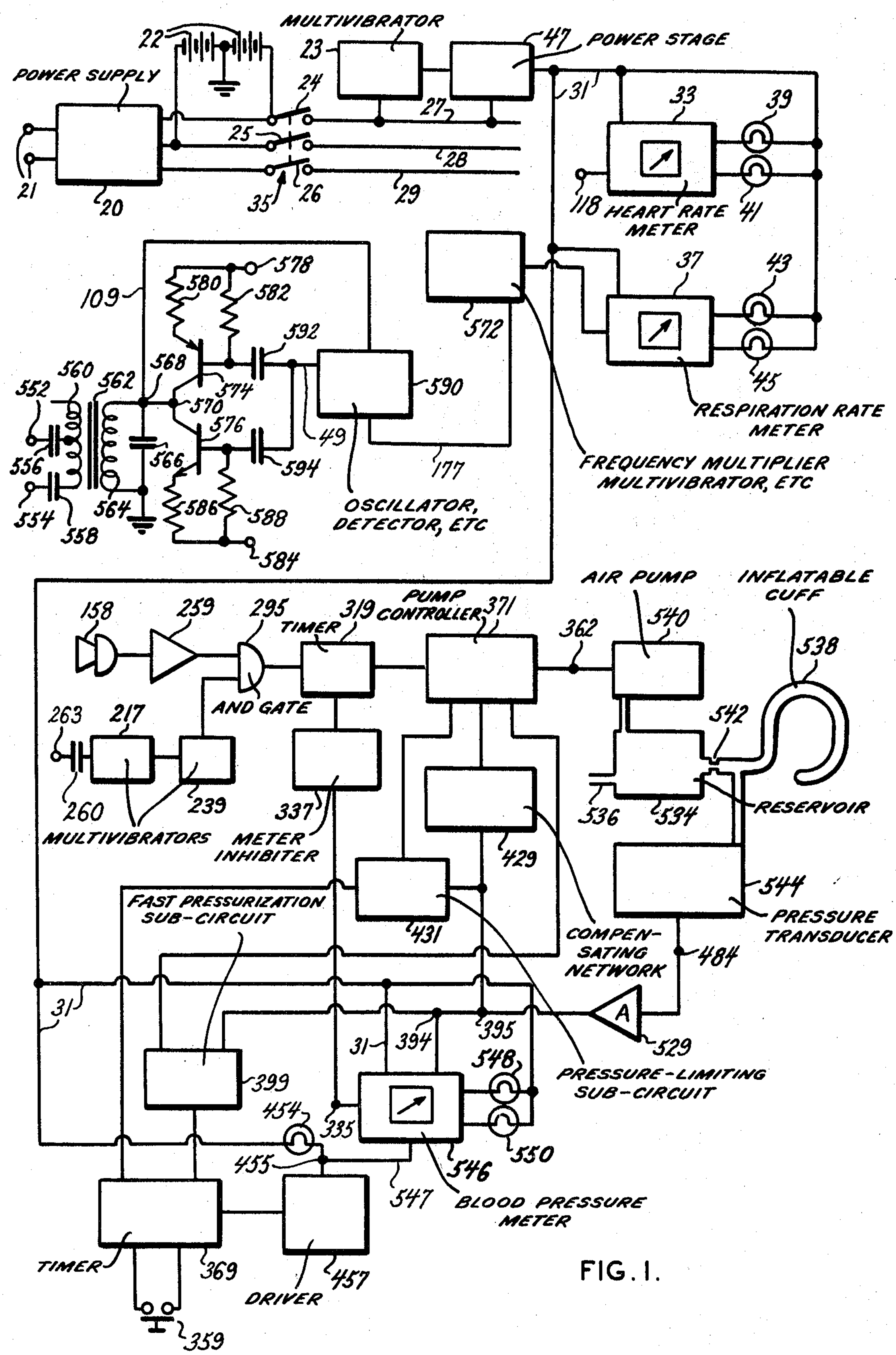

MULTIVIBRATOR
POWER STAGE
POWER SUPPLY
HEART RATE METER
RESPIRATION RATE METER
FREQUENCY MULTIPLIER MULTIVIBRATOR, ETC
OSCILLATOR, DETECTOR, ETC
AIR PUMP
INFLATABLE CUFF
PUMP CONTROLLER
TIMER
AND GATE
MULTIVIBRATORS
METER INHIBITER
RESERVOIR
PRESSURE TRANSDUCER
FAST PRESSURIZATION SUB-CIRCUIT
COMPEN-SATING NETWORK
PRESSURE-LIMITING SUB-CIRCUIT
BLOOD PRESSURE METER
TIMER
DRIVER

FIG. 1.

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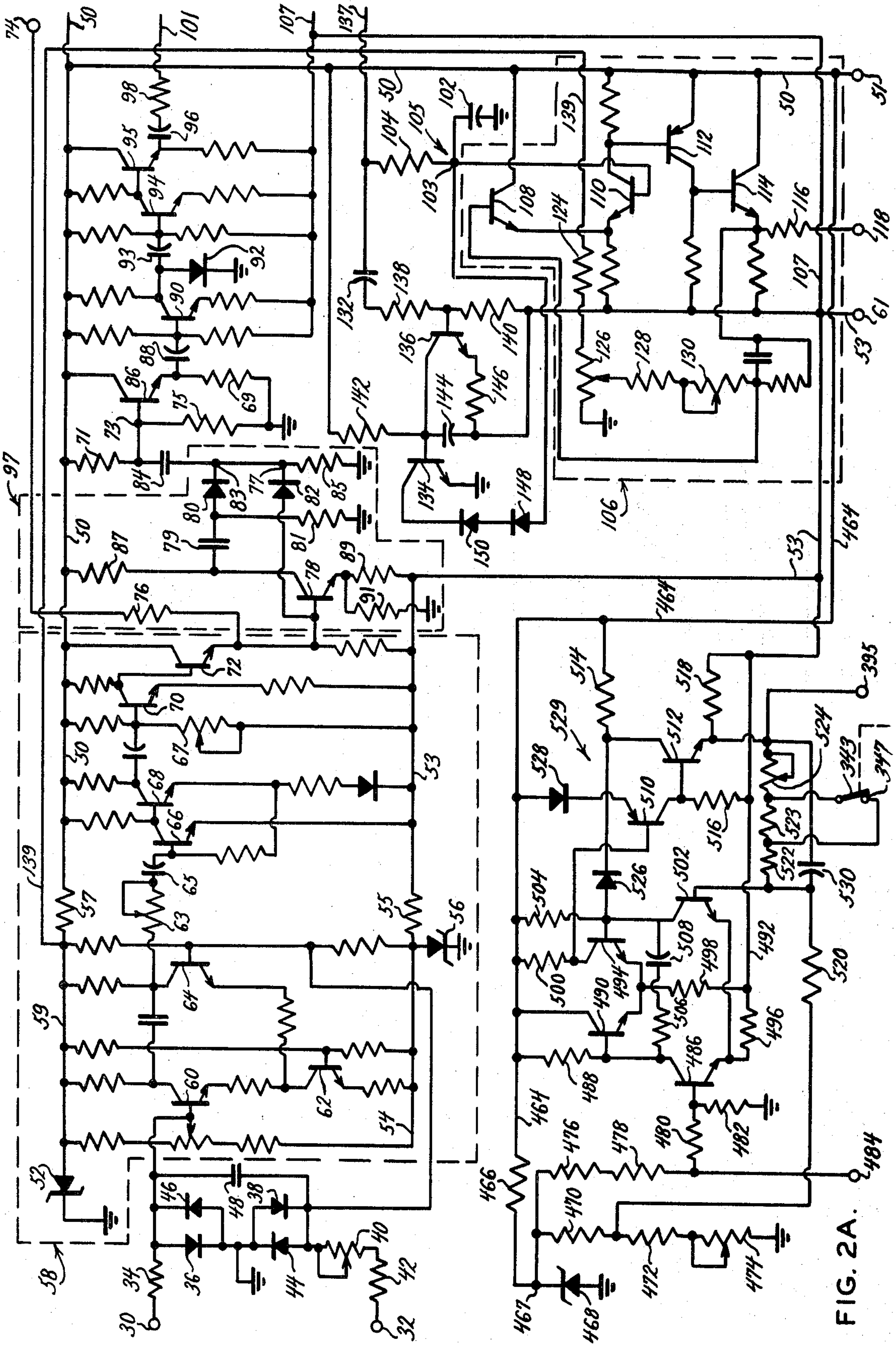


FIG. 2A.

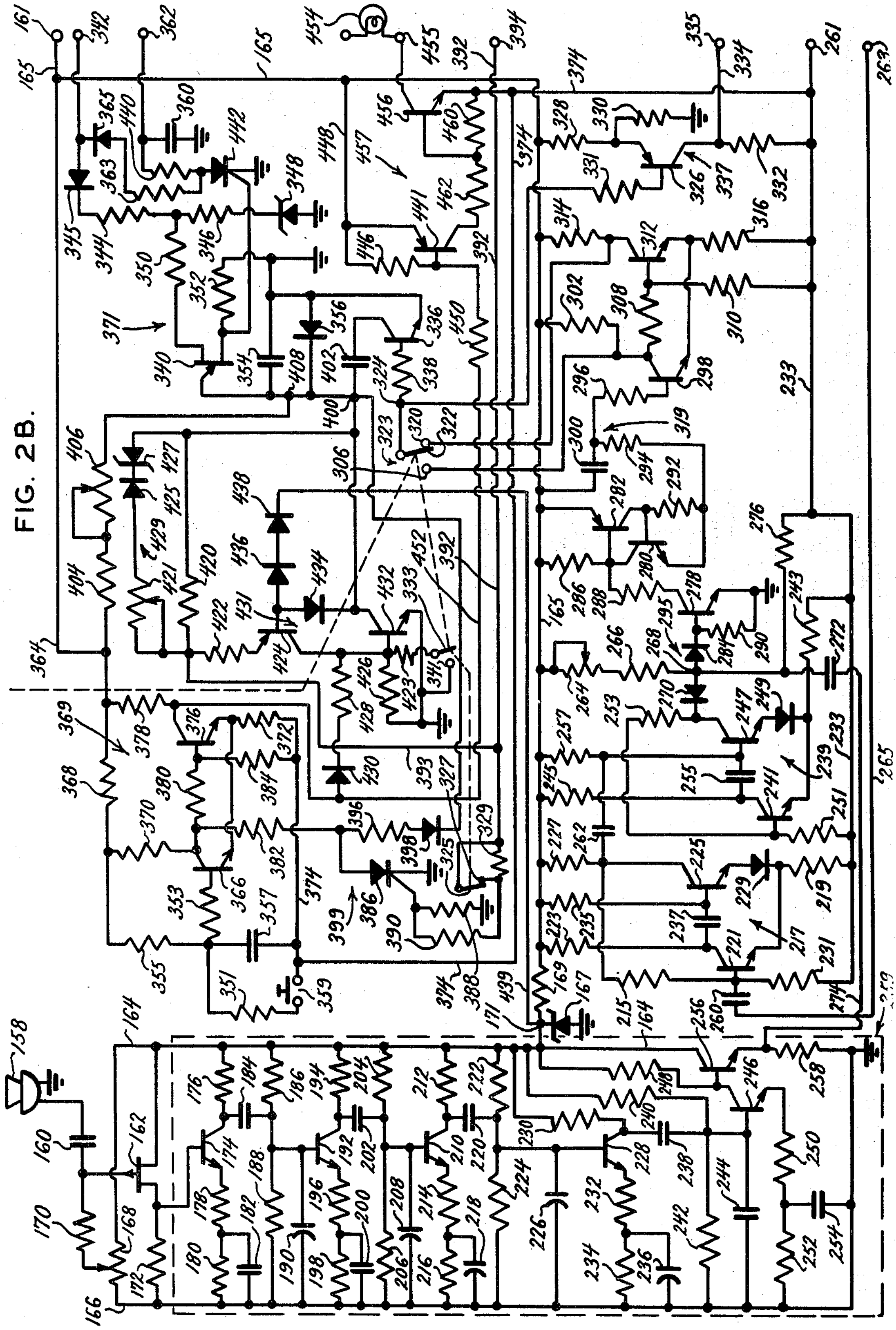
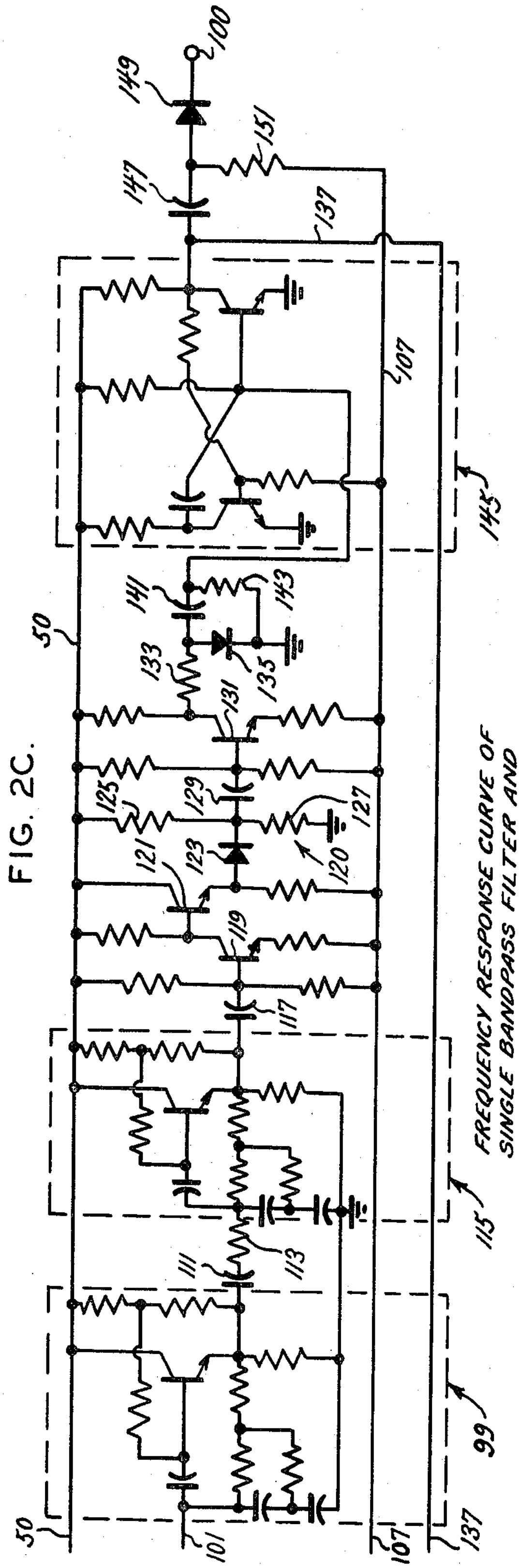


FIG. 2B.


100
149
151
147
137
107
145
50
141
143
133
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131
125
129
127
121
123
120
119
117
115
111
113
99
101

FIG. 2C.

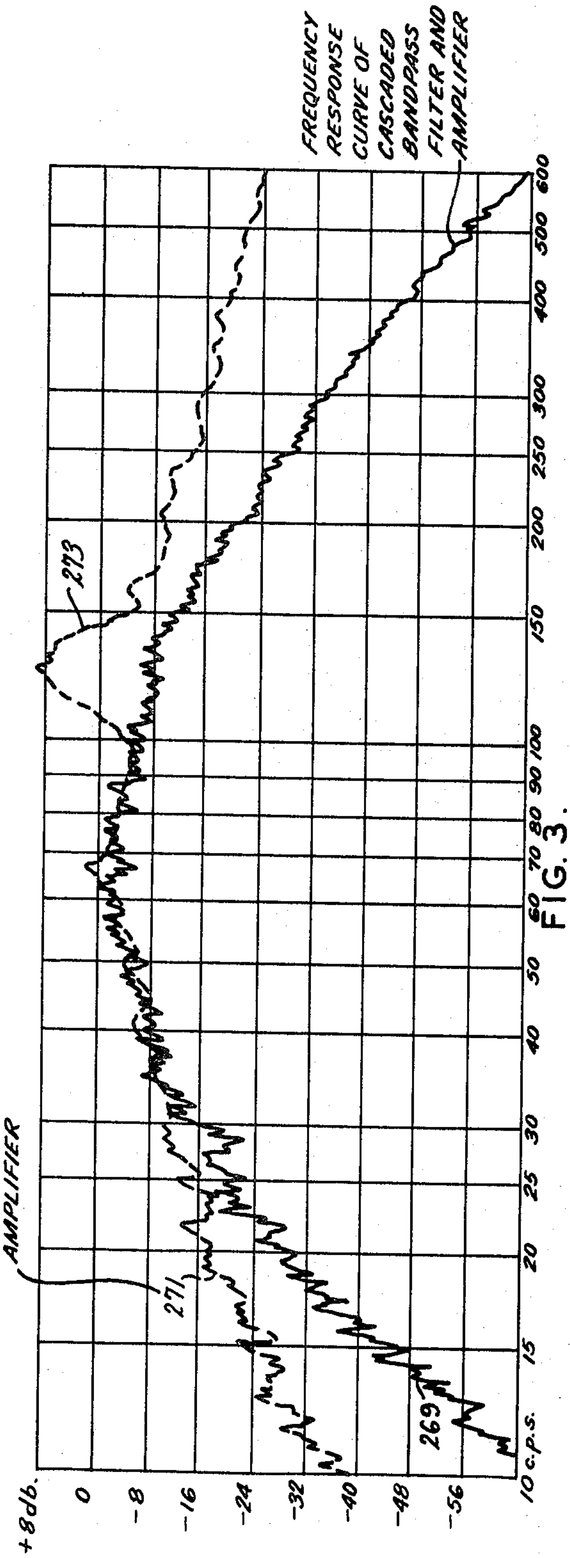
FREQUENCY RESPONSE CURVE OF CASCADED BANDPASS FILTER AND AMPLIFIER
FREQUENCY RESPONSE CURVE OF SINGLE BANDPASS FILTER AND AMPLIFIER
273
271
269
+8db.
0
-8
-16
-24
-32
-40
-48
-56
10 c.p.s.
15
20
25
30
40
50
60
70
80
90
100
150
200
250
300
400
500
600

FIG. 3.

MONITORING SYSTEM FOR HEART RATE, RESPIRATION RATE AND BLOOD PRESSURE

This invention relates to improvements in control systems. More particularly, this invention relates to improvements in control systems that monitor the blood pressure, heart rate, and respiration rate of a person.

It is an object of the present invention to provide an improved control system that can simultaneously and substantially continuously monitor the blood pressure, heart rate, and respiration rate of a person.

It would be desirable to provide a control system that could simultaneously and substantially continuously monitor the heart rate, the respiration rate, and the blood pressure of a person, and that could display that person's heart rate, respiration rate, and blood pressure in readily readable form. Further, it would be desirable for that control system to actuate an alarm circuit in the event that the person's heart rate, respiration rate and blood pressure failed to remain within closely set upper and lower limits. The present invention provides such a control system; and it is, therefore, an object of the present invention to provide a control system which can simultaneously and substantially continuously monitor the heart rate, respiration rate and blood pressure of a person, that can display that heart rate, respiration rate, and blood pressure in readily readable form, and that can actuate an alarm circuit in the event that heart rate, respiration rate, and blood pressure fail to remain within closely set upper and lower limits.

The control system provided by the present invention has an inflatable cuff that will be disposed adjacent some portion of a person's body wherein an artery can be occluded sufficiently to cause Korotkoff sounds to be developed. That inflatable cuff must be alternately pressurized and depressurized to cause it to occlude and then free that artery; and the control system provided by the present invention uses an electromagnetically operated, variable-length stroke, air pump to pressurize and depressurize that inflatable cuff. In doing so, that control system eliminates all need of valves —and thus obviates the initial cost as well as the cost of maintaining air-controlling valves. Further, that control system can provide closer and more precise control of the pressure supplied to the inflatable cuff. It is, therefore, an object of the present invention to provide a control system wherein an electromagnetically operated, variable-length stroke, air pump pressurizes and then depressurizes an inflatable cuff.

The control system provided by the present invention has a microphone which will be secured to the portion of the person's body wherein the artery will be occluded to cause Korotkoff sounds to be developed; and that microphone will sense those Korotkoff sounds. That microphone also will sense other sounds and it would be desirable to keep as many as practicable of those other sounds from affecting the operation of the air pump. The control system provided by the present invention keeps as many as practicable of those other sounds from affecting the operation of the air pump; and it does so by applying all signals from the microphone to a cascaded band-pass filter and amplifier —thus effecting sharp attenuation of all signals below 40 c.p.s. and above 120 c.p.s. —and also by isolating the control circuit for the air pump from the output of that cascaded band-pass filter and amplifier except for the short periods of time when the Korotkoff sounds are to be sensed. That control system attains that desirable result by interposing a "gate" between that cascaded band-pass filter and amplifier and the control circuit for the air pump by using the heart rate circuit to develop a signal each time the person's heart beats, by using that signal to initiate a time delay corresponding to the length of time needed for the surge of blood resulting from that heart beat to reach the occluded portion of the artery, and then opening that gate to permit the signals corresponding to the Korotkoff sounds to actuate the control circuit for the air pump. That gate will be open for just a small portion of the time between consecutive heart beats, and hence most of the sounds sensed by the microphone will be wholly isolated from the control circuit for the air pump; and all of the sounds which are sensed by that microphone while that gate is open will be closely filtered by the cascaded band-pass filter and amplifier. The overall result is that the control system provided by the present invention keeps as many as practicable sounds, other than Korotkoff sounds, from affecting the control circuit for the air pump.

The heart rate circuit and the respiration rate circuit of the control system provided by the present invention avoid all need of grounding the person's body; and this is important because it enables that control system to be used with other devices, systems and equipment without subjecting that person to the risk of electrical shocks due to ground loops through his body and those other devices, systems and equipment. Also, by avoiding all need of grounding the person's body, that control system avoids any aberrations in the readings of the meters of that control system in the event that person touches nearby grounded objects, devices, systems and equipment. Moreover, by avoiding all need of grounding the person's body, that control system reduces the number of electrodes that must be affixed to that person's body. It is, therefore, an object of the present invention to provide a control system that obviates all need of grounding the person's body.

The control system provided by the present invention obviates all need of impedance-matching adjustments, even though the impedances of different persons can vary considerably, and even though the impedance of any given person can change materially as that person shifts from a sitting position to a lying position, or vice versa. This is important; because impedance-matching adjustments are time consuming, and they can lead to erroneous adjustments and erroneous readings on the meters. That control system obviates all need of impedance-matching adjustments; and it does so by providing AC coupling between the respiration rate circuit thereof and the electrodes attached to the body of the person, and by using a differential input amplifier as the input of the heart rate circuit. It is, therefore, an object of the present invention to provide a control system wherein the respiration rate circuit is AC coupled to the electrodes attached to the body of the person, and wherein a differential input amplifier is used as the input of the heart rate circuit.

An electrolyte is customarily used to provide good electrical contact between the body of a person and the electrodes affixed to that person's body. Where the electrodes are to be affixed to that person's body for appreciable periods of time, the electrolyte tends to polarize; and that polarization would be objectionable. The control system provided by the present invention prevents polarization of the electrolyte used to provide good electrical contact between the body of a person and the electrodes affixed to that person's body, irrespective of how long those electrodes are affixed to that person's body; and it does so by using just one pair of electrodes for both the heart rate circuit and the respiration rate circuit of that control system, and by continually passing a high frequency signal through that electrolyte. That high frequency signal will completely and fully prevent polarization of the electrolyte, and will thus avoid the objectionable results which such polarization can produce.

Other and further objects and advantages of the present invention should become apparent from an examination of the drawing and accompanying description.

In the drawing and accompanying description a preferred embodiment of control system that is made in accordance with the principles and teachings of the present invention is shown and described, but it is to be understood that the drawing and accompanying description are for the purpose of illustration only and do not limit the invention and that the invention will be defined by the appended claims.

In the drawing, FIG. 1 is a block diagram of one preferred embodiment of control system that is made in accordance with the principles and teachings of the present invention,

FIG. 2A is a schematic diagram of part of the embodiment of control system shown by FIG. 1,

FIG. 2B is a schematic diagram of another part of the embodiment of control system shown by FIG. 1,

FIG. 2C is a schematic diagram of yet another part of the embodiment of control system shown by FIG. 1, and

FIG. 3 is a graph showing two frequency response curves.

COMPONENTS OF CONTROL SYSTEM

Referring to the drawing in detail, the numeral **20** in FIG. 1 denotes a power supply which has the input terminals thereof connectable to a source of alternating current by conductors **21**. In the said one preferred embodiment of control system provided by the present invention, that source of alternating current will apply about 117 volts of 60 c.p.s. alternating current to the input terminals of that power supply; and the positive output terminal of that power supply will apply a regulated positive 12 volts DC to a movable contact **24**, the negative output terminal of that power supply will apply a regulated negative 12 volts DC to a movable contact **25**, and the AC output terminal of that power supply will apply 100 volts AC to a movable contact **26**. Those movable contacts are preferably ganged together to constitute a triple-pole, single-throw switch **35**. A storage battery **22** has the positive terminal thereof connected to the positive output terminal of the power supply **20** and to the movable contact **24**; and has the negative terminal thereof connected to the negative output terminal of that power supply and to the movable contact **25**. That battery constitutes a stand by source of power; and it will receive battery-charging energy from the power supply **20** rather than supply energy to the movable contacts **24** and **25** as long as that power supply receives power from the conductors **21**. However, in the event a power failure cuts off the power that is normally supplied to the conductors **21**, or in the event the DC portion of the power supply is injured and becomes unable to supply power to the movable contacts **24** and **25**, the battery **22** will automatically and immediately supply power to those movable contacts for several hours.

A conductor **27** connects the movable contact **24** to terminal **51** in FIG. 2A and to terminal **161** in FIG. 2B; and thus can apply a regulated positive 12 volts DC to those terminals. A conductor **28** connects the movable contact **25** to terminal **61** in FIG. 2A and to terminal **261** in FIG. 2B; and thus can apply a regulated negative 12 volts DC to those terminals. A conductor **29** connects the movable contact **26** to a terminal **342** in FIG. 2B, and also connects that movable contact to one terminal of an electromagnetically operated, variable-length stroke, flexible diaphragm air pump **540** in FIG. 1; and that conductor will apply 100 volts AC to that terminal and to that pump.

A free-running multivibrator **23** in FIG. 1 has the input thereof connected to the conductor **27**; and a power stage **47** has one input thereof connected to that conductor, and has the other input thereof connected to the output of the multivibrator **23**. That power stage can constitute one or more transistors connected as an electronic switch to selectively connect the conductor **27** to a conductor **31**. The multivibrator **23** and the power stage **47** will alternately apply power to, and halt the application of power to, the conductor **31**. In the said one preferred embodiment of control system, that multivibrator and power stage alternately apply positive 12 volts DC to the conductor **31** for 100 milliseconds and then halt the application of that voltage to that conductor for 900 milliseconds. That embodiment of control system has a heart rate meter **33**, a respiration rate meter **37**, and a blood pressure meter **546**; and those meters are sensitive, contact less meter relays. Each of those meters has a photocell and a lamp therein which can complete an alarm circuit whenever the needle of that meter reaches an upper adjustable limit, and also has a second photocell and a second lamp therein which can complete a second alarm circuit whenever that needle reaches a lower adjustable limit. The alarm circuits of the heart rate meter **33** have lamps **39** and **41** therein, the alarm circuits of the respiration rate meter **37** have lamps **43** and **45** therein, and the alarm circuits of the blood pressure meter **546** have lamps **548** and **550** therein. In addition, the said one preferred embodiment of control system has a "read" lamp **454**. While each of those lamps will consume only a small amount of power, the six limit-setting lamps within those meters could, by themselves, drain power from the battery **22** at an undesirably high rate during any periods wherein the power supply **20** was not supplying power to those lamps if that battery had to supply power to those lamps on an uninterrupted basis. If any alarm lamps were to draw power from the battery **22** during those periods on an uninterrupted basis, the drain on that battery would be even higher. By using the multivibrator **23** and the power stage **47** to supply power to the conductor **31** for just one tenth of the time, the said one embodiment of control system materially reduces the drain which the lamps of that control system can impose upon the battery **22**.

The numerals **30** and **32** denote terminals that will be connected to electrodes which are attachable to the body of a person; and those electrodes will preferably be the standard and usual electrodes that are used with electrocardiographs. A resistor **34** connects the terminal **30** to the anode of a diode **36** and to the cathode of a diode **46**. The cathode of the diode **36** and the anode of the diode **46** are connected together and to ground; and they also are connected to the cathode of a diode **44** and to the anode of a diode **38**. The anode of the diode **44** and the cathode of the diode **38** are connected together, and they are connected to the terminal **32** by an adjustable resistor **40** and a resistor **42**. A capacitor **48** is connected between the right-hand terminal of resistor **34** and the upper terminal of adjustable resistor **40**.

The numeral **50** denotes a conductor which has one end thereof connected to the terminal **51**; and a resistor **57**, a conductor **59**, and a Zener diode **52** connect the other end of that conductor to ground. That Zener diode will coact with that resistor to establish a regulated positive voltage of less than 12 volts at the conductor **59**. The numeral **53** denotes a conductor which has one end thereof connected to the terminal **61**; and a resistor **55** and a Zener diode **56** connect the other end of that conductor to ground. That resistor and that Zener diode will coact to establish a regulated negative voltage of less than 12 volts at a conductor **54** which is connected to the anode of that Zener diode. The Zener diodes **52** and **56**, the conductors **54** and **59**, the resistors **55** and **57**, parts of the conductors **50** and **53**, NPN transistors **60, 62, 64, 66, 68, 70** and **72**, and the potentiometers, resistors and capacitors associated with those transistors constitute a low-frequency, differential input amplifier. That low-frequency, differential input amplifier is enclosed within a block which is denoted by the numeral **58**. An adjustable resistor **63**, which is connected in series with a capacitor **65** between the collector of transistor **64** and the base of transistor **66**, constitutes the gain adjustment of that amplifier. An adjustable resistor **67**, which is connected between the base of transistor **70** and the conductor **53**, constitutes the "zero adjustment" for the signal at the emitter of transistor **72**.

The transistor **72** is connected as an emitter follower; and a resistor **76** extends between the emitter of that transistor and a terminal **74**. The emitter of that transistor is directly connected to the base of an NPN transistor **78**; and it is connected to ground by a diode **82**, a junction **77**, and a resistor **85**. A junction **83**, a capacitor **84**, and a junction **73** will couple any changes in voltage at the junction **77** to the base of an NPN transistor **86**. The collector of the transistor **78** is coupled to the base of the transistor **86** by a capacitor **79**, a diode **80**, the junction **83**, the capacitor **84**, and the junction **73**. A resistor **81** is connected between the anode of the diode **80** and ground. A resistor **87** connects the collector of transistor **78** to the conductor **50**, and thus to positive 12 volts; and a resistor **91** connects the emitter of that transistor to ground. A resistor **89** connects that emitter to the conductor **53**, and thus to negative 12 volts. The transistor **78**, resistors **81, 85, 87, 89** and **91**, capacitor **79**, and diodes **80** and **82** constitute a subcircuit which can respond to positive-going and negative-going waveforms to produce only positive-going waveforms.

That subcircuit is enclosed within a block which is denoted by the numeral **97**.

A resistor **71**, the junction **73**, and a resistor **75** constitute a voltage divider connected between the conductor **50** and ground; and that voltage divider establishes a positive DC voltage at the base of transistor **86**. The collector of that transistor is connected directly to the conductor **50**, and thus to positive 12 volts; while the emitter of that transistor is connected to ground by a resistor **69**. The transistor **86** is connected as an emitter follower to minimize any "loading" of the diodes **80** and **82** of the subcircuit within the block **97**. A capacitor **88** couples the emitter of transistor **86** to the base of an NPN transistor **90** which is connected as a stage of amplification. A diode **92** is connected between the collector of transistor **90** and ground; and that diode will bypass to ground substantially all positive-going components of the signals amplified by the transistor **90**. A capacitor **93** couples the negative-going signals at the collector of that transistor to the base of an NPN transistor **94** which is connected as a stage of amplification. The collector of the transistor **94** is directly connected to the base of an NPN transistor **95** which is connected as an emitter follower.

A capacitor **96**, a resistor **98**, and a conductor **101** couple the emitter of transistor **95** to the input of a phase-shift oscillator **99** in FIG. 2C; and the components of that oscillator are dimensioned so it will act as a filter. Specifically, the components of that oscillator are dimensioned so it will respond to signals having leading edges with slopes comparable to those of a 25 c.p.s. sinusoid to become shock excited, but will not become shock excited in response to signals having leading edges with materially different slopes. A capacitor **111** and a resistor **113** couple the output of oscillator **99** to the input of a phase-shift oscillator **115**; and the components of the latter oscillator also are dimensioned so it will act as a filter. Specifically, the components of oscillator **115** are dimensioned so it will respond to signals having leading edges with slopes comparable to those of a 25 c.p.s. sinusoid to become shock excited, but will not become shock excited in response to signals having leading edges with materially different slopes. The two oscillators **99** and **115** coact to provide much sharper rejection of signals with undesired slopes for the leading edges thereof than either of those oscillators could provide. A capacitor **117** couples the output of the oscillator **115** to the base of an NPN transistor **119** which is connected as a stage of amplification; and the collector of that transistor is directly connected to the base of an NPN transistor **121** which is connected as an emitter follower.

Resistors **125** and **127** constitute a voltage divider which is connected between the conductor **50** and ground; and that voltage divider establishes a predetermined positive voltage at the cathode of a diode **123**. The anode of that diode is connected to the emitter of transistor **121**; and that diode will be back-biased until a signal appears at the emitter of that transistor which is more positive than the predetermined voltage at the cathode of that diode. As a result, the diode **123** and the resistors **125** and **127** constitute a level detector **120**. A capacitor **129** couples the output of that level detector to the base of an NPN transistor **131** which is connected as a stage of amplification. A resistor **133** and a diode **135** are connected in series between the collector of transistor **131** and ground; and that diode will tend to bypass to ground any positive-going components in the signals at that collector. A capacitor **141** is connected between the resistor **133** and the input terminal of a monostable multivibrator **145**; and a resistor **143** is connected between that capacitor and ground.

The monostable multivibrator **145** will respond to a negative-going pulse at the input terminal thereof to develop a positive-going, rectangular pulse at the output thereof. In the said one embodiment of control system, that pulse will have a duration of 100 milliseconds. A capacitor **147** and a diode **149** are connected in series between the output of the multivibratior **145** and a terminal **100**; and a resistor **151** connects the anode of that diode to a conductor **107** which is connected to conductor **53** —and thus to negative 12 volts. As a result, that diode will be back-biased until the multivibrator **145** develops a positive-going pulse, and the capacitor **147** couples that pulse to the anode of that diode.

The output of the monostable multivibrator **145** is connected to a rate circuit **105** by a conductor **137**, and it is coupled to the base of an NPN transistor **136** by conductor **137** and series-connected capacitor **132** and resistor **138**. The rate circuit **105** consists of a series-connected resistor **104** and capacitor **102**; and that capacitor has one terminal thereof connected to ground. A junction **103** between that resistor and that capacitor is connected directly to the base of an NPN transistor **110**, and is connected to the collector of an NPN transistor **134** by series-connected diodes **148** and **150**. A resistor **142**, the collector-emitter circuit of transistor **136**, and a resistor **146** are connected in series between the conductors **50** and **53**. A capacitor **144** is connected in parallel with the series-connected resistor **146** and collector-emitter circuit of transistor **136**. A resistor **140** is connected between the base of transistor **136** and the conductor **53**.

A conductor **139** connects a resistor **124** and a potentiometer **126** between the conductor **59** and ground; and that resistor and potentiometer constitute a voltage divider. A resistor **128** and an adjustable resistor **130** connect the movable contact of the potentiometer **126** to the base of an NPN transistor **108**. That transistor, the NPN transistor **110**, a PNP transistor **112**, an NPN transistor **114**, the resistors **124** and **128**, the potentiometer **126**, the adjustable resistor **130**, the capacitor and the other resistors associated with those transistors constitute an operational amplifier; and that operational amplifier is enclosed within a block denoted by the numeral **106**. The transistor **114** of that operational amplifier is connected as an emitter follower; and a resistor **116** is connected between the emitter of that transistor and a terminal **118**.

A conductor **165** in FIG. 2B has one end thereof connected to the terminal **161**, and thus to positive 12 volts, and it has the other end thereof connected to ground by a resistor **169**, a junction **171** and a Zener diode **167**. That resistor and Zener diode will develop a regulated DC positive voltage of less than 12 volts at the junction **171**. A conductor **164** is connected to the junction **171**, and a conductor **166** is connected to ground; and a potentiometer **168** is connected between those conductors, and thus between a regulated DC positive voltage and ground. The movable contact of that potentiometer and a resistor **170** apply a regulated DC positive voltage to the gate of a field effect transistor **162**; and the drain of that transistor is connected directly to the conductor **164** while the source of that transistor is connected to the grounded conductor **166** by a resistor **172**. A microphone **158** has one terminal thereof connected to ground, and has the other terminal thereof coupled to the gate of the field effect transistor **162** by a capacitor **160**. That microphone must be capable of being held closely adjacent some portion of the body of a person wherein an artery can be occluded sufficiently to cause Korotkoff sounds to be developed and to be sensed by that microphone. In the said one preferred embodiment of control system, the microphone **158** is small enough to be taped to a finger of a person; and that microphone will usually be taped to that finger distally of an inflatable cuff **538** in FIG. **1** which will be suitably secured to that finger.

An NPN transistor **174** has the collector thereof connected to conductor **164** by a resistor **176**, and has the emitter thereof connected to grounded conductor **166** by a resistor **178** and parallel-connected resistor **180** and capacitor **182**. The base of that transistor is connected to the right-hand terminal of resistor **172**. An NPN transistor **192** has the collector thereof connected to conductor **164** by a resistor **194**, and has the emitter thereof connected to grounded conductor **166** by a resistor **196** and parallel-connected resistor **198** and capacitor **200**. Resistors **186** and **188** constitute a voltage divider connected between the conductors **164** and **166**, and the junction between those resistors is connected to the base of transistor

192. A capacitor 190 is connected between that junction and the grounded conductor 166; and a capacitor 184 couples the collector of transistor 174 to the base of transistor 192. An NPN transistor 210 has the collector thereof connected to conductor 164 by a resistor 212, and has the emitter thereof connected to grounded conductor 166 by a resistor 214 and parallel-connected resistor 216 and capacitor 218. Resistors 204 and 206 constitute a voltage divider connected between the conductors 164 and 166; and the junction between those resistors is connected to the base of transistor 210. A capacitor 208 is connected between that junction and the grounded conductor 166; and a capacitor 202 couples the collector of transistor 192 to the base of transistor 210. An NPN transistor 228 has the collector thereof connected to conductor 164 by a resistor 230, and has the emitter thereof connected to grounded conductor 166 by a resistor 232 and parallel-connected resistor 234 and capacitor 236. Resistors 222 and 224 constitute a voltage divider connected between the conductors 164 and 166, and the junction between those resistors is connected to the base of transistor 228. A capacitor 226 is connected between that junction and the grounded conductor 166; and a capacitor 220 couples the collector of transistor 210 to the base of transistor 228. An NPN transistor 246 has the collector thereof connected to conductor 164 by a resistor 248, and has the emitter thereof connected to grounded conductor 166 by a resistor 250 and parallel-connected resistor 252 and capacitor 254. Resistors 240 and 242 constitute a voltage divider connected between the conductors 164 and 166, and the junction between those resistors is connected to the base of transistor 246. A capacitor 244 is connected between that junction and grounded conductor 166; and a capacitor 238 couples the collector of transistor 228 to the base of transistor 246. An NPN transistor 256 has the collector thereof connected directly to conductor 164, and has the emitter thereof connected to ground by a resistor 258. The base of that transistor is connected directly to the collector of transistor 246.

The transistor 174 and its associated capacitor and resistors constitute a band-pass filter and amplifier; and, similarly, each of transistors 192, 210, 228 and 246 and its associated capacitors and resistors constitutes a band-pass filter and amplifier. The various band-pass filters and amplifiers, of which the transistors 174, 192, 210, 228 and 246 are component parts, are interconnected as a cascaded band-pass filter and amplifier 259; and that cascaded band-pass filter and amplifier has a frequency response curve which is important and extremely desirable. That frequency response curve is generally denoted by the numeral 269 in FIG. 3; and it is markedly different from the dashed-line frequency response curve 271 which was obtained from just a single band-pass filter and amplifier. Not only is the curve 269 free from any "humps", such as the "-hump" 273 in the curve 271, but it has a fast roll-off below 40 c.p.s. whereas the curve 271 does not. Specifically, the frequency response curve 269 has a slope of 24 decibels per octave below 40 c.p.s. whereas the frequency response curve 271 has a slope of only 6 decibels per octave below 40 c.p.s. As a result, the cascaded band-pass filter and amplifier 259 can strongly reject low frequency signals, such as signals corresponding to a person's pulse, which the microphone 158 will sense; whereas a single band-pass filter and amplifier could not appreciably attenuate such signals. It should also be noted that the frequency response curve 269 has a rapid roll-off above 120 c.p.s. whereas the frequency response curve 271 does not. Consequently, the cascaded band-pass filter and amplifier 259 can strongly reject signals above as well as below its passband of 40 —120 c.p.s. and can thus pass signals which truly correspond to the Korotkoff sounds and which are essentially free from other signals and noise.

The resistors 176, 194, 212, 230 and 248 coact with the resistors 178, 196, 214, 232 and 250 to determine the gain for the band-pass filters and amplifiers that are interconnected to constitute the cascaded band-pass filter and amplifier 259. The resistors 180, 198, 216, 234 and 252 determine the bias points of the transistors of those band-pass filters and amplifiers.

A conductor 233 has one end thereof connected to the terminal 261, and thus to negative 12 volts; and a conductor 374 has one end thereof connected to that conductor. The numeral 221 denotes an NPN transistor which has the emitter thereof connected to the conductor 233 by a resistor 219, and has the collector thereof connected to the conductor 165 by a resistor 223. Resistors 227, 215 and 231 constitute a voltage divider connected between conductors 165 and 233; and the junction between the resistors 215 and 231 is connected to the base of transistor 221. The numeral 225 denotes an NPN transistor which has the collector thereof connected to the conductor 165 by the resistor 227, and has the emitter thereof connected to the conductor 233 by a diode 229 and the resistor 219. The base of the transistor 225 is connected to conductor 165 by a resistor 235; and the collector of transistor 221 is coupled to that base by a capacitor 237. The transistors 221 and 225, capacitor 237, resistors 215, 219, 223, 227, 231 and 235, and the diode 229 constitute a monostable multivibrator 217. In the said one preferred embodiment of control system provided by the present invention, that monostable multivibrator will respond to the application of a positive-going pulse to the base of transistor 221 to establish a positive-going pulse at the collector of transistor 225 and to maintain that positive-going pulse for 130milliseconds. A terminal 263 is connected to the terminal 100; and a conductor 265 and a capacitor 260 couple that terminal to the base of transistor 221. As a result, the development of a positive-going pulse at the terminal 100 will cause a positive-going pulse to be established at the collector of transistor 225.

The numeral 241 denotes an NPN transistor which has the emitter thereof connected to conductor 233 by a resistor 243, and which has the collector thereof connected to conductor 165 by a resistor 245. An NPN transistor 247 has the emitter thereof connected to conductor 233 by a diode 249 and the resistor 243, and has the collector thereof connected to conductor 165 by an adjustable resistor 264, a resistor 266, a junction 268, and a diode 270. The base of that transistor is connected to the conductor 165 by a resistor 257; and the collector of transistor 241 is coupled to that base by a capacitor 255. Resistors 253 and 251 connect the collector of transistor 247 to conductor 233; and the junction between those resistors is connected to the base of transistor 241. The transistors 241 and 247, capacitor 255, diode 249, and resistors 243, 245, 251, 253 and 257 constitute a monostable multivibrator 239. In the said one preferred embodiment of control system, that monostable multivibrator will respond to the application of a negative-going pulse to the base of transistor 247 to establish a positive-going pulse at the cathode of diode 270 and to maintain that positive-going pulse for 170 milliseconds.

The transistor 256 of the cascaded band-pass filter and amplifier 259 is connected as an emitter follower; and a conductor 274 and a capacitor 272 couple the emitter of that transistor to the junction 268. The adjustable resistor 264, the resistor 266, the junction 268, and a resistor 276 constitute a voltage divider connected between conductor 165 and conductor 233; and the diode 270, the collector-emitter circuit of NPN transistor 247, the diode 249, and the resistor 243 are connected in series with each other but in parallel with the resistor 276. Also, the series-connected resistors 253 and 251 are connected in parallel with the series-connected collector-emitter circuit of transistor 247, diode 249 and resistor 243. A diode 284 and a resistor 290 are connected between the junction 268 and ground; and the junction between that diode and that resistor is connected to the base of an NPN transistor 278. Resistors 288 and 286 connect the collector of that transistor to the conductor 165, while the emitter of that transistor is connected directly to ground. The diodes 270 and 284, the transistor 278, adjustable resistor 264, and resistors 266, 276, 286, 288 and 290 constitute an And gate; and that And gate is denoted by the numeral 295. That And gate will back-bias the diode **284**, and thus keep the transistor **278** nonconductive, until the transistor **247** is rendered nonconductive and the capacitor **272** couples positive-going signals to the anode of that diode to forward-bias that diode.

The junction between the resistors **286** and **288** is connected to the base of a PNP transistor **282**; and that transistor has the emitter thereof connected directly to the conductor **165**, and has the collector thereof connected to conductor **233** by resistors **292, 294** and **296**, the base-emitter circuit of an NPN transistor **298**, and a resistor **316**. An NPN transistor **280** has the base thereof connected to the collector of transistor **282**, has the collector thereof connected to conductor **165** by the resistor **286**, and has the emitter thereof connected to conductor **233** by the resistors **294** and **296**, the base-emitter circuit of transistor **298**, and the resistor **316**. A capacitor **300** is connected between conductor **165** and the junction between the resistors **294** and **296**. Resistors **302, 308** and **310** constitute a voltage divider connected between the conductors **165** and **233**; and the junction between resistors **302** and **308** is connected to the collector of transistor **298**, while the junction between resistors **308** and **310** is connected to the base of an NPN transistor **312**. The collector of transistor **298** also is connected to a fixed contact **306** of a four-pole double-throw switch **323**. That switch has a movable contact **343** and a fixed contact **347** in FIG. 2A, and has movable contacts **322, 325** and **333** and fixed contacts **320, 327** and **341** —as well as **306** —in FIG. 2B. The movable contacts **322, 325, 333** and **343** are ganged together; and they will be in the positions shown by the drawing whenever a person's diastolic blood pressure is to be sensed, and will be shifted in the clockwise direction whenever that person's systolic blood pressure is to be sensed. The emitter of transistor **298** is connected to the conductor **233** by the resistor **316**; and the emitter of transistor **312** also is connected to that conductor by that resistor. The collector of transistor **312** is connected directly to the fixed contact **320** of switch **232**, and is connected to the conductor **165** by a resistor **314**. The transistors **280, 282, 298** and **312**, the capacitor **300**, and the resistors **286, 292, 294, 296, 302, 308, 310** and **316** constitute a timer **319**. In the said one preferred embodiment of control system, that timer provides a delay of 1½ seconds.

The movable contact **322** of switch **323** is connected to the base of a PNP transistor **326** by a junction **324** and a resistor **331**, and is connected to the base of an NPN transistor **336** by the junction **324** and a resistor **338**. A resistor **328** and a resistor **330** constitute a voltage divider connected between conductor **165** and ground, and the junction between those resistors is connected to the emitter of transistor **326**. The collector of that transistor is connected to a terminal **335** by a conductor **334**; and a resistor **332** is connected between that collector and the conductor **233**. The transistor **326** and the resistors **328, 330** and **331** constitute a meter inhibiter **337**.

A unijunction transistor **340** has the base-two thereof connected to the terminal **342** by a resistor **350**, a resistor **344** and a diode **345**; and a resistor **346** and a Zener diode **348** connect the junction between the resistors **344** and **350** to ground. The base-one of that unijunction transistor is connected to ground by a resistor **352**, and also is directly connected to the gate of a controlled rectifier **442**. That controlled rectifier will preferably be a silicon controlled rectifier; and the cathode thereof will be grounded, while the anode thereof will be connected to a terminal **362** by a resistor **440**. A capacitor **360** is connected between the terminal **362** and ground; and a resistor **363** and a diode **365** connect the anode of the controlled rectifier **442** to the terminal **342**. A capacitor **354** is connected between the emitter of unijunction transistor **340** and ground; and a capacitor **402** and the collector-emitter circuit of the transistor **336** are connected in series with each other and are connected in parallel with the capacitor **354** by junctions **400** and **408**. A discharge diode **356** is connected in parallel with the capacitor **354** and with series-connected capacitor **402** and the collector-emitter circuit of transistor **336**. The capacitors **354, 360** and **402**, the diodes **345, 356** and **365**, the Zener diode **348**, the controlled rectifier **442**, the transistor **336**, and the resistors **344, 346, 352, 363** and **440** constitute a pump controller **371**.

The numeral **359** denotes a normally open pushbutton; and one fixed contact of that pushbutton is directly connected to the conductor **374** —and thus to negative 12 volts —while the other fixed contact of that pushbutton is connected to the base of an NPN transistor **366** by resistors **351** and **353**. The junction between those resistors is connected to the conductor **165** —and thus to positive 12 volts —by resistors **355** and **368** and a conductor **364**; and a resistor **370** connects the junction between the resistors **355** and **368** to the collector of transistor **366**. A resistor **372** connects the emitter of that transistor to the conductor **374** —and thus to negative 12 volts. A capacitor **357** is connected between the junction of resistors **351, 353** and **355** and the conductor **374**. A resistor **380** connects the collector of transistor **366** to the base of an NPN transistor **376**; and a resistor **384** extends between the base of the latter transistor and the conductor **374**. The resistor **372** connects the emitter of transistor **376** to the conductor **374**, and a resistor **378** connects the collector of that transistor to the conductor **364**. The transistors **366** and **376**, the capacitor **357**, and the resistors associated with those transistors constitute a timer **369**; and that timer will successively render the transistor **366** conductive at the saturation level while the transistor **376** is cut off, and will then render the transistor **376** conductive at the saturation level while the transistor **366** is cut off. In the said one embodiment of control system, that timer will render the transistor **366** conductive at the saturation level for 4 minutes, and will then render the transistor **376** conductive at the saturation level for 1 minute.

A resistor **382** and the anode-to-cathode circuit of a controlled rectifier **386** are connected between the collector of transistor **366** and ground; and that controlled rectifier preferably is a silicon-controlled rectifier. A resistor **388** is connected between the gate of that controlled rectifier and ground; and a conductor **392**, a resistor **329**, and a resistor **390** connect a terminal **394** to that gate. The movable contact **325** and the fixed contact **327** of switch **323** effectively "short" the resistor **329** whenever that switch is in the diastolic blood pressure-sensing position shown by the drawing. The terminal **394** is connectable to the blood pressure meter **546**. A resistor **396** and a diode **398** connect the junction between resistor **382** and the anode of controlled rectifier **386** to the junction **400**. The controlled rectifier **386**, the diode **398**, the resistors **329, 370, 382, 388, 390** and **396**, and the switch contacts **325** and **327** constitute a fast-pressurization subcircuit; and that subcircuit is denoted by the numeral **399**.

A diode **430**, a resistor **428**, and a resistor **426** coact with the resistor **378** to constitute a voltage divider connected between the conductor **364** and ground; and the junction between resistors **428** and **426** is connected to the base of an NPN transistor **432**. A resistor **423** has one terminal thereof connected to the junction between resistors **426** and **428**; and the other terminal of that resistor is isolated from ground by the contacts **333** and **341** of switch **323** whenever that switch is in the diastolic blood pressure-sensing position but is connected directly to ground by those contacts whenever that switch is in the systolic blood pressure-sensing position. The emitter of the transistor **432** is grounded, and the collector of that transistor is connected directly to the junction **400**. A PNP transistor **424** has the collector thereof connected to the base of transistor **432**; and the emitter of that transistor is connected to the junction **400** by resistors **422** and **420**, and also is connected to that junction by series-connected resistor **422**, adjustable resistor **421**, diode **425**, and Zener diode **427**. That adjustable resistor, diode and Zener diode constitute a compensating network **429**. The junction **394** is directly connected to the junction between resistors **420** and **422** and adjustable resistor **421** by the conductor **392** and a conductor **393**. A diode **434** is connected between the base of transistor **424** and the collector of transistor **432**, and diodes **436** and **438** are connected in series between the base of transistor **424** and the junction 171 by a conductor 439. A resistor 404 and an adjustable resistor 406 are connected between the conductor 364 and the junction 400 by the junction 408. The transistors 424 and 432, the diodes 434, 436 and 438, and resistors 422, 423 and 426 constitute a pressure-limiting subcircuit 431.

The junction between the anode of diode 430 and the collector of transistor 376 is connected to the base of a PNP transistor 441 by a conductor 452 and a resistor 450. The emitter of the latter transistor is directly connected to the conductor 165 by a conductor 448, and the collector of that transistor is connected to the conductor 374 by resistors 462 and 460. A resistor 446 is connected between the emitter and base of transistor 441. The base of an NPN transistor 456 is connected to the junction between resistors 462 and 460; and the emitter of that transistor is connected directly to the conductor 374, while the collector of that transistor is connected to a terminal 455. The negative terminal of the blood pressure meter 546 is connected to that terminal by a conductor 547, as shown by FIG. 1. The lamp 454 has one lead thereof connected to the terminal 455 and has the other lead thereof connected to the conductor 31, also as shown by FIG. 1. The transistors 441 and 456 and the resistors 446, 450, 460 and 462 constitute a driver for the lamp 454 and for the blood pressure meter 546 and the lamps therein; and that driver is denoted by the numeral 457.

The numeral 464 in FIG. 2A denotes a conductor which has the right-hand end thereof connected to the conductor 50, and thus to positive 12 volts. A resistor 466, a junction 467, and a Zener diode 468 connect the left-hand end of that conductor to ground, and thus establish a regulated positive voltage of less than 12 volts at that junction. A resistor 470, a resistor 472, and an adjustable resistor 474 constitute a voltage divider connected between the junction 467 and ground; and resistors 476, 478, 480 and 482 constitute a second voltage divider connected between that junction and ground. The junction between the resistors 470 and 472 of the former voltage divider is connected to the base of an NPN transistor 502 by a resistor 520; and the junction between the resistors 480 and 482 of the latter voltage divider is connected directly to the base of an NPN transistor 486. A terminal 484 is connected to the junction between the resistors 478 and 480 of that latter voltage divider; and that terminal will be connected to a pressure transducer 544 which can sense a variable pressure and which can supply a signal to that terminal which varies lineraly with that pressure.

A resistor 488 connects the collector of transistor 486 to the conductor 464, and also connects the base of an NPN transistor 490 to that conductor. A resistor 496 and a conductor 492 connect the emitter of transistor 486 to the conductor 53 and thus to negative 12 volts. The collector of transistor 490 is connected directly to the conductor 464, while the emitter of that transistor is connected to the conductor 492 by a resistor 498. An NPN transistor 494 also has the emitter thereof connected to the conductor 492 by the resistor 498, and it has the collector thereof connected to the conductor 464 by a resistor 500. A resistor 504 connects the conductor 464 to the base of transistor 494 and to the collector of transistor 502. A resistor 506 and a capacitor 508 are connected in series between the junction of the collector of transistor 486 and the base of transistor 490 and the junction of the collector of transistor 502 and the base of transistor 494. The collector of transistor 494 is directly connected to the base of a PNP transistor 510; and a diode 528 connects the conductor 464 to the emitter of the latter transistor, while a resistor 516 connects the collector of that latter transistor to the conductor 53. The collector of transistor 510 is directly connected to the base of an NPN transistor 512; and the collector of the latter transistor is connected to the conductor 464 by a resistor 514, while the emitter of that latter transistor is connected to the conductor 53 by a resistor 518, is coupled to the resistor 520 by a capacitor 530, is connected to the latter resistor by a series-connected adjustable resistor 524 and resistors 523 and 522, and is directly connected to a terminal 395. That terminal, as well as the terminal 394, is connected to the blood pressure meter 546. The contacts 343 and 347 of switch 323 effectively "short" the resistor 523 whenever that switch is in the diastolic blood pressure-sensing position shown by the drawing. A diode 526 is connected between the base of transistor 494 and the collector of transistor 512. The transistors 486, 490, 494, 502, 510 and 512, the capacitors 508 and 530, the diodes 526 and 528, and the resistors associated with those transistors constitute an operational amplifier 529. The adjustable resistor 474 constitutes the "zero" adjustment of that operational amplifier.

The outlet of the pump 540 is connected to the inlet of a reservoir 534; and that reservoir is large enough to tend to smooth out the pressure pulsations caused by the successive strokes of that pump. That reservoir has a vent 536 which continuously places the interior of that reservoir in communication with the atmosphere external of that reservoir. The outlet of that reservoir is connected to the inlet of an orifice 542; and that orifice supplies air to the inflatable cuff 538. That orifice will additionally smooth out the pressure pulsations caused by the successive strokes of the pump 540. The pressure transducer 544 is connected to the inflatable cuff 538, and will thus sense the pressure within that cuff.

Numerals 552 and 554 in FIG. 1 denote terminals that are connectable, respectively, to the terminals 30 and 32 of FIG. 2A and thus to electrodes that can be affixed to the body of a person. Terminal 552 is coupled to the center tap of the secondary winding 560 of a transformer 562 by a capacitor 556; and terminal 554 is coupled to the lower terminal of that secondary winding by a capacitor 558. The primary winding 564 of that transformer has a capacitor 566 connected in parallel with it to constitute a tuned circuit; and the lower terminals of that capacitor and primary winding are grounded. The upper terminals of that capacitor and primary winding are connected to a block 590 by a junction 568 and a conductor 109, and are connected to the collectors of a PNP transistor 574 and of an NPN transistor 576 by junction 568 and a junction 570. A terminal 578 is connectable to terminal 51, and thus to positive 12 volts; and a resistor 580 connects the former terminal to the emitter of transistor 574, while a resistor 582 connects that former terminal to the base of that transistor. A terminal 584 is connectable to terminal 61, and thus to negative 12 volts; and a resistor 586 connects the former terminal to the emitter of transistor 576, while resistor 588 connects that terminal to the base of that transistor. The numeral 590 denotes a block that is coupled to the base of transistor 574 by a capacitor 592, and that is coupled to the base of transistor 576 by a capacitor 594. A conductor 177 connects the block 590 with a block 572; and the output of the latter block is connected to the input of the respiration rate meter 37.

The terminals 552 and 554, the transformer 562, the capacitors 556, 558, 566, 592 and 594, the transistors 574 and 576, and the resistors 580, 582, 586 and 588 can be identical to the corresponding terminals, transformer, capacitors, transistors, and resistors disclosed in the concurrently filed "-Control System" patent application Ser. No. 627,034 of Anton J. Horn and Christopher G. Kuni. The block 590 contains a phase-shift oscillator, a detector, an operational amplifier, and other components of said patent application; and the block 572 contains a frequency multiplier, a monostable multivibrator, a rate circuit, an operational amplifier, and other components of said patent application. The blocks 572 and 590 can be identical to the correspondingly numbered blocks in said patent application.

CONNECTIONS OF CONTROL SYSTEM

The terminal 552 in FIG. 1 will be connected to the terminal 30 in FIG. 2A, and then those terminals will be connected to an electrode that can be affixed to the body of a person. Similarly, the terminal 554 in FIG. 1 will be connected to the terminal 32 in FIG. 2A, and then those terminals will be connected to a second electrode that can be affixed to that person's body. Those electrodes will preferably be disposed at opposite sides of the thoracic cage of that person, and they will be placed in good electrical contact with that person's body by means of an electrolyte. Those electrodes and that electrolyte can be the standard and usual electrodes and electrolyte used in the electrocardiograph art.

The terminal 51 of FIG. 2A, the terminal 161 of FIG. 2B, and the terminal 578 of FIG. 1 will be connected to the conductor 27. The terminal 61 of FIG. 2A, the terminal 261 of FIG. 2B, and the terminal 584 of FIG. 1 will be connected to the conductor 28. The terminal 342 of FIG. 2B will be connected to the conductor 29 of FIG. 1, and also will be connected to one terminal of the pump 540. The other terminal of that pump will be connected to the terminal 362 of FIG. 2B.

The terminal 100 in FIG. 2C will be connected to the terminal 263 in FIG. 2B, and the terminal 484 in FIG. 2A will be connected to the pressure transducer 544 in FIG. 1. The terminal 118 in FIG. 2A will be connected to the input of the heart rate meter 33, the terminals 394 and 395 in FIGS. 2B and 2A, respectively, will be connected together and then to the input of the blood pressure meter 546, the terminal 335 in FIG. 2B will be connected to the "inhibit" terminal of that blood pressure meter, and the terminal 455 in FIG. 2B will be connected to the negative terminal of that blood pressure meter. The terminal 74 in FIG. 2A can be connected to a recorder, an oscilloscope, or other instrument which utilizes an analog-type electrocardiograph signal. The terminals 21 in FIG. 1 can then be connected to a source of 117 volts, 60 cycle, single-phase, alternating current. The inflatable cuff 538 will be affixed to a finger of a person; and the microphone 158 will be taped to that finger —usually distally of that inflatable cuff.

It will be noted that only two electrodes need be affixed to the person's body —both the heart rate circuit and the respiration rate circuit being connected to the same pair of electrodes. The use of just two electrodes is desirable, because the skin of a person can develop a physiological reaction to the electrolyte which is used to assure good electrical contact between the electrodes and that person's skin; and the fewer the electrodes, the less electrolyte that is needed and the smaller the overall physiological reaction. Furthermore, the use of just two electrodes simplifies the problem of holding those electrodes in good electrical contact with that person's skin.

It will be noted that the resistor 34 in FIG. 2A, the base-collector circuit of transistor 60, the collector resistor of that transistor, and resistor 57, or the resistor 34, the upper section of the base-biasing potentiometer for the transistor 60, the upper base-biasing resistor for that transistor, and the resistor 57 are interposed between the terminal 30 and the conductor 50. In the said one preferred embodiment of control system, the resistor 34 has a resistance of one million ohms; and it will effectively keep a hurtful positive DC voltage or current from conductor 50 from reaching the body of the person. Even if that resistor should, somehow, become "shorted", the resistor 57, the collector resistor, and the collector-base circuit of transistor 160, or the resistor 57, the upper base-biasing resistor, and the upper section of the base-biasing potentiometer for that transistor would keep any hurtful positive DC voltage or current from reaching the body of the person. Similarly, the resistor 42, the adjustable resistor 40, the lower base-biasing resistor for transistor 64, and the resistor 55 are interposed between the terminal 32 and the conductor 53. In the said one preferred embodiment of control system, the resistance of the resistor 42 is one million ohms; and that resistor will keep any hurtful negative DC voltage or current from reaching the body of the person. Even if the resistor 42 should, somehow, become "shorted", the adjustable resistor 40, the lower base-biasing resistor of transistor 64, and the resistor 55 would keep any hurtful negative DC voltage or current from reaching the body of the person.

It should also be noted that the diode 36 is connected between the movable contact of the base-biasing potentiometer for transistor 60 and ground, and that the diode 44 is connected between the lower base-biasing resistor of transistor 64 and ground. Each of those diodes will limit the maximum voltage which can be developed across it to less than about one-half of a volt; and hence it will limit the voltage which can be applied to the resistor connected between its anode and the person's body to less than one-half of a volt. Further, in the event that resistor should, somehow, become "shorted", that diode would limit the voltage which that "shorted" resistor could apply to the body of a person to a level below about one-half of a volt. The overall result is that the body of the person will be fully protected against any and all potentially hurtful positive DC voltage or current and against any and all potentially hurtful negative DC voltage or current from the heart rate circuit.

The transformer 562 and the capacitors 556 and 558 of the respiration rate circuit will effectively isolate the body of the person from any and all positive and negative DC voltages or currents in the respiration rate circuit. Consequently, that transformer and those capacitors will protect that person against any and all potentially hurtful positive or negative DC voltages or current from that circuit. Even if the transformer 562 were, somehow, to become "shorted", the capacitors 556 and 558 would continue to isolate the person from all positive and negative DC voltages or currents in the respiration rate circuit. Similarly, if either or both of the capacitors 556 and 558 were, somehow, to become "shorted", the transformer 562 would continue to isolate the body of the person from all positive and negative DC voltages or currents in the respiration rate circuit.

The electrodes that will be connected to the terminals 30 and 552 and to the terminals 32 and 554 will constitute the only direct electrical contact between the body of a person and the control system provided by the present invention. A plurality of electrical impedances will be interposed between each of those electrodes and the positive and negative DC voltages or currents in that control system; and those impedances will be of such a nature and will be so dimensioned that they will keep any potentially hurtful positive or negative DC voltages or currents in that control system from reaching that person's body. Moreover, those impedances will be of such a nature and will be so dimensioned that they will keep any potentially hurtful positive or negative DC voltages or currents in that control system from reaching that person's body even if one of those impedances should, somehow, become "shorted". Consequently, the control system provided by the present invention is made doubly safe to use.

The heart rate circuit of the control system provided by the present invention does not require the body of the person to be grounded, and neither does the respiration rate circuit of that control system require that person's body to be grounded. This is important; because it will protect that person against hurtful shocks, due to ground loops extending through his body, which could develop if that heart rate circuit or that respiration circuit required that person's body to be grounded, and if that control system was connected to another device, system or equipment which was grounded. Furthermore, because neither the heart rate circuit nor the respiration rate circuit of that control system requires the body of the person to be grounded, the readings of the meters of that control system will not be aberrated or distorted in the event that person accidentally touches a nearby object, device, system or equipment which is gounded.

OPERATION OF PUMP CONTROLLER

After the various connections, described hereinbefore in CONNECTIONS OF CONTROL SYSTEM, have been made, the four-pole, double-throw switch 323 will be checked to make certain that the movable contacts 322, 325, 333 and 343 thereof are in the diastolic blood pressure-sensing position which is shown by FIGS. 2A and 2B. Thereafter, the switch **35** will be closed to enable the power supply **20** to apply a positive voltage to the conductor **27**, to apply a negative voltage to the conductor **28**, and to apply 100 volts AC to the conductor **29**.

During the first positive-going half-cycle of the AC applied to the conductor **29** —and thus to the terminal **342** —current will flow from that terminal via diode **345**, resistors **344** and **346**, and Zener diode **348** to ground; and, almost immediately, the voltage at the junction between those resistors —and hence at the base-two of unijunction transistor **340** —will reach a predetermined value. Direct current will be flowing from terminal **161** to capacitor **354** via conductors **165** and **364**, and then either through series-connected resistors **368**, **370**, **382** and **396**, diode **398**, and junctions **400** and **408**, or through resistor **404**, adjustable resistor **406**, and junction **408**. The overall ohmic resistance of the parallel-connected resistive paths is substantially less than the overall ohmic resistance of either of those paths, and hence the capacitor **354** will charge quite rapidly. The capacitor **402** and the collector-emitter circuit of transistor **336** are connected in series with each other and in parallel with the capacitor **354**; but the transistor **336** will be nonconductive, and hence substantially no current will flow through the capacitor **402**. As current started flowing through capacitor **354**, current also started flowing from terminal **161** via conductors **165** and **364**, resistors **368**, **370**, **380** and **384**, and conductors **374** and **233** to terminal **261**; and the resulting positive voltage at the base of transistor **376** will render that transistor conductive. The resulting negative voltage at the collector of that transistor will back-bias the diode **430**, and thus render the pressure-limiting subcircuit **431** inactive.

The capacitor **354** will become sufficiently charged, in less than one half-cycle of the AC applied to the terminal **342**, to cause the voltage across that capacitor to reach the emitter peak point voltage of the unijunction transistor **340** and thereby render that unijunction transistor conductive. That capacitor will then discharge through the emitter-base-one circuit of that unijunction transistor and resistor **352**; and the resulting voltage drop across that resistor will cause sufficient current to flow through the gate-to-cathode circuit of the controlled rectifier **442** to render that controlled rectifier conductive. Current will then flow from terminal **342** via pump **540**, terminal **362**, resistor **440**, and the anode-to-cathode circuit of that controlled rectifier; and that pump will respond to that flow of current to flex the flexible diaphragm thereof, and thereby force a quantity of air into the reservoir **534**. Part of that air will pass through the vent **536** and be lost to the atmosphere, but other of that air will pass through the orifice **542** and enter the inflatable cuff **538**; and the pressure transducer **544** will sense the pressure on the air within that inflatable cuff.

During the succeeding negative-going half-cycle of the AC applied to the terminal **342**, the controlled rectifier **442** will be reverse-biased and will become nonconductive. During the next succeeding positive-going half-cycle of that AC, the current flowing through diode **345**, resistors **344** and **346**, and Zener diode **348** will again quickly develop the said predetermined voltage at the base-two of unijunction transistor **340**; and the current flowing through the capacitor **354** will again quickly raise the voltage across that capacitor to the emitter peak-point voltage of that unijunction transistor. Consequently, that unijunction transistor will again become conductive, and the capacitor **354** will again discharge through the emitter-base-one circuit of that unijunction transistor and through resistor **352** to again render the controlled rectifier **442** conductive. The resulting flow of current from terminal **342** via pump **540**, terminal **362**, resistor **440** and the anode-to-cathode circuit of that controlled rectifier will cause the flexible diaphragm of that pump to force further air into the reservoir **534**.

The value of the current flowing through the resistors **368**, **370**, **382** and **396** and the diode **398** plus the value of the current flowing through resistor **404** and adjustable resistor **406** will be great enough to render the unijunction transistor **340**, and hence the controlled rectifier **442**, conductive during the early portion of each positive-going half-cycle of the AC applied to the terminal **342**; and the pump **540** will respond to the resulting long "on" times of that controlled rectifier to force air into the reservoir **534** at a sufficiently rapid rate to cause the pressure in that reservoir, and hence in the inflatable cuff **538** and at the pressure transducer **544**, to increase rapidly from atmospheric pressure to a value of 40 mm. of mercury. In the said one preferred embodiment of control system, the pressure in that inflatable cuff and at that pressure transducer will rise from atmospheric pressure to 40 mm. of mercury in about two seconds. The resulting rapid pressurization of the inflatable cuff **538** is desirable, because pressurization of that inflatable cuff at the normal pressurization rate would require an unduly long period of time. The value of 40 mm. of mercury was selected because it is lower than the diastolic blood pressure of most persons, but is high enough to enable a good part of the pressure needed within the inflatable cuff **538** to be developed rapidly. Another value of mercury could, of course, be selected, and could be incorporated into the operation of the pump controller **371**.

As soon as the pressure transducer **544** senses a pressure in the inflatable cuff **538**, and it will sense such a pressure almost as soon as the pump **540** starts pumping air into the reservoir **534**, that pressure transducer will apply a negative-going signal to the terminal **484**, and thus to the junction between the resistors **478** and **480** adjacent the transistor **486** of the operational amplifier **529**. Those resistors and the resistors **476** and **482** constitute a voltage divider which establishes a positive voltage at the base of that transistor, and thereby renders that transistor conductive. The magnitude of the negative-going signal initially applied to the terminal **484**, and hence to the base of the transistor **486**, by the pressure transducer **544** will be small; but it will reduce the conductivity of that transistor. The operational amplifier **529** will respond to the reduction in conductivity of that transistor to apply a positive voltage to the terminals **394** and **395**, and hence to the input terminal of the blood pressure meter **546** and to the conductors **392** and **393**. That blood pressure meter will respond to that positive voltage to cause the needle thereof to move upwardly to a position corresponding to the pressure in the inflatable cuff **538**; and that meter will provide a readily readable indication of that pressure. The conductor **392** will apply that positive voltage to the resistor **388** and to the gate-to-cathode circuit of controlled rectifier **386** via the "shorting" contacts **325** and **327** of switch **323** and the resistor **390**; but that voltage will not be great enough to render that controlled rectifier conductive. The conductor **392** and the conductor **393** will apply that positive voltage to the resistor **420** and to the compensating network **429**; and while a small amount of current might possibly flow via resistor **420**, junctions **400** and **408**, and capacitor **354** to ground and help charge that capacitor, substantially no current will flow through that compensating network because the Zener diode **427** will be nonconductive.

When the pressure within the inflatable cuff **538** increases to a value corresponding to 40 mm. of mercury, the negative-going signal from the pressure transducer **544** will be great enough to cause the operational amplifier **529** to apply a positive voltage to the terminals **395** and **394** which will cause the needle of the blood pressure meter **546** to provide a reading of 40. That positive voltage also will be applied to the gate of controlled rectifier **386**, and that voltage will be large enough to cause sufficient current to flow through the gate-to-cathode circuit of that controlled rectifier to render that controlled rectifier conductive. As that controlled rectifier becomes conductive, the voltage at the anode thereof, and hence at the anode of diode **398**, will become less positive than the voltage at the cathode of that diode; and, thereupon, that diode will become back-biased. Thereafter, current will be unable to flow from terminal **161** via conductors **165** and **364**, resistors

368, 370, 382, 396 and diode 398 to the capacitor 354 to charge that capacitor. Instead, the current flowing through the series-connected resistors 368, 370 and 382 will be bypassed to ground through the controlled rectifier 386; and the consequent reduction in charging rate of the capacitor 354 will cause the unijunction transistor 340, and hence the controlled rectifier 442, to become conductive later in the positive-going half-cycles of the AC applied to the terminal 342. The resulting shorter "on" times of that controlled rectifier will reduce the lengths of the strokes of the air pump 540, and will thereby decrease the rate at which the pressure in the reservoir 534, and hence in the inflatable cuff 538, will increase. However, the value of the current flowing from terminal 161 via conductors 165 and 364, resistor 404, adjustable resistor 406, junction 408, and capacitor 354 to ground will be great enough to provide "on" times for the unijunction transistor 340, and thus the controlled rectifier 442, which will enable air to be pumped into the reservoir 534 at a rate higher than the rate at which air can escape from that reservoir through the vent 536. As a result, the pressure within the inflatable cuff 538, and hence at the pressure transducer 544, will continue to rise, although at a slower rate. In the said one preferred embodiment of control system, that pressure will rise at the rate of 2 mm. of mercury per second.

The positive voltage which the operational amplifier 529 applies to the terminals 395 and 394 also will be applied to the resistor 420, and it will increase the value of the current which flows through that resistor to help charge the capacitor 354. However, that amount of current will be very small compared to the value of the current which flows through resistor 404 and adjustable resistor 406 to charge that capacitor

As the pressure in the reservoir 534, and thus in the inflatable cuff 538, continues to increase, the pressure transducer 544 and the operational amplifier 529 will increase the positive voltage at the terminals 394 and 395. The blood pressure meter 546 will respond to that higher voltage to indicate that higher pressure; and the resistor 420 will respond to that higher voltage to supply a little more charging current to the capacitor 354. When the pressure in the reservoir 534, and thus in the inflatable cuff 538, reaches a level at which that inflatable cuff can occlude the artery in the person's finger sufficiently to cause Korotkoff sounds to develop, the blood pressure circuit will render the transistor 336 conductive —all as explained hereinafter in OPERATION OF BLOOD PRESSURE CIRCUIT. At that time, the reading on the blood pressure meter 546 will indicate the person's diastolic blood pressure.

As the transistor 336 becomes conductive, it will effectively connect the capacitor 402 in parallel with the capacitor 354; and some of the current that formerly flowed through the capacitor 354 will thereafter flow through the capacitor 402. The reduced flow of current through the capacitor 354 will increase the length of time needed for the voltage across that capacitor to reach the emitter peak-point voltage of the unijunction transistor 340, and will thus cause the unijunction transistor and the controlled rectifier 442 to become conductive at a later time during each positive-going half-cycle of the AC applied to the terminal 342. The resulting shortened "on" times of that controlled rectifier will reduce the lengths of the strokes of the pump 540; and, while that pump will continue to introduce air into the reservoir 534 during each stroke thereof, the rate at which that air is introduced into that reservoir will be less than the rate at which air can escape from that reservoir through the vent 536. Consequently, the pressure within the reservoir 534, and thus within the inflatable cuff 538, will decrease at a rate of 2 mm of mercury per second.

That decrease in pressure will quickly enable blood to flow once again through the artery in the person's finger; and that flow of blood is important, because it will avoid numbness in that finger and will also prevent injury to that finger. The pressure transducer 544 and the operational amplifier 529 will respond to that decrease in pressure to reduce the value of the positive voltage applied to the terminals 395 and 394; and the blood pressure meter 546 will respond to that lesser positive voltage to indicate the reduced pressure. The resistor 420 will respond to that lesser voltage to reduce the value of the current flowing therethrough to the capacitors 354 and 402.

As the blood again flows through the artery in the person's finger, the Korotkoff sounds will disappear; and 1½ seconds after the last Korotkoff sound is sensed by the microphone 158, the transistor 336 will be rendered nonconductive —all as explained hereinafter in OPERATION OF BLOOD PRESSURE CIRCUIT. As that transistor again becomes nonconductive, it will again isolate the capacitor 402 from the capacitor 354. The current which was flowing through the former capacitor will then add to the current flowing through the latter capacitor; and, once again, the unijunction transistor 340 and the controlled rectifier 442 will become conductive earlier in the positive-going half-cycles of the AC applied to the terminal 342. The increased "on" times of that controlled rectifier will cause the pump 540 to supply air to the reservoir 534 at a rate which will enable the pressure in that reservoir, and hence in the inflatable cuff 538, to increase at the normal pressurization rate.

During the depressurization of the inflatable cuff 538, the pressure in that inflatable cuff decreased by a value equal to just a few millimeters of mercury; and hence the needle of the blood pressure meter 546 moved downwardly just a short distance. During the subsequent repressurization of that inflatable cuff, which will begin when the transistor 336 is again rendered nonconductive, the pressure within that inflatable cuff will quickly rise to the level at which that inflatable cuff will again occlude the artery in the person's finger and again cause Korotkoff sounds to develop. As those Korotkoff sounds develop, the blood pressure circuit will again render the transistor 336 conductive; and the capacitor 402 will again be connected in parallel with the capacitor 354 —with a consequent reduction in the "on" times of the controlled rectifier 442.

The transistor 336 will be alternately rendered conductive and nonconductive by the blood pressure circuit, and will thus cause the pressure in the inflatable cuff 538 to recurrently decrease at the normal depressurization rate and then increase at the normal pressurization rate. That pressure will fall and then rise through a value equal to just a few millimeters of mercury during each depressurization and repressurization cycle; and hence the needle of the blood pressure meter 546 will remain close to a value which will correspond to the person's diastolic blood pressure. The transistor 336 will be alternately rendered conductive and nonconductive by the blood pressure circuit until the timer 369 renders the transistor 432 conductive, and thus prevents further charging of either of the capacitors 354 and 402 —as explained hereinafter in OPERATION OF TIMER 369. When the capacitors 354 and 402 are forced to remain uncharged, the unijunction transistor 340 and the controlled rectifier 442 will become inactive, and the pump 540 will be unable to pump further air into the reservoir 534. Air will, thereupon, leak out of that reservoir through the vent 536 until the pressure in that reservoir essentially reaches atmospheric pressure; and, at that time, the inflatable cuff 538 will apply essentially no pressure to the person's finger. The pressure in the reservoir 534 and in the inflatable cuff 538 will fall quite rapidly, because no air is being introduced into that reservoir by the pump 540. The pressure transducer 544 will respond to the decreasing pressure in the inflatable cuff 538 to rapidly reduce the value of the negative voltage which it applies to the input of the operational amplifier 529; and that operational amplifier will rapidly reduce the value of the positive voltage which it applies to the terminals 394 and 395. That falling positive voltage will be applied to the input of the blood pressure meter 546.

The transistor 366 will be rendered conductive by the timer 369; and, thereupon, the voltage at the anode of the controlled rectifier 386 will fall close to ground potential. At such time, the value of the current flowing through that controlled rectifier will be too small to keep that controlled rectifier conductive; and that controlled rectifier will become nonconductive. This is important; because it means that at the start of the next pressurization cycle of the inflatable cuff **538**, the capacitor **354** will again receive charging current through series-connected resistors **368, 370, 382** and **396** and diode **398** as well as through series-connected resistor **404** and adjustable resistor **406**. That total charging current will cause the inflatable cuff **538** to be pressurized at the rapid pressurization rate until the pressure in that inflatable cuff again reaches 40 mm. of mercury. Thereupon, the controlled rectifier **386** will again be rendered conductive to keep the current flowing through resistors **368, 370** and **382** from reaching the capacitor **354** and the pressurization rate will decrease to the normal pressurization rate.

In the preceding portion of the description of the operation of the pump controller **371**, it was assumed that the person's diastolic blood pressure was in the range of 40 —200 mm. of mercury. During such a range of blood pressure, the pump controller **371** can provide a generally linear relationship between the "on" time of the controlled rectifier **442** and the pressurization rate of the inflatable cuff **538**. However, as the pressure in that inflatable cuff increases during that range, a given "on" time of that controlled rectifier will produce a lesser increase in pressure; because air tends to escape more rapidly through the vent **536** at higher pressures than at lower pressures, and because the pump **540** is somewhat less efficient at higher pressures than at lower pressures. Nevertheless, the inherent efficiency of the pump **540** is high enough, and the positive feedback of current to capacitor **354** through the resistor **420** is great enough, to make the relationship between the "on" time of the controlled rectifier **442** and the pressurization rate of the inflatable cuff **538** generally linear up to about 200 mm. of mercury.

At pressures above 200 mm. of mercury, the rate at which air escapes through the vent **536** increases so rapidly, and the efficiency of the pump **540** decreases so rapidly, that a given "on" time of the controlled rectifier **442** would produce a materially smaller increase in pressure than the same "on" time of that controlled rectifier could produce at pressures well below 200 mm. of mercury. It would be desirable to increase the "on" times of the controlled rectifier **442**, beyond the durations of "on" times called for by the signal from the pressure transducer **544**, whenever the pressure in the inflatable cuff **538** is greater than 200 mm. of mercury; because such an increase in "on" times would compensate for the increased rate at which air escapes through the vent **536** and for the decreased efficiency of the pump **540**. The compensating network **429** provides such increases in the "on" times of the controlled rectifier **442** and it does so by causing the Zener diode **427** thereof to become conductive when the pressure in the inflatable cuff **538** is greater than 200 mm. of mercury.

The compensating network **429** always receives the positive signal which the pressure transducer **544** causes the operational amplifier **529** to apply to the terminals **394** and **395**; but the Zener diode **427** of that compensation network is normally nonconductive. As a result, that Zener diode will normally keep current from flowing from terminal **394** via conductors **392** and **393**, adjustable resistor **421**, diode **425** and Zener diode **427**, junctions **400** and **408**, and capacitor **354** to ground. This means that throughout the range of pressures from 0 —200 mm. of mercury, the compensating network **429** will be inactive. However, after the pressure in the inflatable cuff **538** increases above 200 mm. of mercury, the positive voltage applied to the terminal **394** by the operational amplifier **529** will be great enough to render the Zener diode **427** of the compensating network **429** conductive. As that Zener diode becomes conductive, current will flow from terminal **394** via conductors **392** and **392**, adjustable resistor **421**, diode **425** and Zener diode **427**, junctions **400** and **408**, and capacitor **354** to ground. That flow of current will be in addition to the flow of current from terminal **161** via conductors **165** and **364**, resistor **404**, adjustable resistor **406**, junction **408**, and capacitor **354** to ground; and the total flow of current through that capacitor will increase the rate of charging of that capacitor. The resulting increase in "on" time of the controlled rectifier **442**, during each positive-going half-cycle of the AC applied to the terminal **342**, will increase the length of each stroke of the pump **540** thereby enabling that pump to force sufficient air into the reservoir **534** to effectively cause the pressure in the inflatable cuff **538** to continue to increase at a rate close to the normal pressurization rate.

Because the diastolic blood pressures of most persons are below 200 mm. of mercury, the compensation network **429** is used only infrequently. However, for those persons whose diastolic blood pressures are above 200 mm. of mercury, that compensating network enables the control system of the present invention to monitor their diastolic blood pressures. Furthermore, that compensating network enables that control system to provide pressurization rates during the sensing of the diastolic blood pressures of those persons which are similar to the pressurization rates used during the sensing of the blood pressures of persons having more normal diastolic blood pressures thereby avoiding needless concern on the part of those persons or on the part of the operator of that control system.

Whenever the pressure in the inflatable cuff **538** falls below 200 mm. of mercury, the positive voltage applied to the terminals **394** and **395** by the operational amplifier **529** will decrease sufficiently to enable the Zener diode **427** to again become nonconductive. Thereupon, the positive feedback which the compensating network **429** was providing for the capacitor **354** will be cut off. That Zener diode will remain nonconductive, and will thus keep that compensating network from providing further positive feedback for that capacitor, until the pressure in the inflatable cuff **538** again exceeds 200 mm. of mercury.

If, somehow, the occlusion of the artery in the person's finger does not cause Korotkoff sounds to develop, or if, somehow, development of such sounds does not cause the blood pressure circuit to render the transistor **336** conductive, the controlled rectifier **442** will cause the pump **540** to continue to introduce air into the reservoir **534**. The pressure in the reservoir **534** and in the inflatable cuff **538** will increase, in response to the continued introduction of air into that reservoir and as that pressure reaches a preset value —above 200 mm. of mercury but well below a value at which the finger of the person could be injured —the pressure transducer **544** will cause the operational amplifier **529** to apply a positive voltage to the terminals **395** and **394** which will cause sufficient current to flow through resistor **422**, the emitter-base circuit of transistor **424**, diodes **436** and **438**, conductor **439**, junction **171**, and Zener diode **167** to ground to render that transistor conductive. That transistor and the transistor **432** are component parts of the pressure-limiting subcircuit **431**. The resulting positive-going signal at the collector of transistor **424** will be applied to the base of transistor **432** and will render the latter transistor conductive thereby causing the voltages at the junctions **400** and **408** to drop to ground potential. As a result, the capacitor **354** will be unable to charge, and the unijunction transistor **340** and the controlled rectifier **442** will remain nonconductive. The resulting inactivity of the pump **540** will keep further air from being introduced into the reservoir **534**, and the air in the inflatable cuff **538** and in that reservoir will escape to the atmosphere through the vent **536**. As a result, the pressure within that inflatable cuff and within that reservoir will fall rapidly. Consequently, the person will be protected against injury, even if, somehow, Korotkoff sounds do not develop or the development of such sounds does not cause the blood pressure circuit to render the transistor **336** conductive.

Where the transistors **424** and **432** have been rendered conductive by the development of the said preset pressure in the reservoir **534** and in the inflatable cuff **538**, those transistors will remain conductive until the pressure in the inflatable cuff **538** falls to about 30 mm. of mercury. During the time needed for the pressure in that inflatable cuff to fall from the said preset level to 30 mm. of mercury, those transistors will keep the pump **540** inactive. As the pressure in the inflatable cuff **538** falls to 30 mm. of mercury, the voltage applied to the terminal **394** by the operational amplifier **529** will not be great enough to cause sufficient current to flow through the emitter-base circuit of the transistor **424** to keep that transistor conductive; and hence that transistor will become nonconductive. As it does so, the transistor **432** also will become nonconductive; and this means that the voltage at the junctions **400** and **408** will be able to become positive with consequent charging of the capacitor **354**.

It should thus be apparent that the pump controller **371** controls the "on" times of the controlled rectifier **442**, and thus controls the rate at which the pump **540** introduces air into the reservoir **534**. That pump controller will coact with the fast pressurization circuit **399** to provide rapid pressurization of the inflatable cuff **538**, until the pressure in that cuff equals 40 mm. of mercury. Thereafter, that pressure controller will provide reduced "on" times for the controlled rectifier **442**, but will make those "on" times long enough to enable the pump **540** to provide normal pressurization of the inflatable cuff **538**. After a Korotkoff sound is sensed by the microphone **158**, the transistor **336** of the pressure controller **371** will be rendered conductive; and the "on" times of the controlled rectifier **442** will be further shortened. While the pump **540** will continue to supply air to the reservoir **534**, air will escape through the vent **536** at a rate higher than the rate at which that pump supplies air to that reservoir. As a result, slow depressurization of the inflatable cuff **538** will occur. 1½ seconds after the last Korotkoff sounds are heard, the transistor **336** will be rendered nonconductive once again, and the inflatable cuff **538** will again be pressurized at the normal pressurization rate.

If the value of the pressure in the inflatable cuff **538** rises above 200 mm. of mercury, the pressure controller **371** will coact with the compensating network **429** to provide positive feedback for the capacitor **354** which will enable the pump **540** to continue to pressurize that inflatable cuff —and at a rate close to the normal pressurization rate. If the value of the pressure in the inflatable cuff **538** rises to a preset value above 200 mm. of mercury, the pressure controller **371** will coact with the pressure-limiting subcircuit **431** to halt further operation of the pump **540**, until the pressure in the inflatable cuff **538** falls to 30 mm. of mercury.

The pump controller **371** is small and compact, it is inexpensive, it is substantially maintenance-free in operation, and it provides precise control of the pump **540**. Furthermore, that pump controller obviates all need of solenoid-operated valves, relays, and other expensive components which require maintenance.

OPERATION OF HEART RATE CIRCUIT

The electrodes which are affixed to the body of the person will sense a signal which will have the form of a characteristic electrocardiograph waveform. That signal will usually be in the range of 1 —5 millivolts; and the series-connected diodes **36** and **38** and the series-connected diodes **44** and **46** will remain nonconductive when such small voltage signals are developed across the terminals **30** and **32**. As a result, the series-connected diodes **36** and **38** and the series-connected diodes **44** and **46** will not affect the signals which correspond to the electrocardiograph waveforms of the person.

The series-connected diodes **36** and **38**, the series-connected diodes **44** and **46**, the resistors **34** and **42**, and the adjustable resistor **40** are important in the event a countershock must be applied to the body of a person whose heart is experiencing fibrillation. Countershocks having peak values of 1000 volts are sometimes applied to persons whose hearts are experiencing fibrillation; and a voltage of that magnitude could, absent the series-connected diodes **44** and **46**, the series-connected diodes **36** and **38**, the resistors **34** and **42** and the adjustable resistor **40**, adversely affect the differential input amplifier within the block **58**. By providing the series-connected diodes **36** and **38**, the series-connected diodes **44** and **46**, the resistors **34** and **42**, and the adjustable resistor **40**, the voltage which a countershock having a peak value of 1000 volts could apply to the input of that differential input amplifier is limited to about seven-tenths of a volt. Consequently, the series-connected diodes **36** and **38**, the series-connected diodes **44** and **46**, the resistors **34** and **42**, and the adjustable resistor **40** fully protect the differential input amplifier in the block **58** from injury.

The differential input amplifier in the block **58** will enhance signals having frequencies within the range of 20 —90 c.p.s. and it will tend to attenuate signals having frequencies appreciably above and appreciably below that range. As a result, the output of that amplifier will have a reduced content of transients, noise, and signals, from the electrodes connected to the terminals **30** and **32**, which have frequencies appreciably above and below the range of 20 — 90 c.p.s. That differential input amplifier will respond to the signals which correspond to the person's electrocardiograph waveform; and an amplified analog-type signal corresponding to that electrocardiograph waveform will be applied to the terminal **74**, and also will be applied to the base of the transistor **78** and to the anode of the diode **82**. The positive-going components of that signal will forward-bias the diode **82**, and will develop a voltage drop across the resistor **85** which will be coupled to the base of the transistor **86** by junctions **77** and **83**, capacitor **84**, and junction **73**. Those positive-going components of that signal will render the transistor **78** more conductive, and thus will provide a negative-going signal at the left-hand terminal of the capacitor **79**; and that capacitor will couple that negative-going signal to the anode of the diode **80** thereby reverse-biasing that diode. The succeeding negative-going components of the signal from the transistor **72** will back-bias the diode **82**; and they will render the transistor **78** less conductive. The resulting positive-going signal at the collector of that transistor will be coupled by the capacitor **79** to the diode **80**; and that signal will forward-bias that diode and cause a voltage drop to develop across the resistor **85** which will be coupled to the base of the transistor **86** by junctions **77** and **83**, capacitor **84**, and junction **73**. It will thus be noted that the transistor **78**, the diodes **80** and **82**, the capacitor **79**, and the resistors associated with that transistor and those diodes coact with the capacitor **84** to couple the positive-going components of the signals from transistor **72** to the base of transistor **86**, and to invert the negative-going components of those signals and then apply those inverted components to the base of that transistor. The capacitor **84** will tend to remove some low frequency components such as noise from the signals which it couples to the base of the transistor **86**. Also that capacitor will tend to attenuate the "P" waves and the "T" waves of the person's characteristic electrocardiograph waveform; and, in doing so, it will tend to keep those "P" waves and "T" waves from triggering the rate network of the heart rate circuit.

The transistor **86** is connected as an emitter follower; and the capacitor **88** couples the signals at the emitter of that transistor to the base of transistor **90**. The latter transistor is connected as a stage of amplification, and it will amplify and invert the signals which appear at the emitter of the transistor **86**. The diode **92** will bypass to ground the positive-going components of the signals which appear at the collector of the transistor **90**; and, as a result, the capacitor **93** will couple only negative-going components to the base of the transistor **94**. The latter transistor also is connected as a stage of amplification and it will amplify and invert the negative-going signals coupled to the base thereof by the capacitor **93**. The transistor **95** is connected as an emitter follower; and hence it will respond to positive-going signals applied to the base thereof to apply positive-going signals to the capacitor **96**.

That capacitor, resistor **98**, and conductor **101** will couple those positive-going signals to the input of phase-shift oscillator **99** in FIG. 2C, which is connected as a filter. That oscillator has the components thereof dimensioned to enable it to be shock-excited only by signals having frequencies close to 25 c.p.s. The output of that phase-shift oscillator is coupled by capacitor **111** and resistor **113** to the input of phase-shift oscillator **115**, which also is connected as a filter. The components of the latter phase-shift oscillator also are dimensioned to enable that oscillator to be shock-excited only by signals having frequencies close to 25 c.p.s. The cascaded phase-shift oscillators **99** and **115** are particularly effective in rejecting signals and noise having frequencies appreciably below and appreciably above 25 c.p.s. This is important; because the electrodes affixed to the body of a person can have signals applied to them which have frequencies that are fairly close to the desired frequency of 25 c.p.s. For example, the inflatable cuff **538** will apply an occluding force to the artery in the person's finger at a frequency of 60 c.p.s., and the electrodes to which the terminals **30** and **32** are connected can sometimes sense a signal of that frequency. Also, the pulse of a person can develop signals having frequencies below 15 c.p.s. Further, muscular movements and changes in the position of a person's body can cause signals of composite frequencies to be applied to those electrodes; and some of those frequencies can be fairly close to the desired frequency of 25 c.p.s. It would be undesirable to permit any of those signals to pass to the rate circuit **105** of the heart rate circuit, and the cascaded phase-shift oscillators **99** and **115** substantially completely reject such signals. As a result, the output from the phase-shift oscillator **115** is essentially a 25 c.p.s. signal; and that signal initially goes positive but, as that oscillator becomes shock-excited, goes heavily negative.

The negative-going signal from the output of the phase-shift oscillator **115** is coupled to the base of the transistor **119** by the capacitor **117**; and that transistor is connected as a stage of amplification. That transistor will amplify and invert the signals applied to the base thereof thereby making those signals positive-going. The collector of the transistor **119** is connected to the base of the transistor **121**; and the latter transistor is connected as an emitter follower. The level detector **120** will sense the level of the positive-going signals appearing at the emitter of the transistor **121**, and it will apply to the capacitor **129** only those portions of those signals which exceed a predetermined level. That capacitor will couple those portions of those signals to the base of the transistor **131**; and that transistor is connected as a high gain amplification stage. That transistor also will invert the signals applied to the base thereof, and will thus make those signals negative-going. The diode **135** will bypass to ground any positive-going components of the amplifier signals at the collector of the transistor **131**; and the capacitor **141** will couple the negative-going amplified signals to the input of the monostable multivibrator **145**.

The components of the level detector **120** will preferably be dimensioned so only one particular wave of each electrocardiograph waveform will have sufficient amplitude to exceed the threshold value of that level detector. Because the "R" wave of an electrocardiograph waveform will usually have an amplitude greater than the amplitude of any other wave of that waveform, the components of the level detector **120** will usually be dimensioned so only the upper portion of the "R" wave of a person's characteristic electrocardiograph waveform will exceed the threshold value of that level detector.

The right-hand transistor of the monostable multivibrator **145** will normally be conductive, and the left-hand transistor of that monostable multivibrator will normally be nonconductive. Each negative-going signal which corresponds to the "R" wave of a characteristic electrocardiograph waveform and which is applied to the base of that right-hand transistor will render that transistor nonconductive, and will render that left-hand transistor conductive. The resulting decrease in current flow through the collector resistor of that right-hand terminal will provide a positive voltage at the output of that monostable multivibrator; and that positive voltage will remain at that output for 100 milliseconds. Thereafter, the right-hand transistor of that monostable multivibrator will again become conductive and the left-hand transistor of that monostable multivibrator will again become nonconductive.

The positive voltages which appear at the output of the monostable multivibrator **145**, whenever "R" waves are sensed by the level detector **120**, will be coupled to the terminal **100** by the capacitor **147** and the diode **149**, will be applied by conductor **137** to the rate circuit **105** which includes the resistor **104** and the capacitor **102**, and will be coupled to the base of transistor **136** by conductor **137**, capacitor **132**, and resistor **138**. The positive voltages applied to the rate circuit **105** will charge the capacitor **102** and will thereby develop a voltage across that capacitor. The positive-going pulses which are coupled to the base of the transistor **136** by the capacitor **132** and the resistor **138** will render that transistor conductive; and, whenever that transistor is rendered conductive, it will discharge the capacitor **144**. During the intervals between the positive-going pulses from the monostable multivibrator **145**, current flowing from terminal **51** via conductor **50**, resistor **142**, and capacitor **144** to the conductor **53** will charge that capacitor. The time constant of the series-connected resistor **142** and capacitor **144** will be long enough to keep the voltage developed across that capacitor from rendering the transistor **134** conductive, unless that capacitor is permitted to charge uninterruptedly for at least 5 seconds. This means that if the transistor **136** receives at least one pulse from the monostable multivibrator **145** during every 5 seconds, that transistor will discharge the capacitor **144** at least once every 5 seconds and will thus keep that capacitor from charging sufficiently to render the transistor **134** conductive.

On the other hand, if the person's heart did not, for a period as short as 5 seconds, develop an electrocardiograph waveform including an "R" wave capable of actuating the level detector **120**, the monostable multivibrator **145** would be unable to provide a pulse which could render the transistor **136** conductive. In that event, the capacitor **144** would not be discharged; and, instead, would be able to charge uninterruptedly for 5 seconds. The voltage across that capacitor would increase to the point where it would render the transistor **134** conductive; and, as that transistor became conductive, current would flow from the upper terminal of capacitor **102** via junction **103**, diodes **148** and **150**, and the collector-emitter circuit of transistor **134** to ground. The resulting discharging of the capacitor **102** would cause the needle of the heart rate meter **33** to fall to zero. As that needle so fell, it would intercept the light beam between the lamp and photocell of the adjustable lower limit of that meter, and hence would cause the lamp **39** of the lower limit alarm circuit to be illuminated. Also, it would cause an alarm circuit, not shown, which included an audible signal to be actuated; and hence the operator of the control system would immediately be alerted to the fact that the patient's heart did not, for a period of 5 seconds, develop a characteristic waveform with an "R" wave that exceeded the threshold value of the level detector **120**.

The voltage developed across the capacitor **102** of the rate circuit **105** will be coupled to the base of the transistor **110** of the operational amplifier enclosed within the block **106**. That operational amplifier will respond to that voltage to develop a DC voltage level, and it will apply that voltage level to the input of the heart rate meter **33**. The time constant of that rate circuit will be long enough to avoid wide swings of the needle of that meter — even when the heart rate of the person is abnormally low.

In most instances, the heart rate of a person will be fairly regular; and, once the needle of the heart rate meter **33** has moved to a position indicating that heart rate, the operator of the control system can move the upper and lower adjustable alarm limits of that meter close to that position. If, subsequently, the heart rate of the person increases to a value above the upper alarm limit, the needle of that meter will intercept the light beam between the lamp and photocell of that upper alarm limit and will cause the lamp **41** of the upper alarm limit to become illuminated. Also, it will cause an alarm circuit, not shown, which includes an audible signal to be actuated. Immediately, therefore, the operator of the control system provided by the present invention will be alerted to the fact that the heart rate of the person has increased above the preset upper limit.

If, on the other hand, the heart rate of the person decreases to a value below the lower alarm limit, the needle of that meter will intercept the light beam between the lamp and photocell of that lower alarm limit and will cause the lamp 39 of that lower limit alarm circuit to become illuminated. Also, it will cause the alarm circuit, not shown, which includes the audible alarm to be actuated. Immediately, therefore, the operator of the control system will be alerted to the fact that the heart rate of the person has decreased below the preset lower limit.

Because the rate circuit 105 has a relatively long time constant, the capacitor 102 could not respond to a cardiac arrest to discharge quickly. However, the transistors 134 and 136 and the capacitor 144 will promptly discharge the capacitor 102, and thus permit the needle of the meter 33 to actuate the lower limit alarm of that meter, in the event of a cardiac arrest — all as explained hereinbefore.

The resistor 124 and the potentiometer 126 constitute a voltage divider connected between the conductor 139 and ground, and the movable contact of that potentiometer can be adjusted to "zero" the operational amplifier 106. Specifically, that movable contact can be adjusted so the operational amplifier 106 will provide an output of zero volts whenever no signals are applied to the rate circuit 105. The resistor 128 and the adjustable resistor 130 provide the calibration for the output of the operational amplifier 106. Specifically, the movable contact of the adjustable resistor 130 can be adjusted to set the output at the emitter of the transistor 114 so the number of heart beats indicated by the needle of the heart rate meter 33 will correspond directly to the number of "R" waves per minute developed by the person's heart.

The diodes 148 and 150 are desirable, because they will keep the needle of the heart rate meter 33 from moving downwardly below the zero position thereof whenever the person's heart does not, for a period of 5 seconds, develop a characteristic cardiograph waveform including an "R" wave having an amplitude exceeding the threshold value of the level detector 120. Absent the series-connected diodes 148 and 150, the capacitor 102 of the rate circuit 105 could discharge until the voltage at the junction 103 was essentially zero; and, in such event, the needle of the heart rate meter 33 might move below the zero position thereof. With those diodes, however, the voltage at the junction 103 will tend to remain at least 1 volt above ground potential.

OPERATION OF RESPIRATION RATE CIRCUIT

The terminals 552 and 554 are connected, respectively, to the terminals 30 and 32 of the heart rate circuit, and thus are connected to the electrodes affixed to the body of the person. A free-running multivibrator in the block 590 will develop a 50 kc. waveform, and conductor 49 and the capacitors 592 and 594 will apply that 50 kc. waveform to the bases of the transistors 574 and 576. Those transistors will act as a constant current generator, and they will apply that 50 kc. waveform to the tuned circuit which includes the capacitor 566 and the primary winding 564 of the transformer 562. The secondary winding 560 of that transformer will coact with the capacitors 556 and 558, the terminals 552 and 554, and the electrodes affixed to the body of the person to couple that 50 kc. waveform to that person's body. The transthoracic impedance of that person's body will change as that person breathes, and that change in transthoracic impedance will appear as a change in "loading" on the secondary winding 560 of the transformer 562; and that transformer will reflect that change in "loading" back through the primary winding 564, junction 568, and conductor 109 to the block 590. As pointed out in detail in the said Horn and Kuni patent application, most of the 50 kc. waveform in the signals applied to the block 590 will be bypassed to ground; and, as a result, that block will provide a substantially ripple-free signal which corresponds to the respiration rate of the person. That signal will be amplified and will have the frequency thereof quadrupled in the block 572 and will then be applied to the input of the respiration rate meter 37. That meter will be calibrated so it will respond to the quadrupled-frequency signal to provide a reading which is directly proportional to the actual respiration rate of the person.

The high frequency signal developed by the free-running multivibrator in the block 590 is important in preventing polarization of the electrolyte that is used to assure good electrical contact between the skin of the person and the electrodes affixed to that skin. That electrolyte will tend to coact with that skin and with the metal of those electrodes to constitute electric batteries, and to develop a DC voltage between each of those electrodes and the person's skin. Such voltages would not be desirable; and they are completely obviated by the depolarization action of the high frequency signal which is passed continuously through the electrolyte by the respiration rate circuit.

The respiration rate of a person normally is fairly constant, and the needle of the respiration rate meter 37 will provide a substantially steady indication of that rate — even where that respiration rate is abnormally low. Consequently, the upper alarm limit and the lower alarm limit of that respiration rate meter can be set close to the normal respiration rate of the person. If the respiration rate of that person increases sufficiently to cause the needle of the respiration rate meter 37 to intercept the light beam between the lamp and photocell of the upper alarm limit of that meter, the alarm circuit which includes the lamp 45 will illuminate that lamp. Also, that needle can actuate an alarm circuit, now shown, which includes an audible alarm; and hence that meter can immediately alert the operator of the control system to the fact that the respiration rate of the person has increased above its normal level. Similarly, if the respiration rate of the person decreases sufficiently to cause the needle of the respiration rate meter 37 to intercept the light beam between the lamp and photocell of the lower alarm limit of that meter, the alarm circuit which includes the lamp 43 will illuminate that lamp. Also, that needle can actuate an alarm circuit, not shown, which includes an available alarm; and hence that meter can immediately alert the operator of the control system to the fact that the respiration rate of the person has decreased below its normal level.

OPERATION OF BLOOD PRESSURE CIRCUIT

As pointed out hereinbefore, the pump controller 371 will cause the controlled rectifier 442 thereof to actuate the pump 540, and thereby cause that pump to introduce sufficient air into the reservoir 534 to pressurize the inflatable cuff 538. As the pressure in that inflatable cuff increases, it will reach a level at which that inflatable cuff will occlude the artery in the finger of the person; and, thereupon, perceptibly audible Korotkoff sounds will develop. The microphone 158 will sense those perceptibly audible Korotkoff sounds; and capacitor 160 will couple those sounds to the gate of the field effect transistor 162. The source of that field effect transistor is directly connected to the base of the transistor 174 of the cascaded band-pass filter and amplifier 259; and that cascaded band-pass filter and amplifier will enhance all signals having frequencies in the range of 40 c.p.s. through 120 c.p.s. but will sharply attenuate signals having frequencies appreciably below 40 c.p.s. and appreciably above 120 c.p.s. The pulse of the person will cause signals to develop in that person's finger, and the microphone 158 will sense those signals; but those signals will have frequencies below 15 c.p.s., and hence those signals will be sharply attenuated by the cascaded band-pass filter and amplifier 259. Also, transients and noise which can be caused by muscular movements or by movements of the person's body can develop signals which will be sensed by the microphone **158**; but where those signals have frequencies appreciably below 40 c.p.s. or appreciably above 120 c.p.s., those signals will be sharply attenuated by the cascaded band-pass filter and amplifier **259**. The overall result is that the cascaded band-pass amplifier and filter **259** will develop at the output thereof a signal which corresponds to the perceptibly audible Korotkoff sounds sensed by the microphone **158**, and which is largely devoid of signals having frequencies appreciably below 40 c.p.s. or appreciably above 120 c.p.s.

The emitter of the transistor **256** is the output of the cascaded band-pass filter and amplifier **259**, and that emitter is coupled to the junction **268** by the conductor **274** and the capacitor **272**. The collector of the transistor **247** is the output of the monostable multivibrator **239**, and that output is connected to that junction by the diode **270**. The And gate **295** will normally isolate the junction **268** from the base of transistor **282**; but whenever both the cascaded band-pass filter and amplifier **259** and the monostable multivibrator **239** are applying signals to that junction, that And gate will couple that junction to the base of transistor **282**.

Specifically, adjustable resistor **264**, resistor **266**, junction **268**, and resistor **276** constitute a voltage divider connected between the conductors **165** and **233**; and that voltage divider will tend to establish a slightly negative voltage at the anodes of diodes **270** and **284**. However, diode **270**, the collector-emitter circuit of transistor **247**, diode **249**, and resistor **243** are connected in series with each other and in parallel with the resistor **276**; and variations in the conductivity of that collector-emitter circuit can vary the voltage applied to the anodes of the diodes **270** and **284**. For example, whenever the transistor **247** is nonconductive, the voltage at the junction **268** will be slightly negative, and will only moderately back-bias the diode **284**; but whenever that transistor is conductive, that voltage will be heavily negative, and it will sharply back-bias that diode. The transistor **247** will normally be conductive, and hence the diode **284** will normally be sharply back-biased.

When the monostable multivibrator denoted by numberal **145** in FIG. 2C develops a rectangular positive-going pulse of 100 milliseconds duration and applies that pulse to the terminal **100**, that pulse will be applied to the terminal **263** and will then be coupled by the conductor **265** and the capacitor **260** to the input of the monostable multivibrator **217**. The latter monostable multivibrator will promptly render the transistor **221** thereof conductive and the transistor **225** thereof nonconductive; and it will thus develop a positive-going pulse at the collector of the latter transistor. That pulse will have a duration of 130 milliseconds, and it will be coupled to the base of transistor **247** by the capacitor **262**. That pulse will not affect the conductivity of that transistor, because that transistor is normally conductive.

The transistor **225** of the monostable multivibrator **217** will remain nonconductive for the said 130 milliseconds, but will thereafter again become conductive. The resulting negative-going pulse at the collector of that transistor will be coupled to the base of transistor **247** by the capacitor **262**; and that negative-going pulse will render the latter transistor nonconductive — and the monostable multivibrator **239** will keep that latter transistor nonconductive for 170 milliseconds. This means that the voltage at the junction **268** will be only slightly negative, and that the diode **284** will be only moderately back-biased, for a period of 170 milliseconds.

The 130-millisecond period established by the monostable multivibrator **217** was initiated at the instant the person's heart contracted to start blood surging through that person's arteries. During that 130-millisecond period, part of that blood was moving toward, but had not reached, that person's fingers; and not until after the beginning of the 170-millisecond period could that blood reach the person's finger wherein the artery was being occluded. Because the diode **284** was sharply back-biased during the said 130-millisecond period, no sounds that were sensed by the microphone **158** during that period could forward-bias that diode — and this is desirable because those sounds would not be Korotkoff sounds. However, after the beginning of the 170-millisecond period, the diode **284** was only moderately back-biased; and the cascaded band-pass filter and amplifier **259** could respond to signals, developed by the microphone **158** in response to perceptibly audible Korotkoff sounds, to apply positive-going signals to the junction **268** which would forward-bias the diode **284**.

At the end of the 170-millisecond period, the monostable multivibrator **239** will again render the transistor **247** conductive; and, thereupon, the diode **284** will again be sharply back-biased. Thereafter, until a further contraction of the person's heart causes the heart rate circuit to apply a positive-going signal to the input of the monostable multivibrator **217**, and that monostable multivibrator has — after a delay of 130 milliseconds — again caused the monostable multivibrator **239** to render the transistor **247** nonconductive for 130 milliseconds, the diode **284** cannot again be forward-biased. The overall result is that the sounds sensed by the microphone **158** will be wholly unable to cause forward-biasing of the diode **284** except during the 170-millisecond periods, between adjacent heart contractions of the person, wherein the microphone **158** should be able to sense perceptibly audible Kortkoff sounds.

When the microphone **158** senses perceptibly audible Korotkoff sounds during the 170-millisecond period when the transistor **247** is nonconductive, the signals at the output of the cascaded band-pass filter and amplifier **259** will be coupled to the junction **268** by the capacitor **272**; and those signals will forward-bias the diode **284**. Thereupon, the transistor **278** will become conductive; and the resulting flow of current from conductor **165** through resistors **286** and **288** and the collector-to-emitter circuit of that transistor will provide a negative-going pulse at the base of transistor **282**. The latter transistor will then become conductive and will apply a positive-going pulse to the base of transistor **280**, thereby immediately rendering the latter transistor conductive.

As the transistors **280** and **282** become conductive, current will flow from conductor **165** via resistor **286**, transistor **280**, resistors **294** and **296**, the base-emitter circuit of transistor **298**, and resistor **316** to the conductor **233**; and further current will flow from conductor **165** via transistor **282**, resistor **292**, the resistors **294** and **296**, the base-emitter circuit of transistor **298**, and resistor **316** to the conductor **233**. The amount of current flowing through the base-emitter circuit of the transistor **298** will render that transistor conductive; and the resulting increase in current flowing through the resistor **302** will develop a negative-going pulse at the base of the transistor **312**, thereby rendering that transistor nonconductive. As a result, a positive-going signal will develop at the collector of that transistor; and that signal will be applied by the fixed and movable contacts **320** and **322** of switch **323**, the junction **324**, and the resistor **338** to the base of transistor **336**. That signal will render the latter transistor conductive, and will thus connect the capacitor **402** in parallel with the capacitor **354**. As explained hereinbefore in OPERATION OF PUMP CONTROLLER, the connecting of capacitor **402** in parallel with the capacitor **354** will prolong the charging time of the latter capacitor, will cause the unijunction transistor **340** and the controlled rectifier **442** to become conductive later in the positive-going half-cycles of the AC applied to the terminal **342**, and will reduce the "on" times of that controlled rectifier. Thereupon, pressurization of the inflatable cuff **538** will end and depressurization of that inflatable cuff will begin.

The transistor **282** and the resistors **292** and **294** are connected in series with each other and in parallel with the capacitor **300** of the timer **319**. Similarly, the resistor **286**, the transistor **280**, and the resistor **294** are connected in series with each other and in parallel with that capacitor. Whenever those transistors are nonconductive, that capacitor will start charging; but whenever those transistors are conductive, that capacitor will discharge through those transistors. Specifically, whenever the transistors **280** and **282** are nonconductive, the capacitor **300** will respond to current flowing from terminal **161** via conductor **165**, capacitor **300**, resistor **296**, the base-emitter circuit of transistor **298**, resistor **316**, and conductor **233** to the terminal **261** to start charging. The capacitance of that capacitor and the sum of the ohmic resistances of resistors **296** and **316** and of the base-emitter circuit of transistor **298** will coact to provide a time constant for that timer which will be long enough to enable enough current to flow through that capacitor and through the base-emitter circuit of the transistor **298**, for 1½ seconds, to keep that transistor conductive. At the end of that 1½ seconds, the amount of current flowing through that capacitor and through the base-emitter circuit of transistor **298** will decrease to the point where that transistor will become nonconductive. Thereupon, the transistor **312** will again become conductive, and will render the transistor **336** nonconductive once again. The capacitor **402** will, at such time, be effectively isolated from the capacitor **354**; and the latter capacitor will charge, once again, at its normal rate. This means that the unijunction transistor **340** and the controlled rectifier **442** will become conductive earlier in the positive-going half-cycles of the AC applied to the terminal **342**, and will increase the "on" times of that controlled rectifier. Thereupon, depressurization of the inflatable cuff **538** will end and repressurization of that inflatable cuff will begin.

If at any time during the charging of the capacitor **300** the transistors **280** and **282** become conductive, those transistors will discharge that capacitor; and will thus require the timer **319** to start its charging period of one 1½ seconds all over again. Because the transistors **280** and **282** will be rendered conductive whenever signals, corresponding to perceptibly audible Korotkoff sounds, are being applied to the junction **268** by the cascaded band-pass filter and amplifier **259** — during the 170-millisecond period established by the monostable multivibrator **239** — the capacitor **300** will be unable to start its 1½-second charging period until after the perceptibly audible Korotoff sounds have disappeared. However, 1½ seconds after the last perceptibly audible Korotkoff sounds have been sensed, the capacitor **300** will have charged sufficiently to reduce the base-emitter current through the transistor **298** to the point where that transistor again becomes nonconductive.

It will thus be apparent that the blood pressure circuit provided by the present invention utilizes signals corresponding to perceptibly audible Korotkoff sounds to terminate the pressurization of the inflatable cuff **538** and to start depressurization of that inflatable cuff, uses those signals to continue depressurization of that inflatable cuff until the last perceptibly audible Korotkoff sound is sensed, and then continues the depressurization of that inflatable cuff for 1½ seconds. The use of signals, corresponding to perceptibly audible Korotkoff sounds, to halt pressurization of the inflatable cuff **538** is desirable; because it obviates all need of using a pressure greater than the pressure actually needed to occlude the artery in the person's finger. As a result, the minimum pressure which can be used is the pressure that is used. The use of a timer to iniate repressurization of the inflatable cuff **538** is desirable; because it enables the reverse bias on the diode **284** to be made large enough to keep random signals and noise applied to the junction **268** from forward-biasing that diode during the 170-millsecond period established by the monostable multivibrator **239**, and yet makes certain that the pressure within that inflatable cuff will drop below the level of the person's diastolic blood pressure. Absent the timer **319**, the reverse bias on the diode **284** would have to be made quite small during the 170-millisecond period established by the monostable multivibrator **239** — so that even the barely audible Korotkoff sounds could develop signals which would continue the depressurization of the inflatable cuff **538** until the pressure in that inflatable cuff was below the person's diastolic blood pressure — and such a small bias could permit random signals and noise applied to the junction **268** to forward-bias that diode and unduly continue the depressurization of that inflatable cuff.

The 1-1/2-second period provided by the timer **319** can be shortened or lengthened, as desired; but that period should always be slightly longer than the period of time between successive Korotkoff sounds. If that period was made shorter than the period of time between successive Kortokff sounds, the timer **319** might coact with the transistors **298, 312** and **336** to start repressurization of the inflatable cuff **538** while perceptibly audible Korotkoff sounds were still being sensed — and thus at a time when the pressure in that inflatable cuff was still at or above the diastolic blood pressure of the person.

The time required for blood to flow from the heart to the finger of a person will vary from person to person; but it will almost invariably be longer than 130 milliseconds but shorter than 300 milliseconds. Consequently, the blanking period of 130 milliseconds will practically never blank out any perceptibly audible Korotkoff sounds; and the perceptibly audible Korotkoff sounds will almost invariably be developed during the 170-millisecond period when the diode **284** is only moderately back-biased.

If a person's diastolic blood pressure is below 40 mm. of mercury, the cascaded band-pass filter and amplifer **259** may coact with the microphone **158** and the monostable multivibrators **217** and **239** to render the transistor **336** conductive even before the pressure in the inflatable cuff **538** reaches 40 mm. of mercury. However, the resulting paralleling of capacitors **354** and **402** will only retard, and will not halt, the pressurization of that inflatable cuff; because the series-connected resistors **368, 370, 382** and **396** and diode **398**, as well as the series-connected resistor **404** and adjustable resistor **406**, will be supplying current to those capacitors. As soon as the pressure in the inflatable cuff **538** reaches 40 mm. of mercury, the controlled rectifier **386** will become conductive and will back-bias the diode **398**; and the capacitors **354** and **402** will no longer receive current through the series-connected resistors **368, 370, 382** and **396** and diode **398** — receiving current primarily through the series-connected resistor **404** and adjustable resistor **406**. The resulting longer charging time of the capacitor **354** will reduce the "on" times of unijunction transistor **340** and of controlled rectifier **442** to such an extent that air will exhaust from the reservoir **534** through the vent **536** at a greater rate than the pump **540** can introduce air into that reservoir. Thereupon, the pressure within the inflatable cuff **538** will decrease until 1½ seconds after the last perceptibly audible Korotkoff sound is sensed by the microphone **158**. Subsequently, the pump controller **371** and the blood pressure circuit will cause the pressure in that inflatable cuff, and hence at the pressure transducer **544**, to rise to and then fall slightly below that person's diastolic blood pressure and the blood pressure meter **546** will indicate that blood pressure.

As pointed out hereinbefore, the cascaded band-pass filter and amplifier **259** is very desirable because it provides sharp rejection of signals having frequencies appreciably below 40 c.p.s. or appreciably above 120 c.p.s. That cascaded band-pass filter and amplifier also is very desirable because it obviates all need of a gain control adjustment.

The diastolic blood pressure of a person normally is fairly constant and the needle of blood pressure meter **546** will provide a close indication of that blood pressure during each pressure-sensing cycle — even where that blood pressure is abnormally high or low. Consequently, the upper alarm limit and the lower alarm limit of that blood pressure meter can be set close to the normal diastolic blood pressure of the person. If the diastolic blood pressure of that person increases sufficiently to cause the needle of blood pressure meter **546** to interrupt the beam of light between the lamp and photocell of the upper alarm limit of that meter, the alarm circuit which includes lamp **550** will illuminate that lamp. Also, that needle can actuate an alarm circuit, not shown, which includes an audible alarm; and hence that meter can immediately alert the operator of the control system to the fact that the diastolic blood pressure of the person has increased above its normal level.

Similarly, if the diastolic blood pressure of the person decreases sufficiently to cause the needle of blood pressure meter **546** to interrupt the beam of light between the lamp and photocell of the lower alarm limit of that meter, the alarm circuit which includes lamp **548** will illuminate that lamp. Also, that needle can actuate an alarm circuit, not shown, which includes an audible alarm; and hence that meter can immediately alert the operator of the control system to the fact that the diastolic blood pressure of the person has decreased below its normal level.

OPERATION OF TIMER 369

The pump controller **371**, the heart rate circuit, the respiration rate circuit, and the blood pressure circuit will become energized as soon as the switch **35** is closed. Also, the timer **369** will become energized as soon as that switch is closed. Specifically, as soon as the switch **35** is closed, current will flow from terminal **161** via conductors **165** and **364**, resistor **368**, resistor **355**, capacitor **357**, and conductors **374** and **233** to the terminal **261**; and that flow of current will start charging the capacitor **357**. That capacitor and the resistor **355** have a long time constant; and, in the said one perferred embodiment of control system, that capacitor and resistor have a time constant longer than 1 minute. As a result, the voltage across the capacitor **357** will initially be too small to render the transistor **366** conductive, and it will continue throughout 1 minute to be too small to render that transistor conductive.

At the instant current started flowing through resistors **368** and **355** and capacitor **357** to charge that capacitor, current also started flowing through resistors **368**, **370**, **380** and **384** and conductors **374** and **233** to the terminal **261**; and that current developed a positive voltage at the base of transistor **376** and rendered that transistor conductive. Thereupon a negative voltage appeared at the collector of that transistor; and that negative voltage back-biased the diode **430**, thereby keeping the transistor **432** from becoming conductive. Because that transistor is nonconductive, the junctions **400** and **408** are isolated from ground; and a voltage can be developed across the capacitor **354**.

As the voltage at the collector of transistor **376** becomes negative, current will flow from terminal **161** via conductors **165** and **448**, resistors **446** and **450**, conductor **452**, the collector-emitter circuit of transistor **376**, resistor **372**, and conductors **374** and **233** to the terminal **261**. The resulting voltage drop across resistor **446** will make the base of transistor **441** less positive than the emitter of that transistor, thereby rendering that transistor conductive; and, thereupon, current will flow from terminal **161** via conductors **165** and **448**, the emitter-collector circuit of transistor **441**, resistors **462** and **460**, and conductors **374** and **233** to the terminal **261**. The consequent voltage drop across the resistor **460** will render the transistor **456** conductive; and, immediately, current will flow from conductor **31** in FIG. **1** via lamp **454** in FIG. **2B**, terminal **455**, the collector-emitter circuit of transistor **456**, and conductors **374** and **233** to the terminal **261**. The resulting illumination of that lamp will indicate to the operator of the control system that the diastolic blood pressure of the person is to be sensed. Also, as the transistor **456** becomes conductive, the collector-emitter circuit thereof will coact with the terminal **455** and with the conductor **547** to connect the conductor **374** to the negative terminal of the blood pressure meter **546**. Consequently, the needle of that blood pressure meter will be able to start indicating the person's blood pressure.

All of this means that as the switch **35** is closed, the diode **430** will be back-biased to keep the transistor **432** nonconductive so the capacitor **354** can charge, and the transistor **441** will become conductive to enable the transistor **456** to become conductive and illuminate the lamp **454** and connect the negative terminal of the blood pressure meter **546** to the conductor **374**. During the ensuing minute, the pump controller **371**, the fast pressurization subcircuit **399**, and the blood pressure circuit will increase the pressure within the reservoir **534** and within the inflatable cuff **538** at the rapid pressurization rate until that pressure is equal to 40 mm. of mercury; and will thereafter successively cause the pressure in that reservoir and inflatable cuff to rise to and then fall slightly below the diastolic blood pressure of the person.

After the capacitor **357** has charged for 1 minute, the voltage across that capacitor will apply a sufficiently positive voltage to the base of transistor **366** to render that transistor conductive. The resulting negative-going signal at the collector of that transistor will be applied to the base of transistor **376**; and the latter transistor will respond to that signal to become nonconductive. The resulting increase in voltage at the collector of the transistor **376** will prevent further flow of current from terminal **161** via conductors **165** and **448**, resistors **446** and **450**, conductor **452**, the collector-emitter circuit of transistor **376**, resistor **372**, and conductors **374** and **233** to the terminal **261**; and hence the voltage at the base of transistor **441** will become as positive as the voltage at the emitter of that transistor — with a consequent rendering of that transistor nonconductive. As that transistor becomes nonconductive, the transistor **456** also will become nonconductive and will darken the lamp **454** and disconnect the negative terminal of the blood pressure meter **546** from the conductor **374**.

As the voltage at the collector of transistor **376** becomes positive, the diode **430** will become forward-biased; and, thereupon, current will flow from terminal **161** via conductors **165** and **364**, resistor **378**, diode **430**, and resistors **428** and **426** to ground. The resulting positive voltage at the base of transistor **432** will render that transistor conductive; and that transistor will effectively reduce the voltages at the junctions **400** and **408** to ground potential. At such time, the capacitor **354** cannot become charged, and the unijunction transistor **340** and the controlled rectifier **442** cannot be rendered conductive. Thereupon, the pump **540** will become inactive; and any pressure within the reservoir **534** and within the inflatable cuff **538** will be dissipated.

As the transistor **366** becomes conductive, the capacitor **357** will start discharging through resistor **353**, the base-emitter circuit of that transistor, and resistor **372**. The sum of the ohmic values of resistors **353** and **372** will be large enough so substantially 4 minutes will be needed for enough of the charge stored within the capacitor **357** to leak away to permit the base of transistor **366** to become negative, and thereby render that transistor nonconductive. This means that the pump **540** will be kept inactive for a total of 4 minutes; and the person's finger will be substantially free of pressure from the inflatable cuff **538** during those 4 minutes. At the end of the said 4 minutes, the transistor **366** will again become nonconductive, and the transistor **376** will again become conductive. As the latter transistor becomes conductive, the transistor **432** will again become nonconductive, the capacitor **354** will again start charging, and the lamp **454** will again be illuminated and the negative terminal of the blood pressure meter **546** will again be connected to the conductor **374**.

At the time the transistor **366** became conductive, the voltage at the collector of that transistor fell so close to ground potential that insufficient current was able to flow through the controlled rectifier **386** to keep that controlled rectifier conductive. Consequently, that controlled rectifier quickly became nonconductive; and that was desirable because it enabled the succeeding pressurization of the inflatable cuff **538** to start at the rapid pressurization rate.

The 1 minute "on" periods and the 4 minute "off" periods provided by the timer **369** are very desirable and useful. Those "on" periods provide a sufficiently representative indication of the person's diastolic blood pressure to permit adequate monitoring and studying of that blood pressure; and those "off" periods provide sufficient rest, between "on" periods, for the person's finger to enable a person to have his diastolic blood pressure monitored substantially continuously for many hours. However, if desired, the durations of the "on" periods can be shortened or lengthened, and the durations of the "off" periods can be shortened or lengthened.

If, at any time during an "off" period of the timer 369, the operator of the control systems wishes to initiate an "on" period of that timer, such an "on" period can be initiated by closing the pushbutton 359. The ohmic resistance of the resistor 351 is so small that the time constant of that resistor and of capacitor 357 will be extremely short; and hence the capacitor 357 will quickly discharge. As that pushbutton is released, the transistor 366 will be nonconductive, the transistor 376 will be conductive, and the pump controller 371 and the blood pressure circuit will start increasing the pressure within reservoir 534 and within inflatable cuff 538.

If the operator of the control system wishes to monitor the person's blood pressure on a continuous basis for a short period of time, the pushbutton 359 can be held closed for that short period of time. As long as that pushbutton is held closed, the transistor 366 will be nonconductive, the transistor 376 will be conductive, and the pump controller 371 and the blood pressure circuit will continuously cause the pressure in the inflatable cuff 538 to rise to and then fall slightly below the diastolic blood pressure of the person.

OPERATION OF METER INHIBITER

During each "off" period of the timer 369, the transistor 376 will be nonconductive; and hence the transistors 441 and 456 also will be nonconductive —all as explained hereinbefore. Because the transistor 456 will be nonconductive, the negative terminal of the blood pressure meter 546 will be effectively disconnected from the conductors 374 and 233; and this means that the needle of that blood pressure meter will be at zero whenever the timer 369 is "off".

During the ensuing "on" period of that timer, the needle of the blood pressure meter 546 will start moving upwardly toward the level of the person's diastolic blood pressure. It would be undesirable for that needle to effect illumination of the lamp 548 of the lower alarm limit circuit of that blood pressure meter as that needle passed through the beam of light between the lamp and photocell of the lower alarm limit of that blood pressure meter and the meter inhibiter 337 will keep that needle from so effecting illumination of the lamp 548. Specifically, the voltage divider which consists of resistors 302, 308 and 310 will normally render the transistor 312 conductive and the resulting negative voltage at the collector of that transistor, at the junction 324, and at the base of transistor 326 will normally keep the latter transistor conductive. The voltage at the collector of that latter transistor will be relatively close to ground potential; and the conductor 334 and the terminal 335 will apply that voltage to the "inhibit" terminal of the blood pressure meter 546. That voltage will be applied to the cathode of a diode within that blood pressure meter, and it will back-bias that diode and thereby keep either of the lamps 548 and 550 of the alarm limit circuits from being illuminated. Consequently, neither of the lamps 548 and 550 can be illuminated as long as the transistors 312 and 326 are conductive; and those transistors will remain conductive until the microphone 158 senses perceptibly audible Korotkoff sounds. All of this means that the meter inhibiter 337 will keep both of the lamps 548 and 550 from becoming illuminated until the needle of the blood pressure meter 546 reaches a position indicating the diastolic blood pressure of the person.

As soon as the microphone 158 senses perceptibly audible Korotkoff sounds, the transistor 312 will be rendered nonconductive; and it will immediately render the transistor 326 nonconductive. As the latter transistor becomes nonconductive, the voltage at the collector thereof, and hence at the terminal 335, will closely approach negative 12 volts; and, thereupon, the diode within the meter will become forward-biased. At such time, the inhibit circuit within the blood pressure meter 546 will be disabled; and if, at that time, the needle of that blood pressure meter is blocking the beam of light between the lamp and photocell of the lower alarm limit, the lamp 548 will become illuminated. Similarly if, at that time, the needle of that blood pressure meter is blocking the beam of light between the lamp and photocell of the upper alarm limit, the lamp 550 will become illuminated. Usually, the needle of the blood pressure meter 546 will not be blocking either of those beams of light, and hence both of the lamps 548 and 550 will usually remain dark.

The inhibit circuit within the blood pressure meter 546 will be disabled as soon as a perceptibly audible Korotkoff sound is sensed by the microphone 158; and that inhibit circuit will remain disabled until 1½ seconds after a perceptibly audible Korotkoff sound is heard. If, during that period of time, the diastolic blood pressure of the person falls below the lower alarm limit, the lamp 548 will become illuminated. Similarly if, during that period of time, the diastolic blood pressure of the person rises above the upper alarm limit, the lamp 550 will become illuminated.

Thereafter, the transistor 326 will again become conductive, and the voltage applied to the terminal 335 will again be relatively close to ground potential. That voltage will again "enable" the inhibit circuit within the blood pressure meter 546; and that inhibit circuit will keep either of the lamps 548 and 550 from becoming illuminated until further perceptibly audible Korotkoff sounds are sensed by the microphone 158. The meter inhibiter 337 will thus keep the blood pressure meter 546 from actuating any alarm circuit thereof until that blood pressure meter is indicating a person's blood pressure.

SENSING OF SYSTOLIC BLOOD PRESSURE

The control system provided by the present invention can, whenever desired, be used to sense the systolic blood pressure of a person —the shifting of the movable contacts 322, 325, 333 and 343 of the four-pole, double-throw switch 323 from their counterclockwise positions to their clockwise positions enabling such blood pressure to be sensed.

When the movable contact 322 is so shifted, it disconnects the collector of transistor 312 from the base of transistor 336 and it connects the collector of transistor 298 to that base; and it thereby enables Korotkoff sounds to cause negative-going rather than positive-going signals to be applied to that base. When the movable contact 325 is so shifted, it no longer helps "short" the resistor 329; and that resistor is then effectively connected in series with the resistor 390 between the conductor 392 and the gate of controlled rectifier 386. As a result, the pressure transducer 544 will have to sense a pressure considerably greater than 40 mm. of mercury before the operational amplifier 529 can develop a positive voltage that is great enough to render the controlled rectifier 386 conductive. When the movable contact 333 is so shifted, it connects the resistor 423 in parallel with the resistor 426 between the base of transistor 432 and ground, and thus reduces the ohmic value of the resistance across which the pressure-limiting subcircuit 431 must develop a voltage to render the transistor 432 conductive. As a result, the pressure transducer 544 will have to sense a pressure considerably greater than 200 mm. of mercury before the operational amplifier 529 can develop a positive voltage that will render the transistor 424 sufficiently conductive to cause the voltage across parallel-connected resistors 423 and 426 to be great enough to render the transistor 432 conductive. When the movable contact 343 in FIG. 2A is so moved, it will increase the negative feedback in the operational amplifier 529 and thus will reduce the overall gain of that operational amplifier. That reduction in overall gain will coact with the connection of resistor 329 in series with resistor 390 to require the pressure transducer 544 to sense a pressure of about 200 mm. of mercury before that operational amplifier can develop a positive voltage which is great enough to render the controlled rectifier 386 conductive. That reduction in overall gain also will coact with the connection of resistor 423 in parallel with resistor 426 to require that pressure transducer to sense a pressure of about 300 mm. of mercury before the operational amplifier 529 can develop a positive voltage that will render the transistor 424 sufficiently conductive to cause the voltage across parallel-connected resistors 423 and 426 to be great enough to render the transistor 432 conductive. That reduction in overall gain will require the pressure transducer **544** to sense a pressure of 300 mm. of mercury to provide full scale deflection of the needle of the blood pressure meter **546**; whereas the normal gain of the operational amplifier **529** enables the sensing of 200 mm. of mercury by the pressure transducer **544** to provide full scale deflection of the needle of that blood pressure meter. As a result that blood pressure meter will have two individually different scales —a diastolic blood pressure scale of 0—200 mm. of mercury, and a systolic blood pressure scale of 0—300 mm. of mercury.

With the movable contacts **322**, **325**, **333** and **343** of the switch **323** in their clockwise positions, closing of the switch **35** in FIG. **1** will cause the pump controller **371** of FIG. **2B** to initiate pressurization of the inflatable cuff **538** at a rate close to the rapid pressurization rate. Because the pressure in that inflatable cuff will initially be well below the diastolic blood pressure of the person, no Korotkoff sounds will be sensed by the microphone **158**; and hence the transistor **298** will be nonconductive, and the voltage at the collector of that transistor, and thus at the base of transistor **336**, will be positive. The latter transistor will be conductive; and it will connect the capacitor **402** in parallel with the capacitor **354** thereby tending to lengthen the charging time of the latter capacitor. However, the total current flowing through series-connected resistor **404** and adjustable resistor **406** and through series-connected resistors **368**, **370**, **382** and **296** and diode **298** will be great enough to make the "on" times of the controlled rectifier **442** long enough to cause the pump **540** to pressurize the inflatable cuff **538** at a rate close to the fast pressurization rate.

As the pressure in the inflatable cuff **538** causes that inflatable cuff to occlude the artery in the person's finger, Korotkoff sounds will develop; and those sounds will cause the transistor **298** to become conductive. The resulting negative-going signal at the collector of that transistor, and at the base of transistor **336**, will render the latter transistor nonconductive thereby effectively isolating the capacitor **402** from the capacitor **354**. At this time, the "on" times of the controlled rectifier **442** will lengthen; and that controlled rectifier will cause the pump **540** to pressurize the inflatable cuff **538** at the fast pressurization rate.

That pump will continue to pressurize that inflatable cuff at that fast pressurization rate until the pressure within that inflatable cuff reaches 200 mm. of mercury. At that time, the pressure transducer **544** and the operational amplifier **529** will, via terminals **395** and **394**, conductor **392**, and resistors **329** and **390**, apply a voltage to the gate-to-cathode circuit of controlled rectifier **386** which will render that controlled rectifier conductive. The resulting back-biasing of diode **398** will materially reduce the amount of charging current for the capacitor **354** —all as explained hereinbefore in OPERATION OF PUMP CONTROLLER — and hence the "on" times of the controlled rectifier **422** will decrease until the pump **540** pressurizes the inflatable cuff **538** at the normal pressurization rate. That pump will continue to pressurize that inflatable cuff at that rate until the pressure within that inflatable cuff reaches the systolic pressure of the person and halts any further development of Korotkoff sounds. That pump will continue to pressurize that inflatable cuff at that rate for an additional 1½ seconds, until the capacitor **300** charges sufficiently to render the transistor **298** non-conductive; but, as that transistor becomes nonconductive, a positive-going signal will be applied to the base of transistor **336** to render the latter transistor conductive. At such time, that latter transistor will again connect the capacitor **402** in parallel with the capacitor **354** —thereby ending the pressurization of the inflatable cuff **538** and beginning the depressurization of that inflatable cuff.

The pressure in the inflatable cuff **538** will decrease at the normal depressurization rate, and that pressure will decrease until enough blood can flow through the occluded artery to develop a Korotkoff sound. The resulting rendering of the transistor **298** conductive will develop a negative-going signal at the collector of that transistor, and hence at the base of transistor **336**; and the latter transistor will become nonconductive once again, and will again effectively isolate the capacitor **402** from the capacitor **354**. Thereupon, the pump controller **371** will repressurize the inflatable cuff **538** at the normal pressurization rate until the pressure in that inflatable cuff again halts further development of Korotkoff sounds. That pump controller will continue to repressurize the inflatable cuff **538** at the normal pressurization rate for 1½ seconds after the last Korotkoff sound is sensed by the microphone **158**; and then the transistor **298** will again become nonconductive and will again render the transistor **336** conductive.

In this way, the control system will cause the pressure in the inflatable cuff **538** to rise to, and then fall slightly below, the systolic blood pressure of the person. The pressure transducer **544** and the operational amplifier **529** will apply signals to the terminals **395** and **394**, and thus to the blood pressure meter **546**, which will enable the needle of that blood pressure meter to indicate, on the systolic pressure scale, the person's systolic blood pressure. That control system will continue to enable the needle of the blood pressure meter **546** to indicate the person's systolic blood pressure throughout the "on" time of the timer **369**.

At the end of that "on" time, the transistor **366** of that timer will become conductive and will render the transistor **376** nonconductive —all as explained hereinbefore in OPERATION OF TIMER **369**. The resulting forward-biasing of diode **430** will cause current to flow from terminal **161** via conductors **165** and **364**, resistor **378**, diode **430**, resistor **428**, and parallel-connected resistors **423** and **426** to ground; and the voltage drop across those parallel connected resistors will be great enough to render the transistor **432** conductive. The consequent grounding of the junctions **400** and **408** will render unijunction **340**, controlled rectifier **442**, and pump **540** inactive —and the pressure in the inflatable cuff **538** will quickly fall to the ambient pressure level.

At the end of the "off" time of the timer **369**, the control system will again pressurize the inflatable cuff **538** to 200 mm. of mercury at the fast pressurization rate, will then pressurize that inflatable cuff at the normal pressurization rate until no further Korotkoff sounds develop, will continue to pressurize that inflatable cuff at that normal pressurization rate for an additional 1½ seconds, and will then slowly depressurize that inflatable cuff until a Korotkoff sound is sensed by the microphone **158**. Thereafter, throughout the "on" time of the timer **369**, that control system will cause the pressure in the inflatable cuff **538** to rise to, and then fall slightly below, the systolic blood pressure of the person. The pressure transducer **544** and the operational amplifier **529** will apply signals to the terminals **395** and **394**, and thus to the blood pressure meter **546**, which will enable the needle of that blood pressure meter to indicate, on the systolic pressure scale, the person's systolic blood pressure.

If the systolic blood pressure of the person is less than 200 mm. of mercury, the transistor **298** may be rendered nonconductive and the transistor **336** may be rendered conductive while the pump controller **371** is pressurizing the inflatable cuff **538** at the fast pressurization rate. Where that is the case, the control system will initiate the depressurization of that inflatable cuff as soon as the pressure within that inflatable cuff reaches 200 mm. of mercury. That depressurization will continue until the pressure within that inflatable cuff falls far enough to permit a Korotkoff sound to develop; and, thereupon, that inflatable cuff will be pressurized at the normal pressurization rate. Thereafter, the control system will cause the pressure in the inflatable cuff **538** to rise to, and then fall slightly below, the systolic blood pressure of the person. The pressure transducer **544** and the operational amplifier **529** will apply signals to the terminals **395** and **394**, and thus to the blood pressure meter **546**, which will enable the needle of that blood pressure meter to indicate, on the systolic pressure scale, the person's systolic blood pressure.

In the event the pressure within the inflatable cuff **538** ever tended to exceed 300 mm. of mercury, the pressure transducer **544** and the operational amplifier **529** would apply a relatively large positive voltage to the terminals **395** and **394**. Current would then flow from terminal **394** via conductors **392** and **393**, resistor **422**, the emitter-base circuit of transistor **424**, diodes **436** and **438**, conductor **439**, junction **171**, and Zener diode **167** to ground; and that current would render that transistor conductive. The resulting flow of current from terminal **394** via conductors **392** and **393**, resistor **422**, the emitter-collector circuit of transistor **424**, and parallel-connected resistors **423** and **426** to ground would render the transistor **432** conductive —with consequent grounding of the junctions **400** and **408**. Thereafter the unijunction transistor **340**, the controlled rectifier **442**, and the pump **540** would become inactive and would remain inactive until the pressure in the inflatable cuff **538** fell below 50 mm. of mercury.

During the "on" periods of the timer **369**, the needle of the blood pressure meter **546** will hover close to a position equivalent to the systolic blood pressure of the person. As a result, the upper alarm limit and the lower alarm limit of that blood pressure meter can be set close to that position after the needle of that blood pressure meter is close to the position equivalent to the systolic blood pressure of the person. The alarm circuits associated with those upper and lower alarm limits will immediately alert the operator of the control system in the event the person's systolic blood pressure unduly increases or decreases.

During the "off" periods of the timer **369**, the needle of the blood pressure meter **546** will fall to zero; and during the ensuing "on"period of that timer, that needle will again move up to the position equivalent to the systolic blood pressure of the person. Because the meter inhibit circuit **337** is able to inhibit the alarm circuits of that blood pressure meter only until a Korotkoff sound is sensed by the microphone **158**, and because many Korotkoff sounds will usually be sensed by that microphone before the pressure in the inflatable cuff **538** reaches the systolic pressure of the person and halts the further development of Korotkoff sounds, it will usually be desirable to set the lower alarm limit of the blood pressure meter **546** below the level of the diastolic blood pressure of the person. Where that is done, undesired actuation of the lower alarm unit signal circuits can be avoided.

CONCLUSION

The said preferred embodiment of control system provided by the present invention can continuously sense and indicate the heart rate and the respiration rate of a person; and it can substantially continuously sense and indicate the diastolic blood pressure or the systolic blood pressure of that person. As indicated previously herein, that embodiment of control system will keep potentially hurtful positive and negative DC voltages and currents therein from reaching that person —even if a component of that embodiment of control system becomes "shorted". That embodiment of control system also will "fail-safe", insofar as pressure within the inflatable cuff **538** is concerned, in the event the power to the pump controller **371** and the blood pressure circuit is cut off because the vent **536** is always open and will quickly dissipate that pressure.

The heart rate meter **33**, the respiration rate meter **37**, and the blood pressure meter **546** are equipped with reset buttons, not shown. Whenever an alarm lamp of any of those meters has been illuminated, the operator of the control system can darken that lamp by pressing the reset button of that meter. Thereafter, that lamp will remain dark until the needle of that meter again actuates the alarm circuit of which that lamp is a component part.

In the event the DC portion of the power supply **20** becomes injured, and thus becomes unable to supply power to the movable contacts **24** and **25**, the battery **22** will automatically and immediately supply power to those movable contacts; and the control system will continue to sense and indicate the heart rate, the respiration rate, and the blood pressure of the person. A "telltale" lamp, not shown, in the power supply **20** will, however, become dark to indicate that at least a portion of that power supply has failed to function properly. In the event a power failure cuts off the power that is normally supplied to the conductors **21**, the battery **22** will automatically and immediately supply power to those movable contacts and the control system will continue to sense and indicate the heart rate and the respiration rate of the person. That control system will not, of course, operate the pump controller **371**, because that pump controller requires alternating current; and hence the control system will not continue to sense and indicate the person's blood pressure. If desired, however, a suitable inverter could be provided which would respond to the direct current from the battery **22** to develop the alternating current needed to operate the pump controller **371**; but, in that event, the battery **22** would have to have a very large capacity. To keep the cost and size of the battery **22** within moderate limits, the said preferred embodiment of control system provided by the present invention does not attempt to operate the pump controller **371** in the event a power failure cuts off the power that is normally supplied to the conductors **21**. Moreover, that embodiment of control system utilizes a relay, not shown, which disconnects the entire blood pressure circuit from the battery **22** in the event a power failure cuts off the power that is normally supplied to the conductors **21**; and, in doing so, that embodiment of control system keeps the drain on that battery to a minimum.

The heart rate meter **33**, the respiration rate meter **37**, and the blood pressure meter **546** can be located close to the person whose heart rate, respiration rate and blood pressure are being monitored, or they can be located at a nurse's station. In either case, the control system provided by the present invention can be used as an intensive care monitor.

Whereas the drawing and accompanying description have shown and described a preferred embodiment of the present invention, it should be apparent to those skilled in the art that various changes may be made in the form of the invention without affecting the scope thereof.

I claim:

1. In an intensive care monitor which has a heart rate circuit and a respiration circuit, the improvement which comprises terminals for said heart rate circuit that are adapted to be connected to a pair of electrodes which can be affixed to the body of a person, further terminals for said respiration circuit that are connected to the first said terminals, and thus are adapted to be connected to said pair of electrodes, said respiration rate circuit including coupling means between said further terminals and the rest of said respiration rate circuit to effectively isolate said person from potentially hurtful DC voltages and DC currents in said respiration rate circuit, and said heart rate circuit including further coupling means between the first said terminals and the rest of said heart rate circuit to effectively isolate said person from potentially hurtful DC voltages and DC currents in said heart rate circuit, said further coupling means being a DC coupling means and including back-to-back breakdown elements effectively connected across said first said terminals to limit the voltage which said heart rate circuit can apply to said person via said first said terminals.

2. In an intensive care monitor which has a heart rate circuit and a respiration rate circuit, the improvement which comprises terminals for said heart rate circuit that are adapted to be connected to a pair of electrodes which can be affixed to the body of a person, further terminals for said respiration circuit that are connected to the first said terminals, said respiration rate circuit including coupling means between said further terminals and the rest of said respiration rate circuit to effectively isolate said person from potentially hurtful DC voltages and DC currents in said respiration rate circuit, and said heart rate circuit including further coupling means between the first said terminals and the rest of said heart rate circuit to effectively isolate said person from potentially hurtful DC voltages and DC currents in said heart rate circuit, the first said coupling means being an AC coupling and including at least one capacitor, said further coupling means being a DC coupling which includes at least two resistors, said further coupling means also including back-to-back breakdown elements effectively connected across said first said terminals to limit the voltage which said heart rate circuit can apply to said person via said first said terminals.

3. In an intensive care monitor which has a heart rate circuit and a respiration rate circuit, the improvement which comprises terminals for said heart rate circuit that are adapted to be connected to a pair of electrodes which can be affixed to the body of a person, further terminals for said respiration circuit that are connected to the first said terminals, said respiration rate circuit including coupling means between said further terminals and the rest of said respiration rate circuit to effectively isolate said person from potentially hurtful DC voltages and DC currents in said respiration rate circuit, and said heart rate circuit including further coupling means between the first said terminals and the rest of said heart rate circuit to effectively isolate said person from potentially hurtful DC voltages and DC currents in said heart rate circuit, said further coupling means including back-to-back unidirectional elements that have low forward drops whenever they are conductive and that are effectively connected across said first said terminals, and that thus limit the values of the DC voltages that can appear at the first said terminals.

4. In an intensive care monitor which has a plurality of indicating lamps that become illuminated to indicate when predetermined levels have been attained, means responsive to changes in the condition of a person to cause said predetermined levels to be attained, and a power supply that has a normal power source and a standby power source to supply power in the event said normal power source fails, the improvement which comprises second means alternately connecting some of said lamps to and disconnecting said some lamps from said power supply whenever the first said means responds to a change in the condition of a person to cause said predetermined levels to be attained and thereby cause one or more of said some lamps to become illuminated, whereby the total power drawn by said some lamps is less than if said some lamps were connected continuously to said power supply, and whereby said standby power source can supply power to said some lamps for several hours after said normal power source has discontinued the supplying of power to said some lamps.

5. In an intensive care monitor as claimed in claim 4 wherein said second means includes a switching device that disconnects said some lamps from said power supply for periods of time longer than the periods of time during which said second means connects said some lamps to said power supply, whereby said some lamps draw less than one-half of the power which they would draw if they were connected continuously to said power supply.

6. In an intensive care monitor as claimed in claim 4 wherein said second means includes a power stage and a multivibrator connected between said some lamps and said power supply.

7. In an intensive care monitor which has a heart rate circuit that senses and indicates heart rate, a blood pressure circuit that senses and indicates a blood pressure, an inflatable blood pressure cuff, and a pressure source, the improvement which comprises a microphone that can sense Korotkoff sounds to develop signals, means responsive to said signals developed by said microphone to control the actuation of said pressure source, a "gate" in said blood pressure circuit which is interposed between said microphone and said signal-responsive means, and a connection between said heart rate circuit and said gate, said gate normally being closed to isolate said signal-responsive means from said microphone and thereby normally keeping said signals developed by said microphone from acting upon said signal-responsive means but said gate responding to a signal from said connection to open end connect said microphone to said signal-responsive means and thereby enable said signals developed by said microphone to cause said signal-responsive means to actuate said pressure source.

8. In an intensive care monitor as claimed in claim 7 wherein said connection between said heart rate circuit and said gate includes a delay-producing means, said delay-producing means producing a predetermined essentially fixed delay corresponding to the average time between a heart contraction and the movement of a surge of blood to the proximity of said mircophone.

9. In an intensive care monitor which has a heart rate circuit that senses and indicates heart rate, a blood pressure circuit that senses and indicates a blood pressure, an inflatable blood pressure cuff, and a pressure source, the improvement which comprises a transducer that responds to the interaction of blood pressure and cuff pressure to develop signals, means responsive to said signals developed by said transducer to control the actuation of said pressure source, a "gate" in said blood pressure circuit which is interposed between said transducer and said signal-responsive means, and a connection between said heart rate circuit and said gate, said gate normally being closed to isolate said signal-responsive means from said microphone and thereby normally keeping said signals developed by said transducer from acting upon said signal-responsive means but said gate responding to a signal from said connection to open and connect said transducer to said signal-responsive means and thereby enable said signals developed by said transducer to cause said signal-responsive means to actuate said pressure source, said connection between said heart rate circuit and said gate including means that enables said gate to connect said transducer to said signal-responsive means for a predetermined minimum length of time after said gate has responded to said signal from said connection to connect said transducer to said signal-responsive means, whereby said signal-responsive means can continue to sense for signals from said transducer for said predetermined minimum length of time.

10. In an intensive care monitor which has a heart rate circuit that senses and indicates heart rate, a blood pressure circuit that senses and indicates a blood pressure, an inflatable blood pressure cuff, and a pressure source, the improvement which comprises a microphone that can sense Korotkoff sounds to develop signals, means responsive to said signals developed by said microphone to control the actuation of said pressure source, a "gate" in said blood pressure circuit which is interposed between said microphone and said signal-responsive means, and a connection between said heart rate circuit and said gate, said gate normally being closed to isolate said signal-responsive means from said microphone and thereby normally keeping said signals developed by said microphone from acting upon said signal-responsive means but said gate responding to a signal from said connection to open and connect said microphone to said signal-responsive means and thereby enable said signals developed by said microphone to cause said signal-responsive means to actuate said pressure source, said connection between said heart rate circuit and said gate including a delay-producing means, said delay-producing means producing a predetermined essentially fixed delay corresponding to the average time between a heart contraction and the movement of a surge of blood to the proximity of said microphone, and said signal-responsive means having a subcircuit which keeps said signal-responsive means from affecting said pressure source for a predetermined length of time after said microphone fails to sense further Korotkoff sounds, whereby said signal-responsive means will not affect said pressure source as long as said microphone senses Korotkoff sounds and for a predetermined length of time thereafter.

11. In an intensive care monitor as claimed in claim 7 wherein a means normally biases said gate heavily nonconductive, wherein said connection between said heart rate circuit and said gate periodically reduces the bias on said gate until said gate is only moderately biased nonconductive, and wherein said microphone can respond to Korotkoff sounds to overcome the moderate bias on said gate and thereby render said gate conductive.

12. In a control system for sensing a blood pressure which has an inflatable cuff, a reservoir connected to said inflatable

cuff to supply gas to said inflatable cuff, and a vent in said reservoir to vent gas from said reservoir, the improvement which comprises an electrically operated, variable-length stroke, gas pump connected to said reservoir to introduce gas into said reservoir, means to supply current pulses to said electrically operated, variable-length stroke, gas pump to cause said electrically operated, variable-length stroke, gas pump to pressurize gas, and second means to vary the duration of said current pulses provided by the first said means and thereby cause said first said means to vary the lengths of the strokes of said electrically operated, variable-length stroke, gas pump, said first said and said second means providing stroke lengths for said electrically operated, variable-length stroke, gas pump which have a predetermined length that is long enough to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate greater than the rate at which gas can escape from said reservoir through said vent and can thereby enable said electrically operated, variable-length stroke, gas pump to increase the pressure in said reservoir, said first said and said second means subsequently making the lengths of stroke of said electrically operated, variable-length stroke, gas pump shorter than said predetermined length to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate less than the rate at which gas can escape from said reservoir through said vent and thereby enable the pressure in said reservoir to decrease.

13. In a control system for sensing a blood pressure as claimed in claim **12** wherein said first said means includes a selectively conductive control element and a firing circuit therefor.

14. In a control system for sensing a blood pressure as claimed in claim **12** wherein said first said means includes electrical components and is independent of mechanical components, whereby the lengths of said strokes of said electrically operated, variable-length stroke, gas pump are controlled solely by electrical components.

15. In a control system for sensing a blood pressure as claimed in claim **18** wherein a pressure-sensitive circuit is connected to said reservoir and responds to a predetermined pressure in said reservoir to cause said first said and said second means to reduce the lengths of stroke of said electrically operated, variable-length stroke, gas pump from said predetermined length to said shorter length and thereby enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate less than the rate at which gas can escape from said reservoir through said vent.

16. In a control system for sensing a blood pressure which has an inflatable cuff, a reservoir connected to said inflatable cuff to supply gas to said inflatable cuff, and a vent in said reservoir to vent gas from said reservoir, the improvement which comprises an electrically operated, variable-length stroke, gas pump connected to said reservoir to introduce gas into said reservoir, means to supply current pulses to said electrically operated, variable-length stroke, gas pump to cause said electrically operated, variable-length stroke, gas pump to pressurize gas, and second means to vary the duration of said current pulses provided by the first said means and thereby cause said first said means to vary the lengths of the strokes of said electrically operated, variable-length stroke, gas pump, said first said and said second means providing stroke lengths for said electrically operated, variable-length stroke, gas pump which have a predetermined length that is long enough to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate greater than the rate at which gas can escape from said reservoir through said vent and can thereby enable said electrically operated, variable-length stroke, gas pump to increase the pressure in said reservoir, said first said and said second means subsequently making the lengths of stroke of said electrically operated, variable-length stroke, gas pump shorter than said predetermined length to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate less than the rate at which gas can escape from said reservoir through said vent and thereby enable the pressure in said reservoir to decrease, said first said and said second means initially providing stroke lengths for said electrically operated, variable-length stroke, gas pump which are longer than said predetermined length to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate materially greater than the rate at which gas can escape from said reservoir through said vent and thereby enable said electrically operated, variable-length stroke, gas pump to increase the pressure in said reservoir at a rapid rate.

17. In a control system for sensing a blood pressure which has an inflatable cuff, a reservoir connected to said inflatable cuff to supply gas to said inflatable cuff, and a vent in said reservoir to vent gas from said reservoir, the improvement which comprises an electrically operated, variable-length stroke, gas pump connected to said reservoir to introduce gas into said reservoir, means to supply current pulses to said electrically operated, variable-length stroke, gas pump to cause said electrically operated, variable-length stroke, gas pump to pressurize gas, and second means to vary the duration of said current pulses provided by the first said means and thereby cause said first said means to vary the lengths of the strokes of said electrically operated, variable-length stroke, gas pump, said first said and said second means providing stroke lengths for said electrically operated, variable-length stroke, gas pump which have a predetermined length that is long enough to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate greater than the rate at which gas can escape from said reservoir through said vent and can thereby enable said electrically operated, variable-length stroke, gas pump to increase the pressure in said reservoir, said first said and said second means subsequently making the lengths of stroke of said electrically operated, variable-length stroke, gas pump shorter than said predetermined length to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate less than the rate at which gas can escape from said reservoir through said vent and thereby enable the pressure in said reservoir to decrease, said electrically operated, variable-length stroke, gas pump permitting gas to rapidly flow outwardly from said reservoir through said electrically operated, variable-length stroke, gas pump whenever said electrically operated, variable-length stroke, gas pump is inactive, and a subcircuit that can cause said first said and said second means to render said electrically operated, variable-length stroke, gas pump inactive to rapidly depressurize said reservoir.

18. In a control system for sensing a blood pressure as claimed in claim **12** wherein said first said and said second means initially provide stroke lengths for said electrically operated, variable-length stroke, gas pump which are longer than said predetermined length to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate materially greater than the rate at which gas can escape from said reservoir through said vent and thereby enable said electrically operated, variable-length stroke, gas pump to increase the pressure in said reservoir at a rapid rate, said electrically operated, variable-length stroke, gas pump permitting gas to rapidly flow outwardly from said reservoir through said electrically operated, variable-length stroke, gas pump whenever said electrically operated, variable-length stroke, gas pump is inactive, and wherein said second means includes a subcircuit that can render said electrically operated, variable-length stroke, gas pump inactive to rapidly depressurize said reservoir.

19. In a control system for sensing a blood pressure as claimed in claim **12** wherein said first said and said second means initially provide stroke lengths for said variable-length stroke, gas pump which are longer than said predetermined length to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate materially greater than the rate at which gas can escape from said reservoir through said vent and thereby enable said electrically operated, variable-length stroke, gas pump to increase the pressure in said reservoir at a rapid rate, and wherein a pressure-sensitive circuit is connected to said reservoir and responds to a given pressure in said reservoir to cause said first said and said second means to shorten the lengths of the strokes of said electrically operated, variable-length stroke, gas pump to said predetermined length.

20. In a control system for sensing blood pressure as claimed in claim 12 wherein said first said and said second means initially provide stroke lengths for said electrically operated, variable-length stroke, gas pump which are longer than said predetermined length to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate materially greater than the rate at which gas can escape from said reservoir through said vent and thereby enable said electrically operated, variable-length stroke, gas pump to increase the pressure in said reservoir at a rapid rate, wherein a pressure-sensitive circuit is connected to said reservoir and responds to a given pressure in said reservoir to cause said first said and said second means to shorten the lengths of the strokes of said electrically operated, variable-length stroke, gas pump to said predetermined length, and wherein a microphone senses the action of said inflatable cuff upon an artery to cause said first said and said second means to reduce the lengths of stroke of said electrically operated, variable-length stroke, gas pump from said predetermined length to said shorter length and thereby enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate less than the rate at which gas can escape from said reservoir through said vent.

21. In a control system for sensing a blood pressure which has an inflatable cuff, a reservoir connected to said inflatable cuff to supply gas to said inflatable cuff, and a vent in said reservoir to vent gas from said reservoir, the improvement which comprises an electrically operated, variable-length stroke, gas pump connected to said reservoir to introduce gas into said reservoir, means to supply current pulses to said electrically operated, variable-length stroke, gas pump to cause said electrically operated, variable-length stroke, gas pump to pressurize gas, and second means to vary the duration of said current pulses provided by the first said means and thereby cause said first said means to vary the lengths of the strokes of said electrically operated, variable-length stroke, gas pump, said first said and said second means providing stroke lengths for said electrically operated, variable-length stroke, gas pump which have a predetermined length that is long enough to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate greater than the rate at which gas can escape from said reservoir through said vent and can thereby enable said electrically operated, variable-length stroke, gas pump to increase the pressure in said reservoir, said first said and said second means subsequently making the lengths of stroke of said electrically operated, variable-length stroke, gas pump shorter than said predetermined length to enable said electrically operated, variable-length stroke, gas pump to introduce gas into said reservoir at a rate less than the rate at which gas can escape from said reservoir through said vent and thereby enable the pressure in said reservoir to decrease, a compensating circuit that is connected to said second means and that is responsive to the pressure in said reservoir and that can cause said first said and said second means to increase the length of stroke of said electrically operated, variable-length stroke, gas pump, when the pressure in said reservoir is high, to compensate for the reduced efficiency of said electrically operated, variable-length stroke, gas pump and for the increased rate of venting of gas from said reservoir which occur whenever the pressure in said reservoir is high.

22. In a control system for sensing a blood pressure as claimed in claim 12 wherein a compensating circuit is connected to said second means and is responsive to the pressure in said reservoir and can cause said first said and said second means to increase the length of stroke of said electrically operated, variable-length stroke, gas pump, when the pressure in said reservoir is high, to compensate for the reduced efficiency of said electrically operated, variable-length, stroke gas pump and for the increased rate of venting of gas from said reservoir which occur whenever the pressure in said reservoir is high, and wherein said compensating circuit includes a breakdown element that will become conductive whenever the pressure in said reservoir is high.

23. In a control system for sensing blood pressure as claimed in claim 12 wherein said first said means includes a selectively conductive element that is normally nonconductive but that can be selectively rendered conductive and a firing circuit that selectively renders said selectively conductive element conductive, said selectively conductive element being recurrently rendered conductive by said firing circuit to provide power pulses and said second means causing said firing circuit to vary the firing angles supplied to said selectively conductive element and thereby cause said selectively conductive element to provide power pulses of different durations, and wherein said selectively conductive element of said first said means supplies power pulses of a predetermined duration to said electrically operated, variable-length stroke, gas pump to enable said electrically operated, variable-length stroke, gas pump to have strokes of said predetermined length and supplies power pulses of lesser duration to said electrically operated, variable-length stroke, gas pump to enable said electrically operated, variable-length stroke, gas pump to have strokes of said shorter length.

24. In a control system for sensing a blood pressure which has an inflatable cuff, means to supply gas to said inflatable cuff, a circuit that selectively actuates and deactuates said means, a timer that selectively activates said circuit to permit said circuit to selectively actuate and deactuate said means and that selectively deactivates said circuit to keep said circuit from actuating said means, an alarm-type meter including an alarm circuit to indicate the pressure in said inflatable cuff and to provide an alarm when said blood pressure changes beyond a predetermined limit, and a pressure-sensing means connected between said inflatable cuff and said meter to enable said meter to indicate the pressure within said inflatable cuff, the improvement which comprises a meter-inhibiting circuit that renders the alarm circuit of said meter inactive whenever said timer deactivates the first said circuit to keep said first said circuit from actuating the first said means, a microphone to sense Korotkoff sounds as said inflatable cuff partially occludes an artery, and a further circuit that receives signals from said microphone as said microphone senses Korotkoff sounds and supplies signals to said meter-inhibiting circuit, said meter-inhibiting circuit enabling said alarm circuit of said meter whenever said timer activates said first said circuit to permit said first said circuit to selectively actuate and deactuate the first said means and said further circuit supplies signals to said meter-inhibiting circuit.

25. In an intensive care monitor which has a heart rate circuit and a respiration rate circuit, the improvement which comprises terminals for said heart rate circuit that are adapted to be connected to a pair of electrodes which can be affixed to the body of a person, further terminals for said respiration rate circuit that are connected to the first said terminals, said heart rate circuit including DC coupling means between the first said terminals and the rest of said heart rate circuit, said DC coupling means including back-to-back unidirectional elements that have low forward drops whenever they are conductive and also including high impedance elements, said back-to-back unidirectional elements being connected to ground, said high impedance elements being interposed between the first said terminals and said unidirectional elements and coacting with said unidirectional elements to reduce any high voltages, applied to the body of said person to shock the heart of said person, to low voltages before said voltages are applied to said heart rate circuit.

26. In a control system for sensing blood pressure as claimed in claim 18 wherein a pressure transducer is connected to said reservoir and senses the pressure in said reservoir and wherein a subcircuit is connected to said pressure transducer and can respond to a predetermined signal from said pressure transducer to render said means inactive and thereby rapidly depressurize said reservoir, said pressure transducer providing said predetermined signal when the pressure in said reservoir reaches a predetermined level.

27. In a control system for sensing blood pressure as claimed in claim 18 wherein said first said means includes a selectively conductive control element and a firing circuit therefor, wherein said firing circuit includes a member that causes said firing circuit to develop firing pulses at a predetermined rate to enable said selectively conductive control element to provide stroke lengths of said predetermined length for said electrically operated, variable-length stroke, gas pump, wherein said firing circuit includes a further member that causes said firing circuit to develop firing pulses at a lesser rate to enable said selectively conductive control element to provide stroke lengths of shorter length for said electrically operated, variable-length stroke, gas pump, and wherein said second means subsequently connects said further member to the first said member to cause said firing circuit to develop firing pulses at said lesser rate to enable said selectively conductive control element to provide stroke lengths of said shorter length for said electrically operated, variable-length stroke, gas pump.

28. In a control system for sensing blood pressure which has a microphone to detect Korotkoff sounds, a pump, a pump controller, and means sensitive to Korotkoff sounds to control the energization and deenergization of said pump controller, the improvement which comprises a reservoir for gas under pressure, a connection between said pump and said reservoir, subcircuit means that senses signals developed when said microphone detects Korotkoff sounds and that is connected to said pump controller to cause said pump controller to cause said pump to increase the pressure in said reservoir until said microphone detects Korotkoff sounds and thereby indicates that said pressure in said reservoir has risen to the value of the diastolic pressure of a person, said subcircuit means thereafter causing said pump controller to cause said pump to recurrently decrease and increase the pressure in said reservoir relative to said diastolic pressure, second subcircuit means that senses signals developed when said microphone detects Korotkoff sounds and that is connected to said pump controller to cause said pump controlled to cause said pump to increase the pressure in said reservoir until said microphone fails to detect Korotkoff sounds and thereby indicates that said pressure in said reservoir has risen to the value of the systolic pressure of said person, said second subcircuit means thereafter causing said pump controller to cause said pump to recurrently decrease and increase the pressure in said reservoir relative to said systolic pressure, and switch means that selectively actuates the first said subcircuit means while deactuating said second subcircuit means or that actuates said second subcircuit means while deactuating the first said subcircuit means.