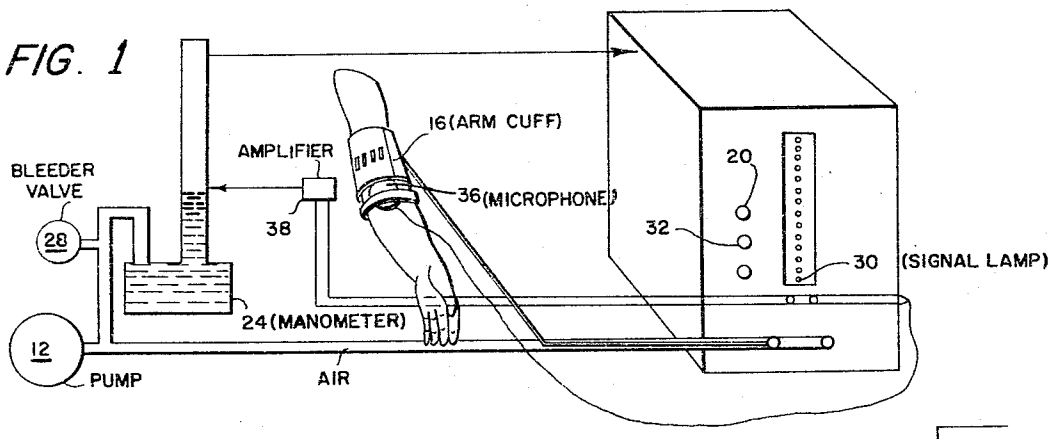
May 16, 1967 S. B. LONDON 3,319,623

BLOOD PRESSURE MONITORS

Filed July 13, 1964 3 Sheets-Sheet 1

FIG. 1



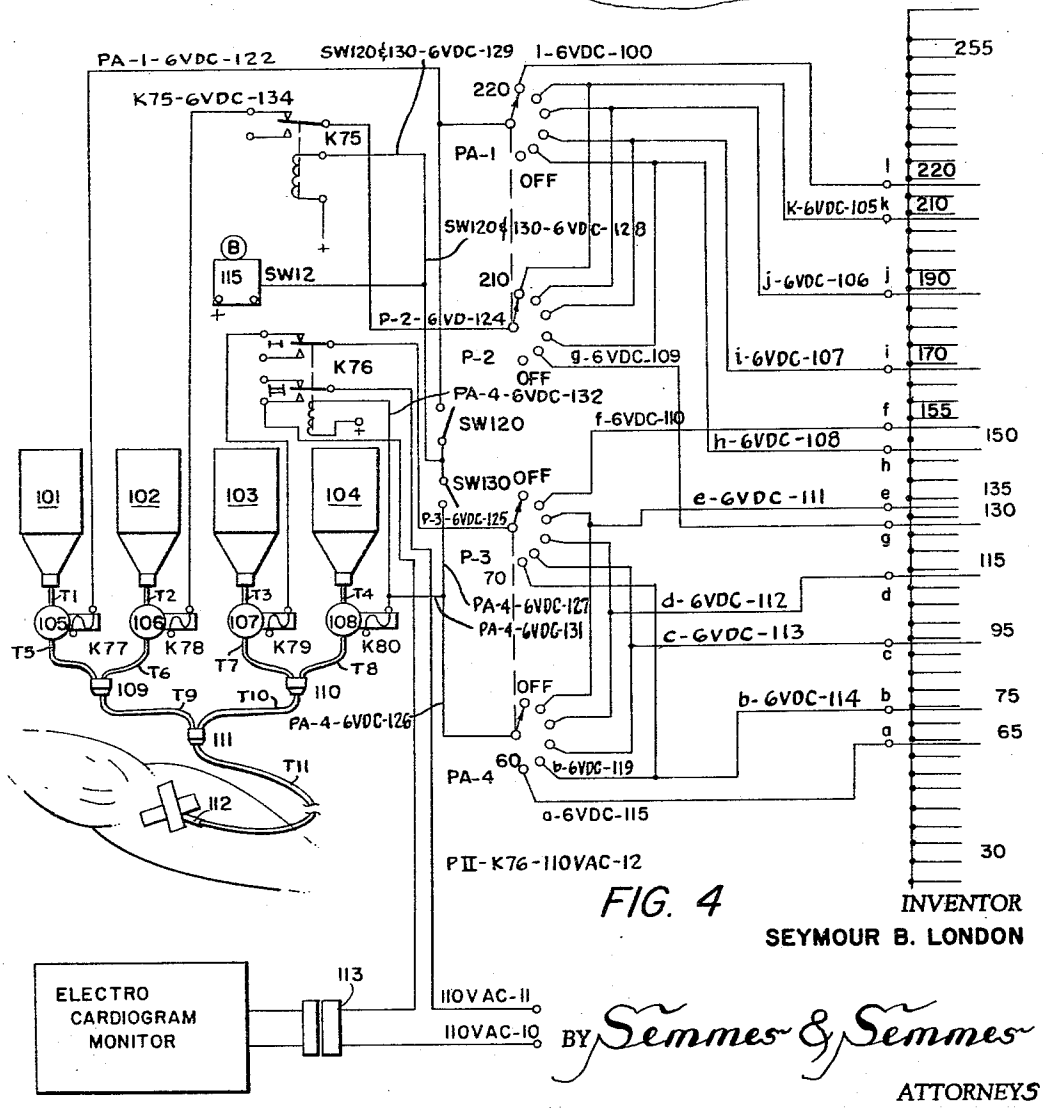


FIG. 4

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BLOOD PRESSURE MONITORS

Filed July 13, 1964 3 Sheets-Sheet 2

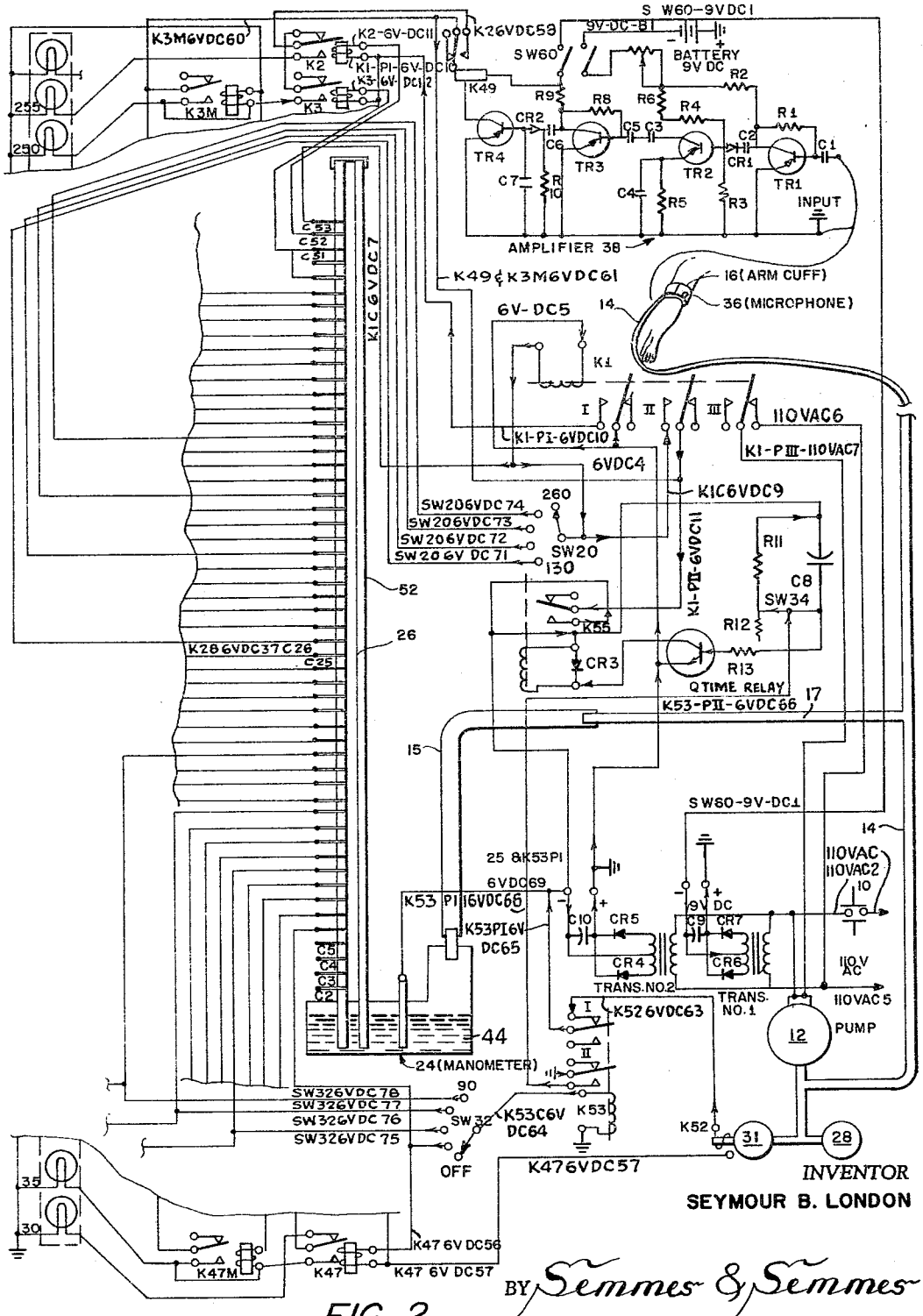

FIG. 2

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BLOOD PRESSURE MONITORS

Filed July 13, 1964 3 Sheets-Sheet 3

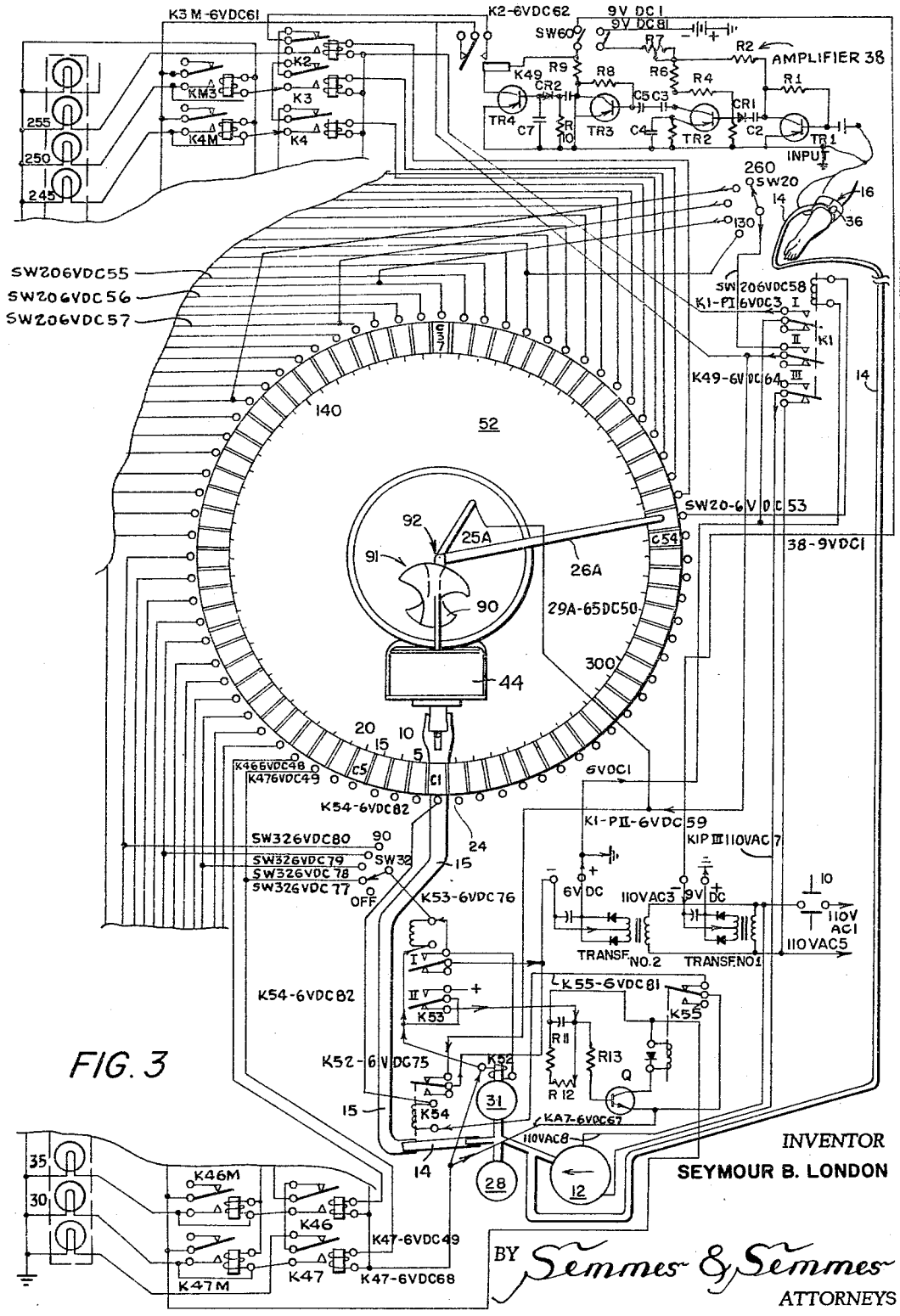

FIG. 3

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3,319,623

BLOOD PRESSURE MONITORS

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Filed July 13, 1964, Ser. No. 382,255
13 Claims. (Cl. 128—2.05)

The present application relates to blood pressure monitors and in particular to "mercury column manometer" and "aneroid manometer" monitors for determining and visually presenting systolic and diastolic blood pressure readings, and in a continuation-in-part of my copending application which issued August 24, 1965 as U.S. Patent No. 3,202,148.

To gain a proper appreciation of the scope of invention of the blood pressure monitors disclosed herein and to properly understand the problems inherent in distinguishing different types of blood pressure determination, the following background of historical medical events relating to blood pressure determination is presented herewith:

SYSTOLIC AND DIASTOLIC

Systole is the forceful contraction of the heart. Acting as a pump each contraction of the heart ejects into the aorta about 60 cc. of blood which produces a wave of blood through the arterial system. The crest of this pressure wave is called systolic pressure. Diastole is the period of relaxation of the heart when the heart fills with blood. The diastolic period of the pressure wave is the trough of the wave; that is a point of minimal pressure coinciding with the resting phase or diastolic phase of the heart. The "mean" pressure of the arterial system is usually given as one-half of the sum of value of the systolic and diastolic pressures but may be slightly lower.

Pulse pressure is the difference between systolic and diastolic pressures. For instance, if the blood pressure were 120 systolic and 80 diastolic, the pulse pressure would then be the difference between 120 and 80 or 40 millimeters of mercury.

The pressure in the arterial system depends upon several factors:

(1) The pumping action of the heart forces blood into the arterial system.

(2) The peripheral resistance of the arterial system. This is determined by the caliber of the small blood vessels which respond to stimulation of the controlling nerves with constriction or relaxation, thus regulating the rate of the outflow of blood from the arterial system into the capillaries and veins.

(3) The amount of blood in the arterial system also contributes to the pressure inasmuch as the blood vessels are elastic, the vessels must be filled to capacity before there is any blood pressure and then overfilled to slightly distend the walls to elevate the pressure to the normal physiologic limits. It is this distention of the elastic walls of the blood vessels which produces blood pressure. The diastolic pressure provides for a uniform flow through the small blood vessels and arterioles.

DIRECT MEASUREMENT

The earliest and perhaps the most complicated method of measuring blood pressure was the direct method. In this method a needle is introduced directly into the artery and by appropriate connection, a transducer is used to relate the pressure in the artery to a graph or other form of recording device. Of the various direct systems the optical method, the first method used, simply consisted of a mirror attached to a membrane or tambour that fluctuated with each pulse as it was transmitted up the needle through a rigid tubing. This fluctuation was inscribed by photographic means on a recording surface. Conclusions could be drawn as to the relative pressure in the arterial system by properly standardizing the equipment. The electrical transducer, a little more sophisticated, consists of three basic varieties:

(a) Condenser,
(b) Strain gauge, and
(c) Inductance type of transducers.

Here the fluctuations of pressure create variations in electrical voltage and by quantitating the electrical current and voltage, a measure of the pressure variations can then be obtained. It is generally conceded that the accuracy of the direct blood pressure determination is quite good with errors of plus or minus 5 millimeters of mercury being considered acceptable.

INDIRECT MEASUREMENT

The "indirect" method of blood pressure determination measures the lateral pressure of the arterial wall as opposed to the end pressure as measured by the intra-arterial needle in the direct method.

(1) *Palpation of pulses.*—About 65 to 70 years ago one of the physiologists in Italy by the name of Riva-Rocci devised the blood pressure arm cuff and manometer as we presently know it. By this means the pressure in the cuff acting as a tourniquet on the arm is increased until the blood flow in the artery beneath the cuff is obstructed. At this point no pulse is palpable below the constricting cuff. By first constricting the artery then feeling for the pulse below, while observing the manometer, the first pulse felt after the constricted artery was released was indicative of the height of the blood pressure wave or systolic pressure. Generally, this pulse was felt about 8 to 12 millimeters below true arterial pressure and while it served as a crude guide it had much to be desired from a point of view of accuracy and direct relationship to the arterial pressure.

(2) *Auscultation or sounds.*—In 1905 the Russian physiologist, Korotkow, made observations which are of extreme importance in clinical medicine today. He found that under ordinary circumstances while listening with a stethoscope placed on an artery, no sounds were heard. Therefore, he concluded that the flow of blood along arterial channels was inaudible to the human ear despite the fact that you could feel a pulse. If the artery was compressed by the cuff attached to a manometer so as to completely arrest the flow of blood, no sounds were heard below the compression, but when the compression of the artery was slowly released, a sharp tapping sound could be heard in rhythm with the heart beat by allowing the pressure in the cuff to fall just enough so that a small amount of blood could pass beyond the compression point. These sounds bear the name of the original observer and are called "Korotkow sounds." They are found over a range of approximately 40 to 50 millimeters of mercury and then disappear. They cannot be heard below the diastolic trough of pressure. Therefore, the first sound that is heard indicates systolic pressure and the last sound heard indicates diastolic pressure. The difference between the systolic and diastolic pressure is again given as pulse pressure. Thus, one must distinguish

the Korotkow sounds heard as opposed to pulses because while the sounds *could not be heard below* the diastolic pressure, the pulses *could easily be palpable without any compression of the artery.*

(3) *Small vessels indices.*—The auscultatory method is used in present-day medicine to determine the indirect blood pressure. The third method of indirect blood pressure determinations which has proved to be of some interest in laboratory investigation but has little clinical value, is the electrical recording of pulse variations either distal to an arm cuff or by transducer directly connected to a finger cuff. Changes in such a plethysmograph type of tracing have been recently devised and modified so that pulse changes can be picked up by a photoelectric cell transducer attached to the ear or finger. Generally these methods have not been reliable because they attempt to detect blood pressure changes only in the small blood vessels and reflect mainly volume and flow type changes in the part (finger, etc.) rather than a true intra-arterial pressure change.

Numerous patents, such as that granted to Williams et al. (U.S. Patent No. 2,352,875), disclose the use of the above-mentioned auscultatory method to determine indirect blood pressure. There is, however, no evidence that the Williams' instrument has ever measured anything except a pulse detected via a wrist cuff. The Williams' machine determines pulses by pressure variations in the cuff touriquet depending on a succession of diastolic pulses to indicate that the diastolic pressure has been reached. Physiologists, who have studied this problem, feel that this type of determination could not give an accurate end point and is merely representative of pulsatile expansion to the artery rather than diastolic pressure. Comparative studies with intra-arterial pressure determinations by means of strain gauge manometers and other measuring devices reveal a great discrepancy between the pulsatile phenomena as detected by a blood pressure cuff and the diastolic blood pressure. The present invention constitutes a substantial improvement in this field since determinations of the diastolic pressure are made by the established principle of indirect blood pressure determination using the disappearance of the Korotkow sounds as the simultaneous end point of diastolic blood pressure. Further, the detection of Korotkow sounds within a range of 2½ mm. Hg is contemplated by the invention disclosed herein. That is, since this invention is designed to detect and register differences of pressure in units of 5 mm. of Hg, the units' sensitivity is ±2.5 mm. of Hg.

Since the unit measures and registers the blood pressure objectively in units and by techniques employed universally, i.e. the recognition of the level of the first and last blood pressure sound, its use in epidemiological studies suitably offers comparative information available for analysis. Indices of the prior art are unsuitable for collecting and comparing epidemiological data as they do not measure the pressure of the brachial artery.

It is further submitted that the present invention constitutes a substantial improvement over the Pigeon (U.S. No. 2,821,188) and Gilford (U.S. No. 2,827,040) patents, which disclose sphygmomanometers having separate circuits used to convert pressures to electrical signals as the pressure drops from systolic to diastolic, since neither of these patents discloses limiting means for actuating indicia at times when Korotkow sounds are detected.

The present invention, then, distinguishes from the prior art devices in its unique capability of performing the following *separate* functions:

(1) *Measuring.*—Continuous intermittent registration of the indirect blood pressure on a read-out panel at intervals which can be varied at will.

(2) *Monitoring.*—Alarm signal or other electrical devices as might be used to resuscitation can be activated if the blood pressure falls below or rises above a prescribed level which can be varied by a selector switch.

(3) *Programming of treatment.*—Intravenous infusion of medication to raise and lower pressure can be completely automated by closed loop system and pressures maintained at a prescribed interval.

Accordingly, it is an object of invention to provide in a single device means for inflating and deflating a compression cuff to preset levels, detecting the Korotkow sounds within a range of 2½ mm. Hg, and converting said sounds to visual indicia.

Another object of invention is to provide a blood pressure monitor device wherein both systolic and diastolic pressure are visually presented.

Another object of invention is to provide in a blood pressure device, of a type having a mercury column manometer and visible indicators correlative to the height of mercury in the column, means for selectively and independently activating the visual indicators as the Korotkow sounds are detected.

Still another object of invention is to provide in a blood pressure monitor device, of the type having an aneroid manometer and visible indicators correlative to air pressure within the manometer, means for selectively and independently activating the visible indicators as the Korotkow sounds are detected.

Still a further object of invention is to provide in a blood pressure monitor device means for separately registering indirect blood pressure on a read-out panel at variable intervals, activating an alarm system when blood pressure falls below or rises above a prescribed level, and programming of treatment.

Yet additional objects of invention will become apparent from the ensuing specification and attached drawings wherein:

FIG. 1 is a schematic view of blood pressure monitor with cuff **16** and microphone **36** affixed adjacent the brachial artery;

FIG. 2 is schematic view of "mercury column" blood pressure monitor and appropriate circuits;

FIG. 3 is schematic view of "aneroid manometer" blood pressure monitor and related circuits; and

FIG. 4 is schematic view of the programming and alarm system used in conjunction with either "mercury column" or "aneroid manometer" blood pressure monitors.

As seen in FIGS. 1 and 2, the basic component parts of the "mercury column manometer" blood pressure monitor consist of a circuit actuating push-button **10**, pump **12**, arm cuff **16**, manometer **24**, bleeder valve **28**, solenoid valve **31**, microphone **36**, amplifier **38**, contact points C2 through C53, relays K1 through K47, signal lamps **30**, **35** . . . **40** . . . **255**, systolic limiting switch **20** and diastolic terminating switch **32**.

The operation of the "mercury column" blood pressure monitor is as follows:

As seen in FIG. 2, the closing of the 110 volt A.C. circuit by push-button **10**, initiates the pump **12** action through 110 volt A.C. line **6** in contact through the normally closed contacts of relay K1 with 110 volt A.C. **7**. The pump acts as a compressor inflating the arm cuff **16** and at the same time through tube **15** connected by a T-tube connection **17** with tube **14** compresses the chamber **44** of the manometer **24**. The increase in pressure in the chamber **44** will force the mercury column **26** up establishing a mercury contact to the various contact points on the contact column **52**. Because contact **25** is connected to the minus side of the 6 volt D.C. by lines DC**69** and 6 volt DC**70** the circuit is closed between the various contact points C2 through C53 and the −6 volt D.C. supply, as long as the mercury is in contact with these points.

The pressure of pump **12** continues to force the mercury column **26** up to contact C53, which is connected by line K1C, DC7 and K1C, DC6 to the coil of the three pole 6 volt D.C. relay K1. The mercury **26** contact acts to close the circuit to the coil, which is supplied directly on the positive side by the lines 6 volt D.C. **1**, 6 volt

D.C. 3, 6 volt D.C. 5 connections. Pole I of K1 relay connected by line 6 volt D.C. 4 to ground, in the active position supplies through its normally open contacts 6 volt D.C. through line 6 volt D.C. 10 to the positive side of the coils of relays K2 through K47 and including solenoid valve 30 (K52). As soon as pole I circuit of relay K1 is closed the isolating relays K2 through K47 are pulled into the active position by closure of their respective circuits by virtue of the contact of the mercury column to contacts C2 through C53 and their connections to lines DC11 through DC56. Pole II of K1, normally open contacts, are connected to the negative side of the 6 volt D.C. supply, through connection with line DC68 through the normally open contacts of sensitive relay K55. By establishing contact with line DC11 through lines DC6, 8 and 9, pole II provides a "hold" for the coil of K1, so that the relay K1 is maintained in an active position. The second pole of relay K1 through line 6 volt D.C. 9 is also connected to switch 20. Switch 20 is a systolic limiting switch and performs a function of shorting from contact 53 to contact 41 and contact 37 and contact 33, as will be further described. Pole III of K1 through the 110 volt connection of AC6 and AC7 in the normally closed position, supplies 110 volt circuit to the pump 12, until relay K1 coil is closed (interrupting the 110 volt circuit and discontinuing the pump action). Following interruption of the pump 12 circuit, slow decompression of the cuff 16 and the chamber 44 of the manometer 24 occurs simultaneously as a result of the bleeder valve 28. With the drop in pressure in the chamber 44, the mercury column 26 will drop at a controlled rate of 2½ to 5 mm. per second.

In the upper right hand corner of the schematic is the amplifier 38 whose input is connected to microphone 36 held in the arm cuff 16. The power supply to the amplifier is through line 9 volt D.C. 1 and an additional 9 volt D.C. battery by 9 volt D.C. B1. With the detection of a Korotkow sound by microphone 36, held in place over the artery on the arm, amplification through the amplifier 38 circuits by transistors 1, 2, 3 and 4, would cause sensitive relay K49 to "pull in" to an active position. This creates a signal by virtue of the connections of lines DC59 and DC58 with the normally open contacts of relay K49. DC58 leads to the normally open contacts of relay K2 which corresponds to a position of 255 mm. of Hg (C52) and since the mercury column 26 is still in contact with C52, K2 will switch the 6 volt signal through its normally open but now closed contacts to signal lamp 255, causing signal lamp 255 to flash simultaneously with each pulse and Korotkow sound heard in the artery above 255 mm. of Hg.

As the mercury column 26 descends due to the action of bleeder valve 28 contact of the mercury with contact C52 is lost, K2 coil is interrupted, and the normally closed contact of K2 will switch the signal of line 6 volt D.C. 58 to the normally open, but now closed contacts of K3. Pressure sounds detected by the microphone with the mercury column 26 at this contact point, will close the circuit of the memory relay coil K3M. Providing a connection between this side of the coil of memory relay with line 6 volt D.C. 60 by the normally open contact will result in a "hold" action to the coil and the K3M relay will remain in an active position. Since signal light 250 is parallel to K3M coil, the signal light will remain illuminated as long as the coil is in an active position. Similarly, as the mercury column descends, K3 coil will become interrupted when contact of the mercury column 26 to C51 is interrupted. The normally closed contacts of K3 will switch the signal to the normally open, but now closed contacts of K4, which in turn will close the circuits to the K4M memory relay and signal light 245 will become illuminated upon detection of a signal by microphone 36.

As the mercury column 26 drops, each subsequent isolation relay (K3 through K47) switches the signal circuit

and contact to its companion memory relay, K4M through K47M, only while its own coil is closed by the connection to the mercury column. As each isolation relay coil is interrupted, its normally closed contacts switch the signal from the microphone (through K49 to DC58) to the next relay with the closed coil at the "top" of the mercury column. Thus each relay isolates the signal so that the signal is transmitted only to its companion memory relay illuminating the signal lamp that corresponds to the millimeters of Hg at which the sound was detected. A signal produced at any other time except for this sensitive or receptive period has no effect on any of the memory relays. Since the level of the blood pressure corresponds to the level at which sounds in the artery are present, the signal lamps will become illuminated and give a "read out" of the blood pressure.

Switch 32 is a diastolic termination switch, so that after diastolic pressure has been established, the cuff can rapidly be decompressed to atmospheric pressure. Since in individual patients diastolic termination may be desirable at different levels, the choice between 90, 70 and 50, 30 mm. of Hg is offered by contact points 7, 11, 15 and 19. Switch 32 through line DC78, 77, 76 and 75 with contact to DC64 provides the negative side of the coil of relay K53 with a closed circuit. The positive side of the coil of K53 is to ground so that K53 will remain in an "active" position until the dropping mercury column opens the circuit of coil of relay K53 through switch 32 and through line DC64.

During its active state, pole II of relay K53 acts to charge capacitor C8 of the time delay. When capacitor C8 is charged, transistor Q of the time delay circuit will conduct and maintain the normally open contacts of relay K55 closed. When transistor Q ceases to conduct by virtue of decay of the charge of capacitor C8, the contacts of relay K55 open and the minus side of the 6 volt circuit is interrupted, the coil of K1 is opened and the entire cycle is re-started. Pole I of relay K53 through the normally closed contacts, closes the circuit to solenoid valve 30 (K52) and rapid decompression of the arm cuff 16 and mercury chamber 44 occur. The positive side of solenoid valve 30 (K52) is through line DC57, thus the solenoid valve will be held in an active position, i.e., valve is open, until the 6 volt D.C. circuit is interrupted by K55 through the time delay mechanism. The length of time that the time delay maintains the normally open contacts of K55 in a closed position depends upon the capacitor 8 charge. When capacitor 8 is charged, because Q, the transistor in the time delay is an NPN configuration, conduction through the transistor will occur. Relay K55 is a sensitive relay and will be activated by conduction through the transistor. The duration of conduction through the transistor controlled by switch 34 which, by virtue of R12, a variable resistor can regulate the rate of decay by increasing or decreasing the resistance.

Switch 32, the diastolic limiter switch, in effect, then controls the solenoid valve 30 through pole I of relay K53 and also starts the time or interval delay mechanism in operation through pole II.

Switch 20 similarly performs a function of limiting the level of compression of the arm cuff 16 and the mercury manometer 24, so that by the connections with lines DC71, 72, 73 and 74 to contacts 27, 33, 37 and 41 respectively, inflation of the cuff to 130, 160, 180, 200 or 250 mm. of Hg can be selected. Systolic limiting switch 20 establishes a contact between C53 which corresponds to a level of 260 mm. of Hg and either contact 41 corresponding to 200 mm. of Hg or contact 37, 180 mm. of Hg or contact 33, 160 mm. of Hg or contact 27, 130 mm. of Hg.

As seen in FIG. 2, the basic component parts of the "aneroid manometer" blood pressure monitor consist of pump 12, arm cuff 16, the aneroid manometer 24A (comprising chamber 44A, contact arm 26A, piston arrangement 90 and eccentric gears 91 and 92), bleeder valve

28, microphone 36, amplifier 38, contact points C1 through C53, relays K1 through K54, signal lamps 30, 35, 40 . . . 255, systolic limiting switch 20 and diastolic terminating switch 32.

The operation of the "aneroid manometer" blood pressure manometer is as follows:

By virtue of the connection of the 100 A.C. 7 and 110 A.C. 8, the pump action is initiated and pump 12 through tubings 14 and 15 simultaneously inflates the arm cuff 16 and at the same time compresses air into the chamber 44A of the aneroid manometer 24A. As the pressure is increased in the chamber 44A, a piston arrangement 90 rotates an eccentric gear 91 which because of its ratio to the gear 92 rotates the contact arm 26A from its zero position in a clockwise direction. The 6 volt D.C. current reduced and rectified through transformer number two by a lead from the minus side of the 6 volt D.C. power supply labeled 6 volt D.C. 60 is led to relay K54 and the normally closed contacts of K54 allow the circuit to continue via 6 volt D.C. 59 connection to 6 volt D.C. 50 leading to point 25A which is a contact point supplying the arm 26A closing circuit from 26A to the various contact points. The arm 26A would continue to rotate until contact 53, which corresponds to a pressure of 260 millimeters of mercury, is reached. At this point through 6 volt D.C. lines 53, and 6 volt D.C. 52, the coil of relay K1 is closed since 6 volt D.C. 51 is connected directly to positive pole or ground.

Relay K1 is a three pole relay. Pole 1 connected by 6 volt D.C. 2 and 6 volt D.C. 1 to ground supplies 6 volt D.C. by line labeled 6 volt D.C. 3 to the isolating relays as soon as K1 is in the active position. Pole 2 by virtue of its connection to 6 volt D.C. 53 through 6 volt D.C. 58 line supplies the negative leads which maintains K1 in a closed position by D.C. 59 connection with 6 volt D.C. 60. Through the contacts of relay K54 the circuit is opened by activation of relay K54 at the termination of the cycle. Pole 3 of K1 through the 110 volt A.C. 6 in the normally closed position supplies 110 volt circuit to the pump by AC7 until K1 is pulled into the active position and the circuit to the pump interrupted.

Following interruption of the pump circuit, decompression of the cuff, and the chamber 44A occur simultaneously as a result of bleeder valve 28 which allows a slow escape of air rotating the arm 26A on the face of dial 52A counterclockwise from contact 53 to 52 to 51 etc. down to contact 1, establishing a contact at each of these contact points.

In the upper right hand corner of the schematic is amplifier 38 which is connected to microphone 36. It is supplied by a 9 volt lead DC1 plus the small 9-volt transistor battery labeled B. As illustrated when a Korotkow sound is detected, amplification by transistors 1, 2, 3, and 4 occur after filtering etc. and K49 the sensitive relay pulls into an active position. With the detection of the Korotkow sounds by microphone 36, a signal is created by K49 as the minus 6 volt lead D.C. 63 leads through the closed contacts of K49 via DC62 to the contacts of relay K2. Relay K2 corresponds by virtue of connection DC4 to contact C52 to a position of 255 millimeters of mercury. If this signal is present because the normally open circuits of K2 are closed when lever arm 26A is at contact point C52, a signal lamp 255 will be illuminated as a flash. As the decompression of the cuff and chamber occurs simultaneously, signal arm 26A will slowly rotate down or counterclockwise by virtue of gears 91 and 92 from contact 52 to contact 51 and relay K3 will, because of its contact to 6 volt D.C. 5, pull into the active position. A Korotkow sound received at microphone 36 is switched through the normally closed contacts of K2 through the normally open but now closed contacts of K3 (closing the circuit of the isolation relay to the memory relay K3M). The Korotkow sound received at the microphone which closes the signal circuit by relay K49 will thus activate the relay of K3M, cause K3M contacts to close, which in the closed position will form a lock or hold by virtue of the common supply to N.O. contacts and to the coil of K3M by WC61. Signal light 250 will therefore also become illuminated simultaneously since in essence it is parallel to the coil of K3M. Thus, as the arm rotates to the next contact point represented by C50 at 245 millimeters of mercury, relay K4 will, in turn, become active as the coil K4 is closed by virtue of 6 volt D.C. 6. A signal via K49 is switched through the new closed contacts of K4, relay K4M is activated and signal light 245 becomes illuminated.

In contrast to signal light 255, the remainder of the signal lights once illuminated remain illuminated for the duration of the cycle. This effect is obtained through the hold or lock effect used by the memory relays K3M through K47M which are illustrated in a bank next to the signal lamps. Each isolation relay K2 through K47 illustrated next to the memory relays is in turn pulled into an active position by virtue of the contact arm 26A rotating to the isolated contacts and supplying in turn a negative terminal to the coil of each relay. The signals of K49 (originating from Korotkow sounds) can be detected by each memory relay only when the corresponding isolation relay is in the active position. A signal produced at any other time has no effect on any of the memory relays.

As the arm rotates each subsequent signal lamp is illuminated until the diastolic level is reached. Since no further sounds are heard, and despite the fact that each subsequent isolation relay is activated, no further signals are produced. When the contact arm rotates to zero position by contact and connection DC82, relay K54 is activated. When relay K54 is activated, the circuit to the minus side of the power supply is opened through leads DC59 and DC60. This in turn releases the hold mechanism for K1, all the signal lights are turned off because of the interruption of the hold relays K3M to K47M and the cycle restarts when the normally closed contacts of pole 3 close the 110 volt circuit for the pump 12.

Switch 32 provides a diastolic termination regulator so that after the diastolic pressure has been established the cuff can rapidly be decompressed to atmospheric pressure avoiding discomfort and irritation of the sensitive tissues of the arm. This is accomplished by switching contacts 90, 70, 50 and 30 marked by asterisks to the far left of the illuminated signal lamp column through switch 32 through the coil of K53 which is a two pole relay. Pole 1 supplies negative lead to the coil of solenoid 30 and DC68 and 69 supply positive leads; when solenoid 30 is activated the entire system is decompressed to zero atmospheric pressure. Because the contacts of switch 32 allow choice of 90, 70, 50 or 30 millimeters of mercury as a diastolic terminal point, clinical situations are more comfortably monitored. An additional function of relay K53 is supplied by pole 2. Pole 2 through the N.C. contacts by 6 volt D.C. 73 supplies a positive lead through 6 volt D.C. 74 to the positive side of the capacitor in the time delay circuit thus charging the capacitator.

Because of the NPN configuration of Q, a positive charge will produce flow in the NPN transistor Q and relay K55 will pull in, interrupting the circuit supplied by DC67 to the contact points of K55. Because of a hold or lock type circuit when contact arm 26A returns to C1 position, the coil of K53 remains closed interrupting the positive charging of the same delay capacitor by 6 volt D.C. 74. The time delay however will, because of the charged capacitor, cause the transistor to conduct until the charge is dissipated or decayed. The length of time can be adjusted by potentiometer R12, i.e. increasing (SW34) R12 diminishes the rate of decay and prolongs conduction of Q. When the capacitor is discharged and the relay K55 returns to its normally closed contact position, positive 6 volt D.C. via 81 is conducted to positive pole of K54 opening the circuits from the 6 volt power supply lead 60 and 59. As indicated earlier, this immedi-

ately restarts the entire cycle. As in our previous descriptions **52A** is a plastic face with the contacts superimposed and isolated from each other. The side view of the plastic face and the contacts and the contact arm **26A** is provided to the right of the schematic. Contact **25A** is also demonstrated.

In addition to the diastolic terminating switch **32** there is a systolic terminating switch or a systolic limiting switch **20**. The purpose of switch **20** as illustrated is to establish a contact between **C53** which corresponds to a level of 260 millimeters of mercury, **C41**—corresponding to 200 millimeters of mercury, **C37**—180 millimeters of mercury, **C33**—160 millimeters of mercury, **C29**—130 millimeters of mercury. By this switch **20** the pump compression of the arm cuff and chamber can be terminated at any of these points once it is determined that useful range of monitoring is accomplished by a lower level than 260 millimeters of mercury.

The electrical circuitry for the programming and alarm system, as shown in FIG. 3, is initiated by relay **K53** (in both FIGURES 1 and 2). Upon completion of measuring cycle, rapid decompression of the cuff is accomplished by closing the coil of relay **K53**, a double pole relay. Pole II through its N.O. contacts supplies a 6 v. D.C. positive supply in the active poosition to coils of the relays and solenoids of the alarm and programming system, **K75, K76, K77, K78, K79, K80** and the positive terminal of alarm buzzer **B115**. The negative leads to close the various circuits originate with the terminal contacts of the circuits of the memory relays K3M through K47M as illustrated in FIGURES 1 and 2.

For this type of therapy programming a range of 20–30 points millimeters of mercury is desirable and contact points to the left of the read-out panel, *a* to *c, d, e, f,* corresponding to 60 thru 150 mm. Hg were selected for shock treatment programming with *g, h, i, j, k, l* points corresponding to 130 to 220 mm. Hg for high blood pressure treatment programming. Each of points *a* thru *f* will close circuits only if their respective memory relay coil is open, points *g* thru *l* will close circuits only if their respective memory relay circuits are closed. Between 120 and 150 mm. Hg, the two types of programming overlap without interferences.

Automated closed loop "feed back" high blood pressure control and treatment is directed to the regulation of the amount of certain medications introduced by the intravenous tubing into the blood stream, dependent upon the level of blood pressure (FIGURE 3), flask **101** and **102** contain stronger and relatively weaker concentrations of the medications respectively. In essence the treatment program depends on the ability to cycle off and on either flask **101** or **102** depending on the blood pressure control point selected. Selector switch **PA1** and **P2** regulate levels at which the medications in flasks **101** and **102** are available for intravenous therapy. **PA1** differs from **PA2** only inasmuch as **PA1** sounds alarm in addition to programming therapy when its circuit is closed. Switch **120** closes the circuit to the alarm buzzer **B115**. It is parallel electrically to the coils of relay **K75**, a disconnect relay. The two systems are coordinated so that **PA1** will automatically supersede the circuitry of **P2** through the disconnect relay of **K75** since the lead from switch **P2** to flask **102**, solenoid valve **106** (**K78**) is through the normally closed contacts of relay **K75** by means of leads **DC124** and **DC134**.

Two contact points, one 20 mm. below the other are programmed as a sequence, *l* and *k, k* and *j, j* and *l, l* and *h, h* and *g*, each will function to cycle flask **102** on, if the blood pressure reading on the manometer coordinates with the contact point from the switch **P2**. If the blood pressure continues to move up another 20 mm. Hg, flask **102** is cycled off, flask **101** will be automatically cycled on and treatment will proceed through the tubing **T1, T5, T9, T11** allowing fluid into the vein **112**.

A sample response to therapy can be illustrated as follows: With **PA1** set at 220 and **P2** set at 210 and switch **120** closed, if after the first measuring cycle the pressure is registered on the panel at 210 mm. Hg, by means of leads **DC124, 134**, the circuit to solenoid valve **106** (**K78**) is closed. The closing of the circuit to **K78** pulls open solenoid valve **106** allowing the fluid in the flask **102** to flow into the vein and treatment is started. If upon completion of the next measuring cycle of the blood pressure manometer, the blood pressure continues elevated and 220 mm. Hg is registered, the circuit of **PA1** is closed by contact **1**, 6 v. D.C. **121**, 6 v. D.C. **122** to the solenoid valve **105** (**K77**) of flask **101**. Not only will flow start in flask **101** through tubing **T1, T5, T9, T11** but simultaneously through 6 v. D.C. **123**, 6 v. D.C. **128**, 6 v. D.C. **130**, the alarm **B115** will sound and through 6 v. D.C. **129**, the coil of **K75** will be closed interrupting the circuits of solenoid valve **106**. The fluid in flask **101** will continue to run into the vein until the next automatic blood pressure measuring cycle. If the blood pressure responds to the medication and drops below 220, flask **101** will be cycled to the Off position and the circuit to flask **102** will automatically be closed and solenoid valve **106** opened. Thus the elevation of blood pressure above the preselected point, in this case 210, instituted therapy with flask **102**, continuation of blood pressure elevation to 220 mm. Hg started flask **101**, discontinued flask **102**, and sounded alarm **B115**. Return of blood pressure to levels below 220 discontinued treatment by flask **101**, restarted flask **102**, and discontinued the buzzer alarm **B115**. Upon response of blood pressure to below 210, both flask **101** and flask **102** will be discontinued. By moving the switch clockwise blood pressure control contact points labeled "*l* to *g*" on FIGURE 3 can be selected to automatically maintain relatively stable and constant blood pressure at a medically desirable level using appropriate concentration of medications in flasks **101** and **102**.

The lower portions of FIGURE 3 diagrammatically illustrates the programming of the monitor to automatically control treatment of dangerously low blood pressure such as may be seen in heart conditions, injuries, burns, etc. For low pressure, switch **120** is opened and switch **130** closed the control switches **P3** and **PA4** are positioned to the desired control points. Control programming switch **P3** and programming alarm switch **PA4** are interlocked and coordinated providing two control contact points, one 20 mm. Hg below the other, programmed as a sequence. When switch **P3** circuit is closed, flask **103** will institute intravenous corrective treatment. But if the pressure drop to the next control point, **P3** is superseded by **PA4** and flask **104** replaces **103** as treatment.

In a patient, whose blood pressure should be maintained at 110 mm. Hg **P3–PA4** is rotated clockwise to position *d–c* corresponding to 110 mm. Hg in the **P3** circuit and 90 mm. Hg in the **PA4** circuit. Following the blood pressure measuring cycle of the automatic monitor, no action will ensue if the read-out panel lamp corresponding to 110 mm. Hg remains illuminated. If on the next determination there is a drop in blood pressure to levels less than 110 mm. Hg, i.e. 105 mm. Hg the circuitry of **P3** is closed, 6 v. D.C. **112**, 6 v. D.C. **117**, 6 v. D.C. **125** through the normally closed contacts of pole II of relay **K76** and 6 v. D.C. **133**, close the coil of **K79** of solenoid valve **107**, opening solenoid valve **107** and allowing the medicated contents of flask **103** to flow through tubing **T3, T7, T10, T11** and into the vein **112**. If this therapy is adequate the blood pressure again on the next cycle will be back to its original level of 110, **P3** circuits will be open and treatment by flask **103** discontinued through the closing of the solenoid valve **107** to its normally closed position. If, however, on the next measurement cycle the pressure drops below 90 mm. Hg the circuit of the programming alarm switch **PA4** will be closed. Leads 6 v. D.C. **126, 131, 132** close the coil of **K76** a two-pole relay, whose pole I nor-

mally closed contacts are opened, opening the circuit to flask **103** returning solenoid valve **107** to its normally closed position. Pole II of relay K**76** normally open contacts close the 110 volt A.C. circuit to the ECG monitor (commercially available). Simultaneously institution of therapy with contents of flask **104** replaces flask **103** closing the circuit to K**80**, controlling solenoid valve **108**, allowing the fluids to flow through the tubing T**4**, T**8**, T**10**, and T**11** into the vein **112**. With the onset of therapy with flask **104** the buzzer alarm B**115** continues to ring until manually discontinued by switch **130** or until the next automatic measuring cycle. If the blood pressure on the next cycle is registered at 90 mm. Hg, switch PA**4** circuit remains open and switch P**3** circuit will be closed. Flask **103** will be restarted for treatment into the vein, flask **104**, electrocardiogram monitor and alarm B**115** discontinued. Thus flask **103** and **104** in essence cycle off and on depending on the level of the blood pressure and the setting selected on switch P**3** and PA**4**, controlling abnormally low dangerous level by an automated closed feed back system.

Manifestly, various substitutions of parts and changes in circuitry can be adopted without departing from the spirit and scope of invention defined in the subjoined claims.

I claim:

1. A blood pressure monitor apparatus comprising:

(a) an inflatable cuff;

(b) pump inflating means including a conduit in communication with said cuff;

(c) a bleeder valve positioned in said conduit to allow said cuff to so decompress;

(d) an electrically conductive pressure responsive aneroid manometer in communication with said conduit;

(e) a display panel electrically connected via a series of independent circuits to respective pressure gradient contact points adjacent said aneroid manometer, said display panel including visual indicia means corresponding to mid-pressure gradient contact points adjacent said manometer;

(f) a source of electrical energy supplying said pump inflating means, said aneroid manometer, and said display panels;

(g) a pressure select switch in circuit with said aneroid manometer and said pump inflating means, said pressure select switch being actuable within said aneroid manometer to cut off said source of electrical energy from said pump inflating means at a predetermined pressure;

(h) a decompression valve in said conduit and a pressure responsive switch interconnecting said aneroid manometer and said valve, gauging decompression according as a pre-set pressure is detected in said manometer;

(i) an interval control switch in circuit with said source of electrical energy and closing said source of energy with said pump inflating means at predetermined intervals; and

(j) sound detecting means in communication with said cuff and independently relayed to said visual indicia, so as to limit electrical energization of said indicia, except as Korotkow sounds are detected.

2. A blood pressure monitor as in claim **1**, wherein said sound detecting means includes a microphone positionable adjacent said cuff for detection of Korotkow sounds, together with an independent amplifier.

3. A blood pressure monitor apparatus comprising:

(a) an inflatable cuff;

(b) pump inflating means in communication with said cuff;

(c) bleeder valve means positioned intermediate said pump inflating means and said cuff to allow said cuff to slowly decompress;

(d) electrically conductive pressure detecting means in communication with said cuff and responsive to changes in pressure therein;

(e) a display panel electrically connected to said pressure detecting means, said display panel including visual indicia means corresponding to pressure level gradients of 5 mm. of Hg registered by said pressure detecting means;

(f) a source of electrical energy supplying said cuff inflating means, pressure detecting means, and display panel;

(g) sound detecting means in electrical communication with said cuff and energized independently of said source of electrical energy supplying said pump inflating means, said pressure detecting means and said display panel so as to limit electrical energization of said indicia, except as Korotkow sounds are detected; and

(h) therapy programming means including

(1) a plurality of flasks containing variations of medications therein together with intravenous systems for introducing said medications into the blood stream;

(2) valve means associated with said flasks for regulating the flow of medications therethrough; and

(3) electrical means for translating said changes in pressure determined by said pressure detecting means into actuation of certain of said valve means of said flasks, as predetermined.

4. Method of blood pressure monitoring and treatment programming, comprising:

(a) pressurizing a sound detecting cuff adjacently positioned to a blood containing artery and a pressure detecting device;

(b) electrically energizing said pressure detecting device and a visual display indicia so as to be responsive to changes in pressure within said cuff;

(c) detecting Korotkow sounds through said cuff and limiting energization of said visual display indicia, except as Korotkow sounds are detected; and

(d) translating electrically said detected changes in pressure to regulation of intravenous medications introduced into the bloodstream.

5. Method as in claim **4**, wherein said regulation includes automatic cycling of medications of varying strength.

6. Method as in claim **5**, wherein said pressure detecting and introduction of medications are cycled such that response to said medications can be gauged by said pressure detecting device before introduction of further medications.

7. Method as in claim **6**, wherein said regulation includes both shock treatment programming and pressure treatment programming.

8. Method as in claim **6**, including translating electrically detected changes in pressure of preselected level to actuation of an electrocardiogram monitor.

9. Method as in claim **8**, including translating electrically detected changes in pressure of preselected levels to actuation of alarm signal to coincide wtih cycling of preselected medications.

10. A blood pressure monitor as in claim **3**, including means for automatically cycling medications from preeslected flasks in response to changes in pressure determined by said pressure detecting means.

11. A blood pressure monitor as in claim **9**, including an electrocardiogram monitor and means for actuating same as preselected pressure level is gauged by said pressure detecting means.

12. A blood pressure monitor as in claim **11**, including an alarm system and means for actuating same as preselected pressure levels are gauged by said pressure detecting means.

13. A blood pressure monitor as in claim **12**, including means for cycling the operation of said pressure detecting

means and actuation of said valve means of said flasks such that response to intravenous treatment by said medications can be gauged before continuing said therapy.

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