Aug. 6, 1957 K. W. EDMARK, JR 2,801,629

HEART BEAT INDICATOR

Filed Nov. 12, 1954 2 Sheets-Sheet 1

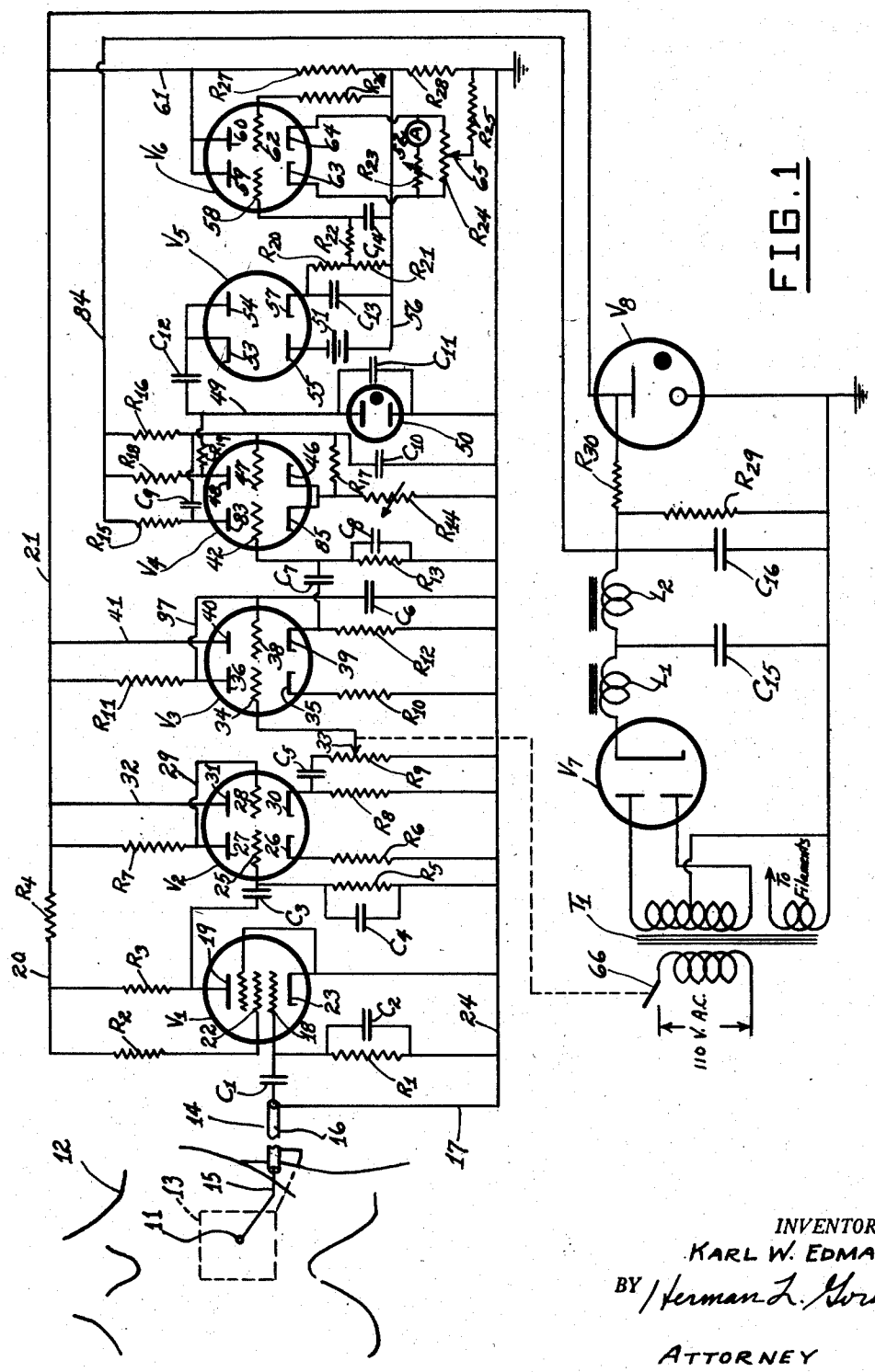

FIG. 1

INVENTOR.
KARL W. EDMARK, JR
BY Herman L. Gordon
ATTORNEY

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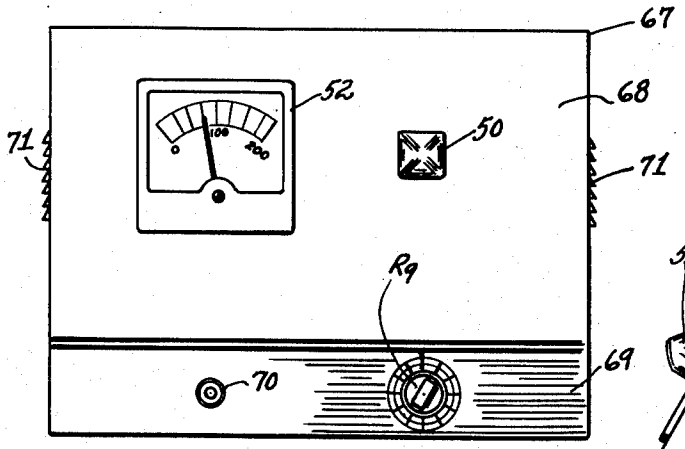

FIG. 2

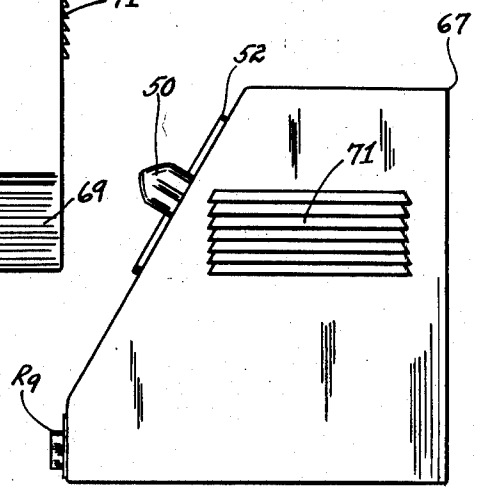

FIG. 3

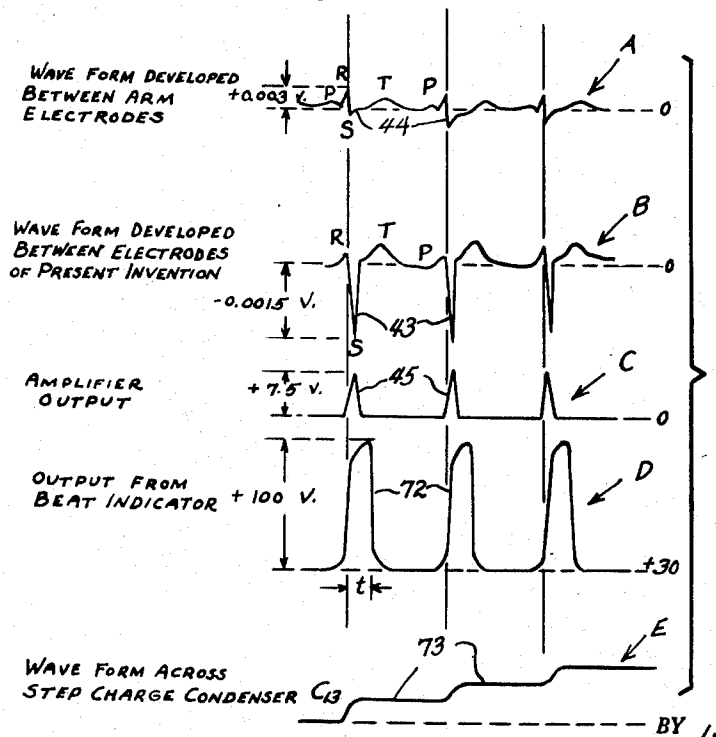

FIG. 4

SWEEP RATE = 25 mm/sec.
HEART RATE = 75/min.

INVENTOR.
KARL W. EDMARK, JR
BY /Herman L. Gordon
ATTORNEY

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HEART BEAT INDICATOR

Karl W. Edmark, Jr., Brookline, Mass., assignor to Physio-Control Company, Inc., Brookline, Mass., a corporation of Delaware

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8 Claims. (Cl. 128—2.05)

This invention relates to heart beat indicating apparatus, and more particularly to an electrical apparatus for simultaneously providing a positive, highly visible heart beat indication and an accurate indication of the heart beat rate of a patient to whom it is attached.

A main object of the invention is to provide a novel and improved apparatus which may be attached to a patient undergoing surgery or the like, to provide an instantaneous and constant visual indication of the heart rate and rhythm of the heart action of the patient.

A further object of the invention is to provide an improved apparatus for use in simultaneously providing a positive visual indication of the heart action of a patient undergoing surgery or other medical procedure, and of the heart rate of the patient, said apparatus being simple in construction, being reliable in operation, and providing an unmistakable and highly visible indication of the patient's heart action.

A still further object of the invention is to provide a compact and easily viewed instrument for indicating the heart action and heart beat rate of a patient undergoing surgery or the like, said apparatus being easy to attach to a patient, providing a heart action indication which is visible from a considerable distance, and being highly sensitive.

A still further object of the invention is to provide a combined heart beat and heart rate indicator which gives constant and instantaneous information of the heart rate and rhythm of a patient while the patient is being induced into or is under anesthesia, or is undergoing a procedure wherein it is important for the persons attending to notice rapidly any change in rate or rhythm of the patient's heart action, and enabling the anesthetist or surgeon to be rapidly aware of, and thus to treat, any sudden change in the heart rate or rhythm of the patient.

A still further object of the invention is to provide an improved electrical heart beat and heart rate indicator which utilizes an improved method of placement of the input electrodes, whereby an input signal of greater clarity and much greater amplitude is obtained than in the electrical devices heretofore employed for this purpose.

Further objects and advantages of the invention will become apparent from the following description and claims, and from the accompanying drawings, wherein:

Figure 1 is a schematic wiring diagram of an improved combination heart beat and heart rate indicator according to the present invention, showing the method of applying the electrodes to the body of a patient.

Figure 2 is a front elevational view of the main portion of an improved combination heart beat and heart rate indicator according to this invention.

Figure 3 is a side elevational view of the instrument of Figure 2.

Figure 4 is a group of typical curves showing how input signals of substantially increased amplitude are obtained by employing the improved electrode placement of the present invention and showing wave forms generated by the input signals at various stages of the circuit.

Referring to the drawings, and more particularly to Figure 1, **11** designates a small electrode which is attached to the front of the chest of the patient, shown at **12**. The electrode **11** may be fastened in any suitable manner to the patient's chest, or may comprise a needle inserted just under the skin. Designated at **13** is a relatively large grounding electrode which is placed on the back of the patient opposite the small electrode **11**, as shown. The large electrode **13** may be fastened in any suitable manner to the patient's back.

Designated at **14** is a shielded cable having the center conductor **15** and the outer shield **16**. Electrode **11** is connected to center conductor **15** and electrode **13** is connected to shield **16**. Shield **16** is connected to the instrument ground, as shown, by a conductor **17**. Thus, electrode **13** and the patient's body are maintained at the instrument ground potential.

The center cable conductor **15** is connected through a coupling condenser C_1 to the grid **18** of a pentode V_1 operating as a class A_2 amplifier.

In the input portion of the instrument, tubes V_2 and V_3 are also provided, said tubes being twin triodes operating as cathode follower amplifiers. High-mu triodes are preferably employed, which afford high amplification and at the same time, extreme stability because of the inherent negative feed-back due to the high values of cathode resistance characteristic of the circuit.

As shown, the plate **19** of tube V_1 is connected through a plate resistor R_3 to a wire **20**, which is in turn connected through a resistor R_4 to a plate voltage supply wire **21**. The screen **22** of tube V_1 is connected through a screen resistor R_2 to the wire **20**. The cathode **23** is connected to the instrument ground wire **24**. A grid resistor R_1 is connected between grid **18** and ground wire **24**. A grid by-pass condenser C_2 is connected across resistor R_1.

Plate **19** is connected through a coupling condenser C_3 to the input grid **25** of tube V_2. A grid resistor R_5 is connected between grid **25** and ground wire **24**. A by-pass condenser C_4 is connected across grid resistor R_5. Cathode **26** of tube V_2 is connected to ground wire **24** through a cathode resistor R_6. Plate **27** of said tube is connected to plate supply wire **21** through a plate resistor R_7.

Plate **27** is connected to the grid **28** of the second triode section of tube V_2 by a wire **29**. The cathode **30** of said second section is connected to ground wire **24** through a cathode resistor R_8. The plate **31** of said second section is connected to plate supply wire **21** by a wire **32**.

Cathode **30** is connected through a coupling condenser C_5 and the resistance element of a potentiometer R_9 to the ground wire **24**. The adjustable contact **33** of potentiometer R_9 is connected to the grid **34** of the first section of tube V_3. The cathode **35** of said first section is connected through a cathode resistor R_{10} to ground wire **24**. The plate **36** of said first section is connected through a plate resistor R_{11} to the plate supply wire **21**. Plate **36** is connected by a wire **37** to the grid **38** of the second section of tube V_3. A by-pass condenser C_6 is connected between grid **38** and ground wire **24**. Cathode **39** of said second section is connected through a cathode resistor R_{12} to ground wire **24**. Plate **40** of said second section is connected to plate supply wire **21** by a wire **41**.

Cathode **39** is connected through a coupling condenser C_7 to the input grid **42** of a twin triode indicator tube V_4.

The voltage gain of the amplifier thus far described is of the order of 5000.

Referring to Figure 4, a typical input wave form across grid resistor R_1 from a human heart using the electrode arrangement of the present invention is shown at B. Designated at A is the wave form which is developed when

wrist electrodes are employed, as in previous arrangements. By employing the electrode arrangement of the present invention, a deep negative S wave spike, shown at **43**, is developed, not obtained when wrist electrodes are employed, the corresponding negative spike **44** of curve A being relatively small in amplitude as compared with negative spike **43**.

By using the negative spike **43** as the rate-determining impulse, interference is eliminated from the P and T portions of the waves, shown in curves A and B.

In curve A, using wrist electrodes, it is necessary to use the positive R pulses as the rate-determining signals, whereby interference is present from the P and T portions of the waves.

In the circuit of the present invention, the negative S wave form elements from the heart are amplified to trigger the beat indicator, and this amplified S wave at the output of the amplifier (across resistor R_{12}) is shown at **45** in the wave form curve C of Figure 4. With the sensitivity control R_9 set at maximum, the average peak of the amplified S wave elements **45** from a normal heart is about 7.5 volts.

It will be seen that the negative input spikes **43** of curve B of Figure 4 have been amplified and converted to the positive wave form peaks **45** of curve C, appearing across resistor R_{12}. The positive spikes **45** may vary from about plus 3.0 volts to plus 10.0 volts, and are fed across a grid resistor R_{13} connected between grid **42** of tube V_4 and ground wire **24**. A by-pass condenser C_8 is connected across resistor R_{13}.

The plate **83** of the input section of tube V_4 is connected to a plate voltage supply wire **84** through a plate resistor R_{15}. The cathodes **85** and **46** of tube V_4 are connected to ground wire **24** through a variable bias resistor R_{14}.

Plate **83** is coupled to the grid **47** of the second section of tube V_4 through a condenser C_9. The plate **48** of said second section is connected to wire **84** through a plate resistor R_{18}. A grid resistor R_{17} is connected between grid **47** and the cathodes **85**, **46**. A condenser C_{10} is connected between grid **47** and ground wire **24**. Grid **47** is connected to the plate supply wire **84** through a relatively high resistance R_{16} which is of the order of one megohm.

Plate **48** of tube V_4 is connected through a resistor R_{19}, a wire **49**, and a neon lamp **50** to ground wire **24**. A condenser C_{11} is connected across neon lamp **50**, as shown.

The positive wave C of Figure 4, when fed across resistor R_{13} produces a constant-shaped positive wave D (Figure 4) over a range of zero to 200 beats per minute. The voltage across the neon lamp **50** is maintained at a relatively low level of about plus 30 volts, with a supply voltage of about 250 volts on wire **84**, by biasing grid **47** positive by means of resistor R_{16}. This reduces the internal resistance of the second section of tube V_4 to a level where a voltage drop of about 210 volts occurs across resistor R_{18}. This enables neon lamp **50** to be off at the zero signal levels. Resistor R_{14}, employed as a common cathode bias resistor, controls the trigger level of tube V_4, and by this means, the cathode bias is maintained at a sufficiently high level to keep the circuit from going into a slow self-oscillation, which it is capable of doing at low bias levels. Through the system of bypassing by the condensers C_8, C_{10}, and C_{11}, the system is not affected by 60 cycle interference, other than to increase its sensitivity, which can be controlled by adjusting the potentiometer R_9.

The time constant t of the wave form across condenser C_{11} and neon lamp **50** (see curve D, Figure 4) is controlled by the R-C network R_{16}, C_9, and is adjusted to give a light flash which roughly corresponds with the duration of the systolic (first) heart sound at normal heart rates. In operation, this is approximately 0.1 second.

Condenser C_{10} and resistor R_{17}, in addition to bypassing 60 cycle interference, have a stabilizing influence on the modified univibrator circuit defined by tube V_4.

Plate resistors R_{15} and R_{18} are chosen to provide the most stable circuit. If they are too low in value, the circuit goes into self-oscillation, and if they are too high, a short weak blink is produced by the neon lamp **50**, which is not desirable from a clinical standpoint. R_{15} should be of the order of 220,000 ohms and R_{18} should be of the order of 150,000 ohms.

A double diode V_5 is employed in conjunction with a condenser C_{13} and a battery **51** as a step charging circuit to actuate a rate meter circuit including the microammeter **52**. As shown, one cathode **53** and one anode **54** of tube V_5 are connected together and are coupled to wire **49** through a coupling condenser C_{12}. The anode **55** of the first section of tube V_5 is connected to the negative terminal of battery **51**. The positive terminal of said battery is connected to a wire **56**. Condenser C_{13} is connected between the cathode **57** of the second section of tube V_5 and wire **56**. Connected in series across condenser C_{13} are the resistors R_{20} and R_{21}. The junction of said resistors is connected to the input grid **58** of a double triode V_6 through a resistor R_{22}. A by-pass condenser C_{14} is connected between grid **58** and wire **56**.

The anodes **59** and **60** of tube V_6 are connected by a wire **61** to the plate voltage supply wire **21**. A resistor R_{27} is connected between wire **61** and wire **56**. A resistor R_{28} is connected between wire **56** and ground wire **24**. The grid **62** of the second section of tube V_6 is connected to wire **56** through a grid resistor R_{26} of relatively high value. Connected in series across the cathodes **63** and **64** of tube V_6 are the variable resistance R_{23} and the microammeter **52**. Also connected across said cathodes is the resistance element of a potentiometer R_{24}. The adjustable contact of said potentiometer is connected to ground through a bias resistor R_{25}.

It will be seen that double triode V_6 is thus employed in an electrometer circuit with microammeter **52**, which gives a nearly linear heart rate indication from zero to 200 beats per minute. Linearity is controlled by the choice of proper values for the condensers C_{12}, C_{13}, the resistors R_{20}, R_{21}, and the negative bias source, battery **51**. The electrometer circuit is adjusted to give full scale deflection with a positive voltage of about 1.5 volts applied to the grid **58** of the first section of tube V_6 by means of the variable resistance R_{23}. Zero adjustment is obtained by adjusting the contact element **65** of potentiometer R_{24}.

The curve E of Figure 4 shows the wave form across the step charge condenser C_{13}. As shown by this curve, the charge on condenser C_{13} is built up in steps derived from the successive positive pulses, shown at **72**, developed across the neon lamp **50**, said positive pulses causing lamp **50** to conduct with each heartbeat, since with a normal heart signal, the amplitude of the pulses **72** is sufficiently great to ionize the gas in lamp **50**. Each pulse **72** causes a current pulsation in the circuit comprising cathode **53**, anode **55**, battery **51**, resistor R_{21}, resistor R_{20}, cathode **57** and anode **54**. Normally (in the absence of the pulses **72**) battery **51** places a negative bias on anode **55** of tube V_5 which is sufficient to prevent any thermionic-emission flow of current through the circuit comprising cathode **53**, anode **55**, battery **51**, resistor **21**, resistor **20**, cathode **57**, and anode **54**. This maintains grid **58** of tube V_6 at zero reference voltage with respect to wire **56**. The potentiometer R_{24} is adjusted to give a zero indication on microammeter **52**. When current pulsations are produced in tube V_5, the current through resistors R_{21} and R_{20} is in a direction to make grid **58** positive, removing the normal negative bias thereon. The current pulsations through resistors R_{21} and R_{20} produce steps **73** of charge on the condenser C_{13}, said condenser discharging at a relatively slow rate through said resistors during the intervals between pulses **72**. The equilibrium charge level on condenser C_{13} is reached after a few pulses **72**, said equilibrium charge level being in accordance with the frequency of the pulses **72**. Since this charge level provides the positive voltage on grid **58**,

the deflection of the electrometer microammeter **52** will be in accordance with the pulse frequency.

It will be further noted that tube V_6 is connected in a bridge circuit and that the bridge becomes unbalanced when the voltage on grid **58** is changed from the null value thereof. Normally, namely, at balance of the bridge, grids **58** and **62** are at relative potentials such that no current flows through the circuits connecting the cathodes **63** and **64**.

The power supply employed is conventional in design and comprises a power transformer T_1, a full-wave rectifier V_7 and a double-section filter network consisting of inductances L_1, L_2, and filter capacitors C_{15} and C_{16}, connected as shown. This provides approximately 250 volts across a bleeder resistor R_{29} with a ripple component of about 0.012%. Additional regulation is obtained by the use of a dropping resistor R_{30} and a voltage regulator tube V_8, to provide a constant voltage source of 145 volts to wire **21** (to the amplifier and electrometer circuits) over a wide range of varying line voltage conditions, adding to the stability and accuracy of the entire circuit.

The main control switch **66** of the power supply is mechanically coupled to the adjustable element of the sensitivity control R_9 so that a single knob may be employed to energize the instrument and to control its sensitivity.

The instrument is contained in a metal housing **67**, shown in Figures 2 and 3. The front wall of the housing has the sloping upper portion **68** on which are mounted the microammeter **52** and the neon lamp **50** in side-by-side adjacent relationship, so as to be easily viewed simultaneously, so that the flashing of the neon lamp and the indication of the meter **52** may be observed at the same time. The housing has the vertical lower front wall portion **69** on which is mounted a cable connector **70** to which the cable **14** may be connected, and the sensitivity control potentiometer R_9, said potentiometer being provided with the instrument control switch **66**, as above described, which is operated by the knob of the potentiometer. The side walls of the housing **67** are provided with suitable ventilating louvers **71**.

The following circuit values were employed in a typical instrument constructed in accordance with the present invention:

RESISTORS

R_1	megohms	2.2
R_2	ohms	100,000
R_3	do	220,000
R_4	do	150,000
R_5	megohms	1.5
R_6	ohms	2,700
R_7	do	270,000
R_8	do	270,000
R_9	megohms	2
R_{10}	ohms	2,700
R_{11}	do	270,000
R_{12}	do	270,000
R_{13}	do	270,000
R_{14}	do	15,000
R_{15}	do	220,000
R_{16}	megohm	1.0
R_{17}	ohms	560,000
R_{18}	do	150,000
R_{19}	do	39,000
R_{20}	megohm	1.0
R_{21}	do	1.0
R_{22}	ohms	560,000
R_{23}	do	10,000
R_{24}	do	10,000
R_{25}	do	47,000
R_{26}	megohms	1.5
R_{27}	ohms	33,000
R_{28}	do	68,000
R_{29}	do	27,000
R_{30}	do	6,800

CAPACITORS

	Mfd.
C_1	1.0
C_2	.05
C_3	1.0
C_4	.05
C_5	1.0
C_6	.05
C_7	1.0
C_8	.25
C_9	1.0
C_{10}	.25
C_{11}	1.0
C_{12}	.005
C_{13}	1.0
C_{14}	1.0
C_{15}	20.0
C_{16}	20.0

TUBES

V_1	6AU6
V_2	12AX7
V_3	12AX7
V_4	12AU7
V_5	6H6
V_6	12AU7
V_7	6X4
V_8	OA2

INDUCTORS

L_1	microhenries	8.5
L_2	do	8.5

TRANSFORMERS

T_1	650 V. CT

While a specific embodiment of an improved heart beat indicator and heart rate counter has been disclosed in the foregoing description, it will be understood that various modifications within the spirit of the invention may occur to those skilled in the art. Therefore it is intended that no limitations be placed on the invention except as defined by the scope of the appended claims.

What is claimed is:

1. Apparatus for utilizing the negative S pulse of the heart action wave of a patient to provide simultaneous heart beat visual signals and heart beat rate indications comprising a first electrode adapted to be positioned on the front of the chest of a patient, a second electrode adapted to be placed on the patient's back, an amplifier circuit arranged to provide a positive output signal in response to a negative input signal furnished thereto, means connecting said electrodes to the input of said amplifier circuit, a neon lamp, means connecting said neon lamp to the output of said amplifier circuit, a condenser, means charging said condenser simultaneously with the application of output voltage from said amplifier circuit to said neon lamp, a meter, and means connecting said meter to said condenser and being arranged to provide a reading on said meter in accordance with the frequency of the negative S pulses.

2. Apparatus for utilizing the negative S pulse of the heart action wave of a patient to provide simultaneous heart beat signals and heart beat rate indications comprising a first electrode adapted to be positioned on the front of the chest of a patient, a second electrode adapted to be placed on the patient's back, an amplifier circuit arranged to provide a positive output signal in response to a negative input signal furnished thereto, means connecting said electrodes to the input of said amplifier circuit, a voltage-responsive intermittent signal device, means connecting said signal device to the output of said amplifier circuit, a pair of diodes, means connecting the cathode of one of said diodes and the anode of the other diode

to one terminal of said signal device, and a rate indicating circuit connected to the anode of said one diode and the cathode of the other diode.

3. Apparatus for simultaneously providing a flashing visual signal in synchronism with the heart beats of a patient and for indicating the rate of such heart beats comprising in combination a neon lamp, means for conductively energizing said lamp in response to a heart beat signal of predetermined amplitude, a pair of diodes, a rate indicating circuit, means connecting the cathode of one diode and the anode of the other diode to one terminal of the neon lamp, and circuit means connecting the rate indicating circuit between the anode of said one diode and the cathode of said other diode and being formed and arranged to provide an indication in accordance with the frequency of energization of said neon lamp.

4. Apparatus for simultaneously providing a flashing visual signal in synchronism with the heart beats of a patient and for indicating the rate of such heart beats comprising in combination a neon lamp, means for conductively energizing said lamp in response to a heart beat signal of predetermined amplitude, a pair of diodes, means connecting the cathode of one of said diodes and the anode of the other diode to one terminal of said neon lamp, and a rate indicating circuit connected between the anode of said one diode and cathode of the other diode, said rate indicating circuit being arranged to provide an indication of the frequency of the energizing voltage applied to said neon lamp.

5. Apparatus for simultaneously providing a flashing visual signal in synchronism with the heart beats of a patient and for indicating the rate of such heart beats comprising in combination a neon lamp, means for conductively energizing said lamp in response to a heart beat signal of predetermined amplitude, a pair of diodes, means connecting the cathode of one of said diodes and the anode of the other diode to one terminal of said neon lamp, a condenser connected in circuit with the anode of said one diode and the cathode of the other diode, a voltage indicating circuit connected across said condenser and having a terminal connected to the remaining terminal of the neon lamp, and means for charging said condenser in accordance with the frequency of the energizing voltage applied to said neon lamp.

6. Apparatus for simultaneously providing an intermittent perceptible signal in synchronism with the heart beats of a patient and for indicating the rate of such heart beats comprising in combination a signal device arranged to be energized when a voltage exceeding a predetermined value is applied thereto, means for energizing said signal device in response to a heart beat signal of predetermined amplitude, a pair of diodes, means connecting the cathode of one of said diodes and the anode of the other diode to one terminal of said signal device, a condenser connected in circuit with the anode of said one diode and the cathode of the other diode, a voltage indicating circuit connected across said condenser and having a terminal connected to the remaining terminal of said signal device, and means for charging said condenser in accordance with the frequency of the energizing voltage applied to said signal device.

7. Apparatus for simultaneously providing an intermittent signal in synchronism with the heart beats of a patient and for indicating the rate of such heart beats comprising in combination an indicating device, means for energizing said indicating device in response to a heart beat signal of predetermined amplitude, a pair of diodes, a rate indicating circuit, means connecting the cathode of one diode and the anode of the other diode to one terminal of the indicating device, and circuit means connecting the rate indicating circuit between the anode of said one diode and the cathode of said other diode and being formed and arranged to provide an indication in accordance with the frequency of energization of said indicating device.

8. Apparatus for simultaneously providing an intermittent signal in synchronism with the heart beats of a patient and for indicating the rate of such heart beats comprising in combination an electrical indicating device, means to energize said indicating device in response to a heart beat, a pair of diodes, an electrical rate indicator, means connecting the cathode of one diode and the anode of the other diode to one terminal of the indicating device, and circuit means connecting the rate indicator between the anode of said one diode and the cathode of said other diode and being formed and arranged to provide an indication in accordance with the frequency of energization of said indicating device.

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