# United States Patent [19]

**Sanderson**

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[54] **BLOOD PRESSURE RECORDER**

[75] Inventor: **Leslie George Sanderson,** Cambridge, England

[73] Assignee: **Cambridge Scientific Instruments Limited,** Cambridge, England

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[21] Appl. No.: **450,393**

**Related U.S. Application Data**

[63] Continuation-in-part of Ser. No. 260,745, June 8, 1972, abandoned.

[30] **Foreign Application Priority Data**

July 23, 1971 United Kingdom ............... 34767/71

[52] **U.S. Cl.... 128/2.05 M;** 128/2.05 Q; 128/2.05 S

[51] **Int. Cl.** ............................................. **A61b 5/02**

[58] **Field of Search** .... 128/2.05 R, 2.05 M, 2.05 G, 128/2.05 C, 2.05 A, 2.05 Q, 2.05 E, 2.05 S

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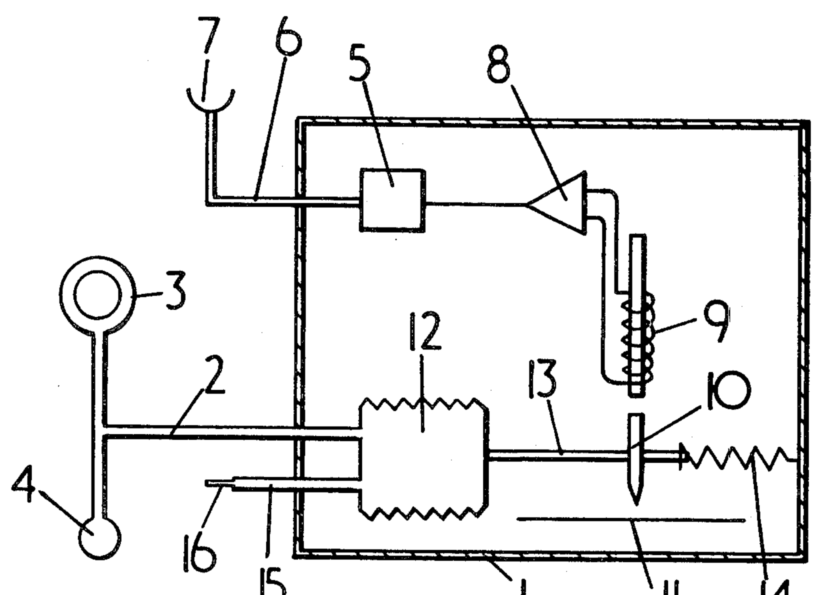
*Primary Examiner*—Kyle L. Howell
*Attorney, Agent, or Firm*—Wigman & Cohen

[57] **ABSTRACT**

An automatic blood pressure recorder of the kind comprising an inflatable occluding cuff, and means for detecting Korotkoff sounds in an artery occluded by the cuff, in which the sound detecting means include a cup adapted to be placed over an artery to be occluded by the cuff, a flexible tube connecting the cup to a microphone and amplifying means for amplifying the output of the microphone thereby to generate an electrical output signal whose magnitude is dependent on the amplitude of the Korotkoff sounds, said sound-detecting means being operatively arranged to provide a sensitivity to Korotkoff sounds such that the magnitude of the said electrical output signal is greater at a frequency corresponding to the frequency of the Korotkoff sounds at pressures above the diastolic pressure than at a frequency corresponding to the frequency of the Korotkoff sounds at pressures below the diastolic pressure.

**8 Claims, 7 Drawing Figures**



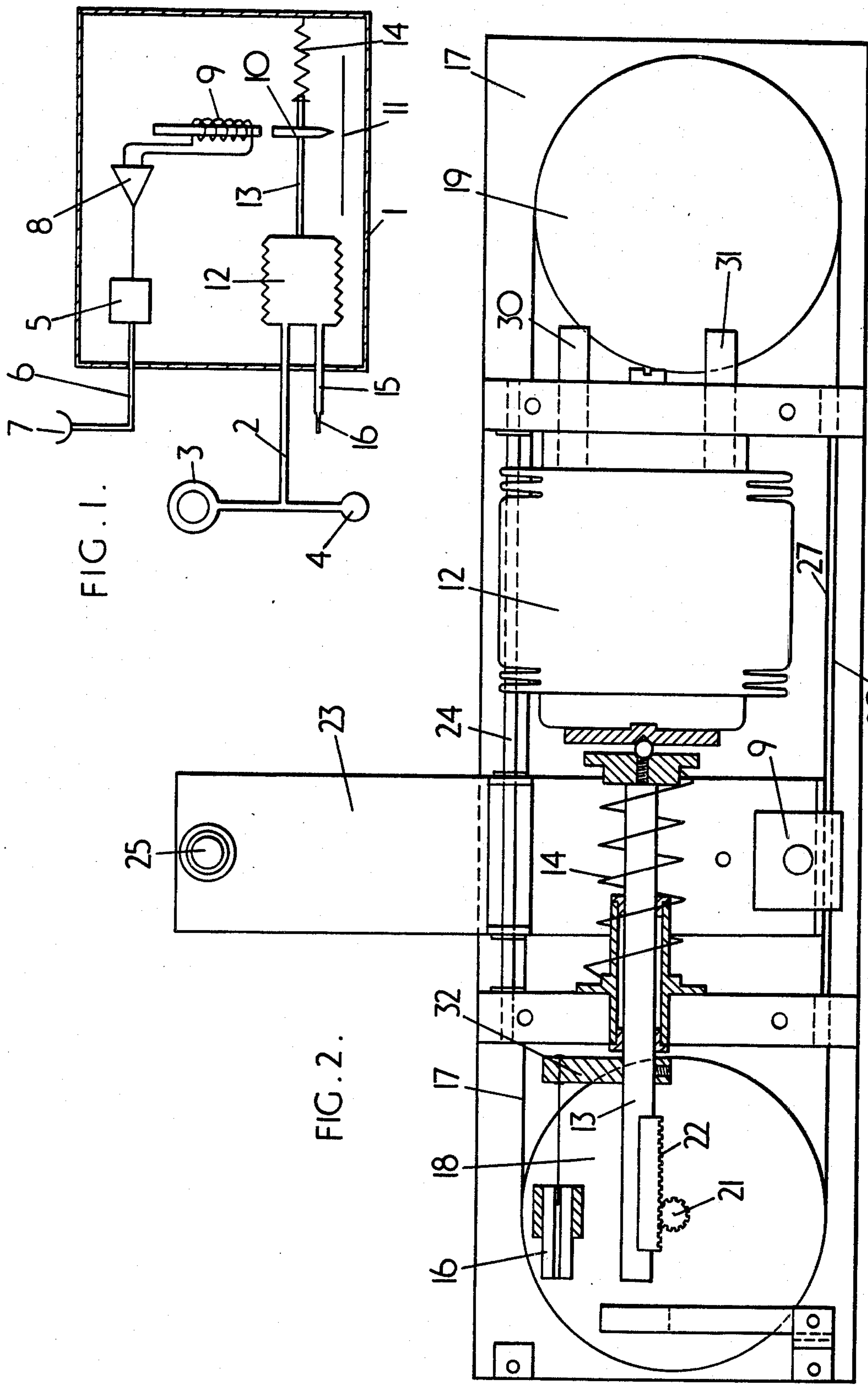



FIG. 1.

FIG. 2.

FIG. 3.

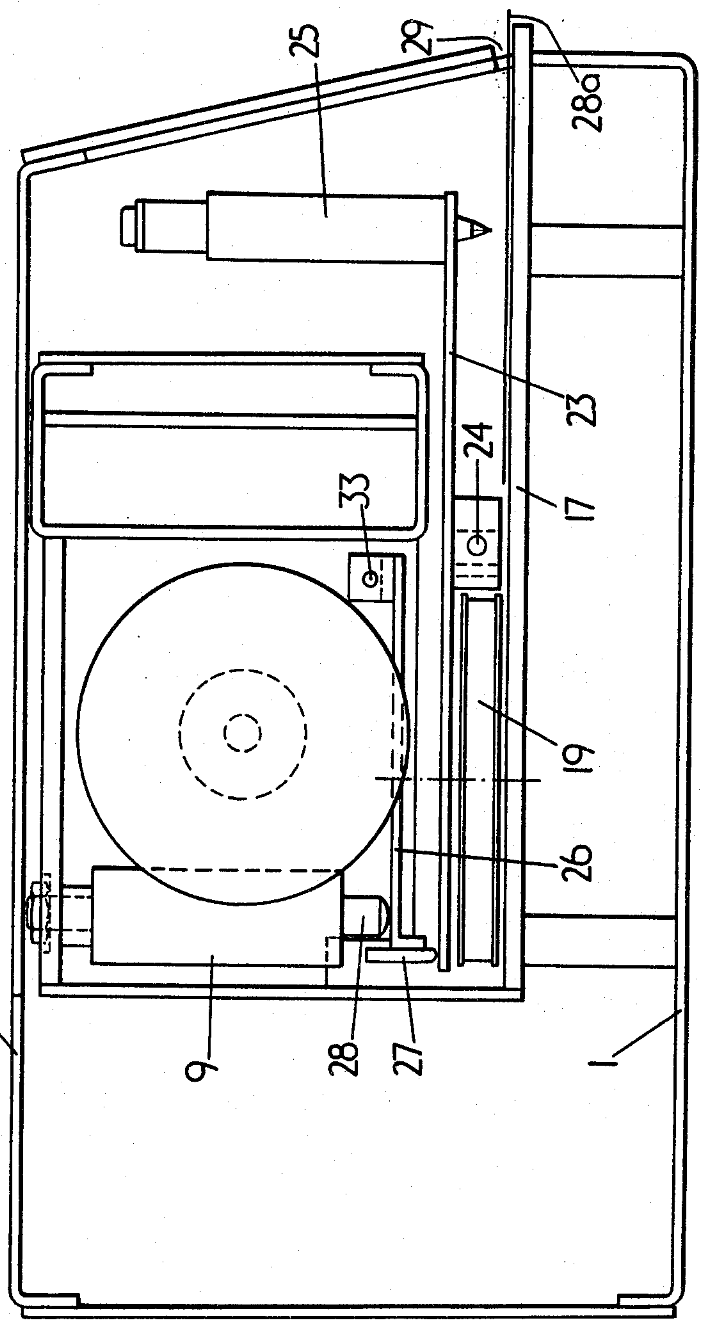


FIG. 4

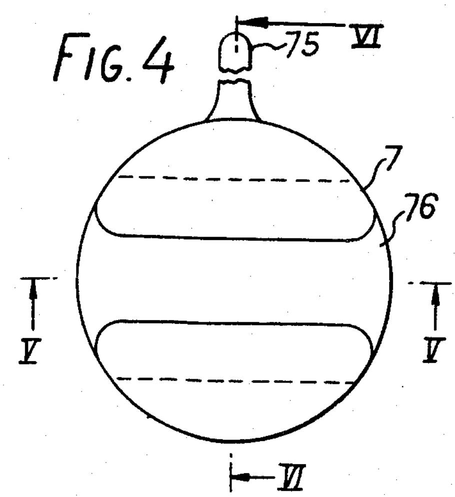



FIG. 5

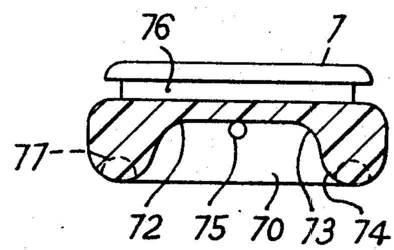



FIG. 6

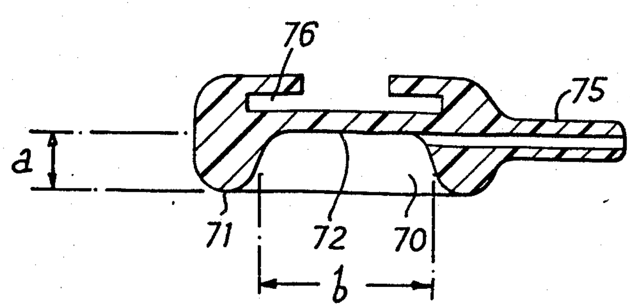
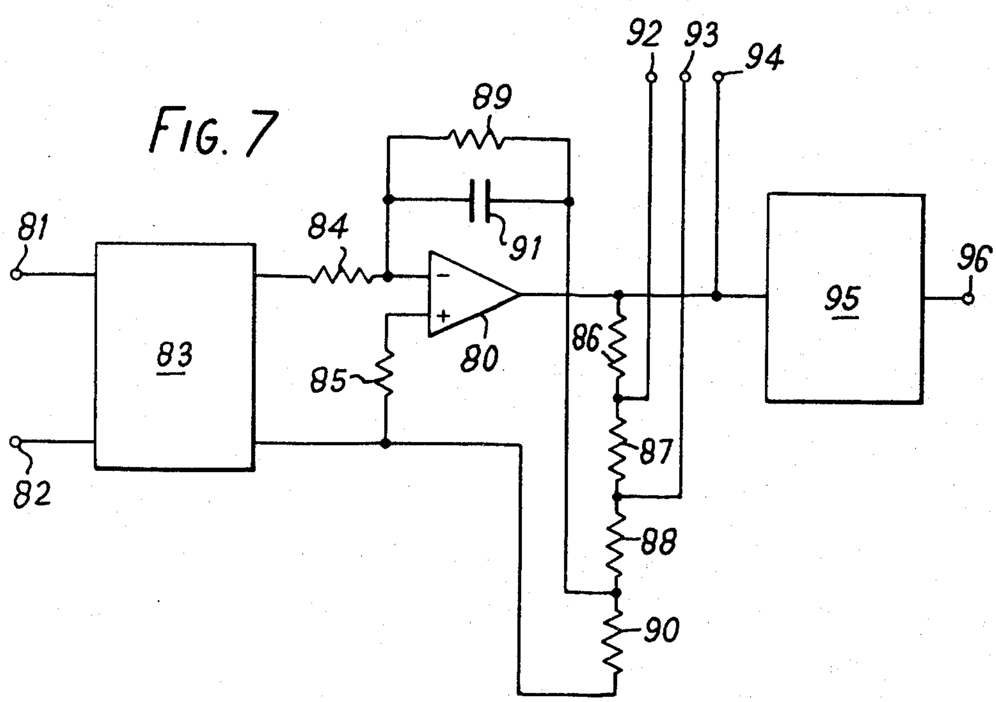



FIG. 7



# BLOOD PRESSURE RECORDER

## CROSS-REFFERENCE TO RELATED APPLICATION

This application is a continuation-in-part application of co-pending application No. 260,745, filed June 8, 1972, now abandoned.

THIS INVENTION relates to a blood pressure recorder.

Measurement of blood pressure is commonly carried out by fitting an occluding cuff around the limb of a patient, inflating the cuff to a pressure above the systolic pressure to occlude blood flow in any artery, and allowing the pressure in the cuff to fall whilst sensing the so-called Korotkoff sounds produced in the artery below the cuff. The Korotkoff sounds commence at an occluding pressure just below the systolic level, and persist at the heart rate until the occluding pressure is well below the diastolic level.

At the commencement of pulsation at the higher occluding pressure, the frequency of the Korotkoff sounds generated during each heartbeat is approximately 100 Hz, and the sounds persist at about that frequency, but with gradually decreasing amplitude as the occluding pressure is reduced.

At a pressure just above the diastolic level the amplitude of the Korotkoff sounds falls off considerably, and the frequency drops to approximately 50 Hz. As the occluding pressure is still further reduced, low level sounds persist at the heart rate.

According to this invention there is provided a blood pressure recorder comprising an inflatable occluding cuff, means for inflating the cuff, bleed valve means for allowing controlled leakage of air from the inflated cuff, sound detecting means including a cup adapted to be placed over an artery to be occluded by the cuff, a microphone and a flexible tube connecting the cup to the microphone so that the microphone can detect Korotkoff sounds in the artery and amplifying means for amplifying the output of the microphone thereby to generate an electrical output signal whose magnitude is dependent on the amplitude of the Korotkoff sounds, and pressure measuring and recording means connected to the cuff and including electrical circuitry receiving the output signal from the amplifier, the pressure measuring and recording means being operable to record an indication of the pressure in the cuff when the magnitude of the output signal from the amplifying means passes through a predetermined value, said sound-detecting means being operatively arranged to provide a sensitivity to Kortokoff sounds such that the magnitude of the said electrical output signal is greater at a frequency corresponding to the frequency of the Korotkoff sounds at pressures above the diastolic pressure than at a frequency corresponding to the frequency of the Korotkoff sounds at pressures below the diastolic pressure.

Preferably, the sensitivity of the sound-detecting means is greater at a sound frequency of 100 Hz than at a sound frequency of 50 Hz.

Suitably, the dimensions of said flexible tube are such that, in transmission from the cup to the microphone sounds of a frequency corresponding to the frequency of Korotkoff sounds at pressures above the diastolic pressure are attenuated to a lesser extent than are sounds of a frequency corresponding to the frequency



of Korotkoff sounds at pressures below the diastolic pressure.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a schematic diagram of a blood pressure recorder constructed in accordance with the invention,

FIG. 2 is a plan view of part of the recorder of FIG. 1,

FIG. 3 is a transverse sectional view of the part of the apparatus shown in FIG. 2,

FIG. 4 is a plan view of a cup of the recorder,

FIGS. 5 and 6 are cross-sections taken on lines V-V and VI-VI respectively of FIG. 4, and

FIG. 7 is a diagram of part of the electrical circuitry of the recorder.

There is shown in FIG. 1 a diagrammatic representation of the apparatus for recording blood pressure, in which there is provided a case **1** which houses most of the apparatus and which has leading therefrom a tube **2**, which is connected to a conventional cuff **3**, and pressure raising bulb **4**, by which the air pressure in the cuff **3** can be raised in the normal manner to a pressure above the systolic level of the patient. In order to detect the Korotkoff sounds, there is provided a microphone **5** within the casing **1** and flexible tube **6** which leads to a small cup **7** which can be applied to the patient's skin above the artery which is being occluded by the cuff **3**. Generally the occluding cuff **3** is fitted around the patient's upper arm and the cup **7** is usually placed over the brachial artery just inside the elbow.

Signals produced by the microphone **5** are applied to the amplifier **8**, the output of which controls energisation of a solenoid **9**, the solenoid being energised when the amplifier output exceeds a predetermined value to cause the recording pen **10** to be lowered onto the recording chart **11**.

The tube **2** is connected to a bellows **12** which is connected to the pen **10** by a rod **13**. When the cuff **3** is inflated the bellows **12** carries the pen towards the right hand end of the chart, against the action of a spring **14**, but as soon as the pumping stops, air leaks from the bellows **12**, by way of a tube **15** and a capillary tube **16**, to allow the pen to traverse the chart from right to left under the action of spring **14**.

As shown in FIGS. 2 and 3 the case **1** contains a base plate **17** upon which is supported a pair of reels **18** and **19**, which carry an endless loop of thin metal tape **20**. Rotatable with reel **18** is a pinion **21**, which is engaged by a toothed rack **22** fastened to the rod **13**. Thus, when rod **13** is moved longitudinally by expansion of the bellows **12** against the action of the spring **14**, or in the opposite direction by spring **14** as the bellows contracts, as described with reference to FIG. **1**, reel **18** is rotated by the rack and pinion **21, 22**.

A table **23**, pivoted on, and slidable longitudinally on, a horizontal rod **24**, is coupled to the band **20** by a suitable coupling (not shown), so that rotation of reel **18** causes linear movement of table **23**. At one end, table **23** carries a felt tipped pen **25**. Above the table **23** is a lever **26**, pivotable about horizontal axis **33**. A bar **27** fixed to the free end of lever **26** rests upon the end of the table **23** remote from pen **25**.

Above the lever **26** is mounted the solenoid **9** and an armature **28**, which normally rests upon lever **26**. The weight of the armature, acting through lever **26**, pivots table **23** about rod **24** to lift the pen **25** clear of a chart

28a inserted into the recorder through a slot 29 in case 1. When the solenoid 9 is energised, the armature 28 is lifted and allows the pen 25 to fall on to the chart 28a, thereby making a dot on the chart.

Two tubes 30 and 31 extend from the fixed end (i.e. the right hand end as seen in FIG. 2) of bellows 12 and are in communication with the interior of the bellows. To one of these tubes is connected the cuff 3 and bulb 4, through the flexible tube 2, while the other tube is connected by a tube (not shown) to a capillary tube 16, supported above reel 18. A fine wire needle, held in bracket 32 fastened to the rod 13, extends into the bore in capillary tube 16, so that as the bellows 12 contracts, the effective length of the capillary is gradually reduced by movement of the needle and the rate of expulsion of air from bellows 12, and thereby, the rate of movement of the pen is kept substantially constant during deflation of the bellows.

The felt tipped pen 25 may be easily replaceable.

It will be apparent that the position at any instant of the pen relative to a chart placed in the recorder gives an indication of the pressure in bellows 12 and therefore of the pressure in the cuff. The recorder can be calibrated by connecting a manometer to the cuff and bellows, observing the pressure measured by the manometer as the bellows deflates, and tapping the cup 7 as the pressure falls through a number of specific levels to cause the pen to mark the chart, so that marks on the chart are produced corresponding to those known pressures.

As shown in FIGS. 4 to 6, the cup 7, which is a one-piece nylon moulding, has a cavity 70 bounded by a circular rim 71 which in use contacts the patient's skin. The cavity is generally cylindrical, having a depth *a* of 5.0 mm and a mean diameter *b* of 13 mm, the flat end face 72 of the cavity being joined to rim 71 by respectively concave and convex curved surfaces 73 and 74 each having a radius of curvature, as seen in section in FIGS. 5 and 6, of 3.0 mm. A spigot 75, of outside diameter 3.0 mm and about 11 mm long, extends radially from the cup, and a cylindrical bore 1.0 mm in diameter extends through the spigot and the body of the cup to emerge into cavity 70 at a point adjacent the flat end face 72. On the side opposite cavity 70 the cup 7 is formed with a slot 76 which receives a strap (not shown) for holding the cup 7 in position on the patient's arm. Instead of a strap, the cup 7 could be provided with a hollow suction ring, shown in dotted lines at 77 in FIG. 5, extending around rim 71 and connected to a suction bulb by means of which suction could be applied to the hollow ring when the rim 77 is in contact with the patient's skin so that the cup is held firmly in place. The flexible tube 6 joining the cup 7 to microphone 5 is a push fit over spigot 75 and has a bore of 3.0 mm diameter and a length of 100 cm.

It is found, in use, that Korotkoff sounds transmitted via the cup and tube to the microphone are attenuated during their passage through the tube, and it has further been found experimentally that with a cup 7 and tube 6 of the described dimensions sounds of a frequency of 50 Hz are attenuated approximately twice as much as sounds of a frequency of 100 Hz.

The microphone 5 is a ceramic cartridge microphone sold by Shure Brothers Incorporated of Evanston, Ill. under model No. 99B 405. This microphone has a substantially flat response over the relevant range from 50 Hz to 100 Hz.

FIG. 7 shows in more detail the amplifier 8 and its associated circuitry. The amplifier comprises an operational amplifier 80, which may be of the type Ser. No. 72741 sold by Texas Instruments. The output of microphone 5 is connected to terminals 81 and 82 and is applied through suitable impedance matching circutiry 83 to the inverting and non-inverting inputs of amplifier 80. In series with the inverting input is a resistor 84, and a resistor 85 is in series with the noninverting input. A feed-back path consisting of resistors 86, 87, 88 and 89 in series and a capacitor 91 in parallel with resistor 89, is connected between the output of the amplifier 80 and its inverting input. A resistor 90 is connected between resistor 85 and the junction of resistors 88 and 89. Either or both of resistors 86 and 87 in the feed-back path can be shorted out by selectively connecting together pairs of the terminals 92, 93 and 94 to alter the overall sensitivity of the amplifier. The output of the amplifier is supplied to a trigger circuit 95 which provides an output signal 96 whenever the output of the amplifier exceeds a predetermined value. The trigger circuit may be of any suitable well-known kind.

Typically, the values of the components of the amplifier circuitry may be as follows:

| | | | |
|---|---|---|---|
| Resistor | 84 | 1.0 | Kilohm |
| do | 85 | 100 | do. |
| do. | 86 | 15 | do. |
| do. | 87 | 8.2 | do. |
| do. | 88 | 6.8 | do. |
| do. | 89 | 91 | do. |
| do. | 90 | 1.0 | do. |
| Capacitor | 91 | 4.7 | nanofarads |

It is found experimentally that with the amplifying circuit described, with both resistors 86 and 87 in circuit, the output voltage supplied by the amplifier to trigger circuit 95 when an input signal of 100 Hz frequency is supplied from the microphone is somewhat greater than the output signal provided with an input of the same amplitude but of 50 Hz frequency, the ratio of the two output signals being approximately 1.2.

It will be apparent therefore that the overall sensitivity of the system to Korotkoff sounds, i.e., the magnitude of the amplifier output signal produced in response to Korotkoff sounds of a given intensity, is about twice as great for sounds of 100 Hz frequency than for sounds of 50 Hz frequency, the larger part of this difference being attributable to the differential attentuation of sound transmitted from the cup 7 to the microphone 5 by flexible tube 6.

In using the recorder, the cuff 3 is fitted to the patient's upper arm, and the cup 7 is strapped to the arm below the cuff so that the cup lies over an artery. The cuff is inflated by means of bulb 4 to a pressure of, say 200 to 250 mm mercury, and then begins to deflate through the bellows and tube 15 as described above. When the pressure in the cup falls to the systolic pressure, Korotkoff sounds are detected by microphone 5 and an output signal is provided by amplifier 80. This signal exceeds the predetermined value at which the trigger circuit 95 responds to energise the solenoid 9, during each systole as blood flow recommences through the artery. The pen 25 therefore commences to make dots on the chart at a frequency equal to the patient's heart rate, and continues dotting until the pressure in the cuff falls to the level of diastolic pressure, when the intensity of the Korotkoff sounds falls and with it the output of the amplifier, so that acutation of the pen ceases. Thus, as the pen traverses chart **28***a* during deflation of the cuff and bellows, a row of dots is produced on the chart, the positions of the first and last dots indicating respectively the systolic and diastolic pressures. Since the pen moves continuously, there is a possible margin of error in the reading given by the first and last dots equal to the distance through which the pen moves between successive actuations of the solenoid. This margin of error can however be allowed for by taking a number of measurements in quick succession, as can be done readily with the described apparatus.

The response level of the trigger circuit **95** is chosen so that the solenoid **9** is actuated only when Korotkoff sounds are produced between the systolic and diastolic levels. The sensitivity of the amplifier can be adjusted as described above to compensate for the different intensities of the Korotkoff sounds produced by different patients.

Since, as discussed above, the overall response of the system to Korotkoff sounds is greater for sounds of 100 Hz than for sounds of 50 Hz, the change in frequency of the sounds from approximately 100 Hz to approximately 50 Hz as the pressure falls through the diastolic level causes a fall in the amplifier output over and above that due to the drop in intensity of the sounds. This helps to produce a clear demarcation at the diastolic level, so that the last dot marked on the chart provides an accurate indication of diastolic pressure.

Since the dots are marked on the chart at a frequency equal to the heart rate, the apparatus will also provide a record of heart rate, if the speed of movement of the pen is known.

It will be apparent that modifications could be made in the described embodiment within the scope of the appended claims. For example, other diemnsions of the cup **7** and tube **6** could be employed to give the desired differential attenuation of sounds. Instead of relying solely on the differential attenuation of sound by the cup and tube, a microphone could be employed having a greater response at 100 Hz than at 50 Hz, to enhance the differential overall response of the system.

I claim:

**1.** A blood pressure recorder comprising an inflatable occluding cuff, means for inflating the cuff, bleed valve means for allowing controlled leakage of air from the inflated cuff, sound detecting means including a cup adapted to be placed over an artery to be occluded by the cuff, a microphone and a flexible tube connecting the cup to the microphone so that the microphone can detect Korotkoff sounds in the artery and amplifying means for amplifying the output of the microphone thereby to generate an electrical output signal whose magnitude is dependent on the amplitude of the Korotkoff sounds, and pressure measuring and recording means connected to the cuff and including electrical circuitry receiving the output signal from the amplifier, the pressure measuring and recording means being operable to record an indication of the pressure in the cuff when the magnitude of the output signal from the amplifying means passes through a predetermined value, said sound-detecting means being operatively arranged to provide a sensitivity to Korotkoff sounds such that the magnitude of the said electrical output



signal is greater at a frequency corresponding to the frequency of the Korotkoff sounds at pressures above the diastolic pressure than at a frequency corresponding to the frequency of the Korotkoff sounds at pressures below the diastolic pressure.

**2.** A blood pressure recorder as claimed in claim **1**, in which the sensitivity of the sound-detecting means is greater at a sound frequency of 100 Hz than at a sound frequency of 50 Hz.

**3.** A blood pressure recorder as claimed in claim **2**, in which the sensitivity of the sound-detecting means at 100 Hz is approximately twice than at 50 Hz.

**4.** A blood pressure recorder as claimed in claim **1**, in which the dimensions of said flexible tube are such that, in transmission from the cup to the microphone sounds of a frequency corresponding to the frequency of Korotkoff sounds at pressures above the diastolic pressure are attenuated to a lesser extent than are sounds of a frequency corresponding to the frequency of Korotkoff sounds at pressures below the diastolic pressure.

**5.** A blood pressure recorder as claimed in claim **4**, in which the dimensions of the flexible tube are such that, in transmission from the cup to the microphone, sounds of a frequency of 50 Hz are attenuated to a greater extent than sounds of a frequency of 100 Hz.

**6.** A blood pressure recorder as claimed in claim **1**, in which the pressure measuring and recording means includes a bellows the interior of which is in communication with the cuff, a pen linked to the bellows so as to be moved across a chart by contraction of the bellows during deflation of the cuff, and electromagnetic means operable on receipt of an output signal from the sound-detecting means of magnitude greater than said predetermined value to move the pen into engagement with the chart.

**7.** Apparatus for sensing and measuring blood pressure comprising means for detecting Korotkoff sounds in an artery and for indicating the point at which said sounds represent a demarcation of the diastolic pressure, said means for detecting including means for sensing the amplitude and frequency of said sounds and generating a signal in response thereto the magnitude of which is proportional to said amplitude, means for attenuating the amplitude of the Korotkoff sounds as a function of the frequency thereof, and wherein said means for attenuating include means for attenuating the amplitude of the Korotkoff sounds at frequencies occurring below the diastolic pressure to a greater extent than the amplitude at frequencies above the diastolic pressure, whereby the magnitude of said signal will be greater at pressures above the diastolic pressure than at pressures below the diastolic pressure thereby indicating a demarcation of the diastolic pressure.

**8.** Apparatus as defined in claim **7** wherein for Korotkoff sounds having a frequency of 100 Hz at pressures above the diastolic pressure and 50 Hz at pressures below the diastolic pressure said means for attenuating are adapted to attenuate the respective amplitudes such that the magnitude of said signal at pressures above the diastolic pressure is approximately twice as great as at pressures below the diastolic pressure.

* * * * *