June 20, 1961 G. D. ZUIDEMA ET AL 2,989,051

INDIRECT BLOOD PRESSURE RECORDER

Filed May 29, 1956 3 Sheets-Sheet 1

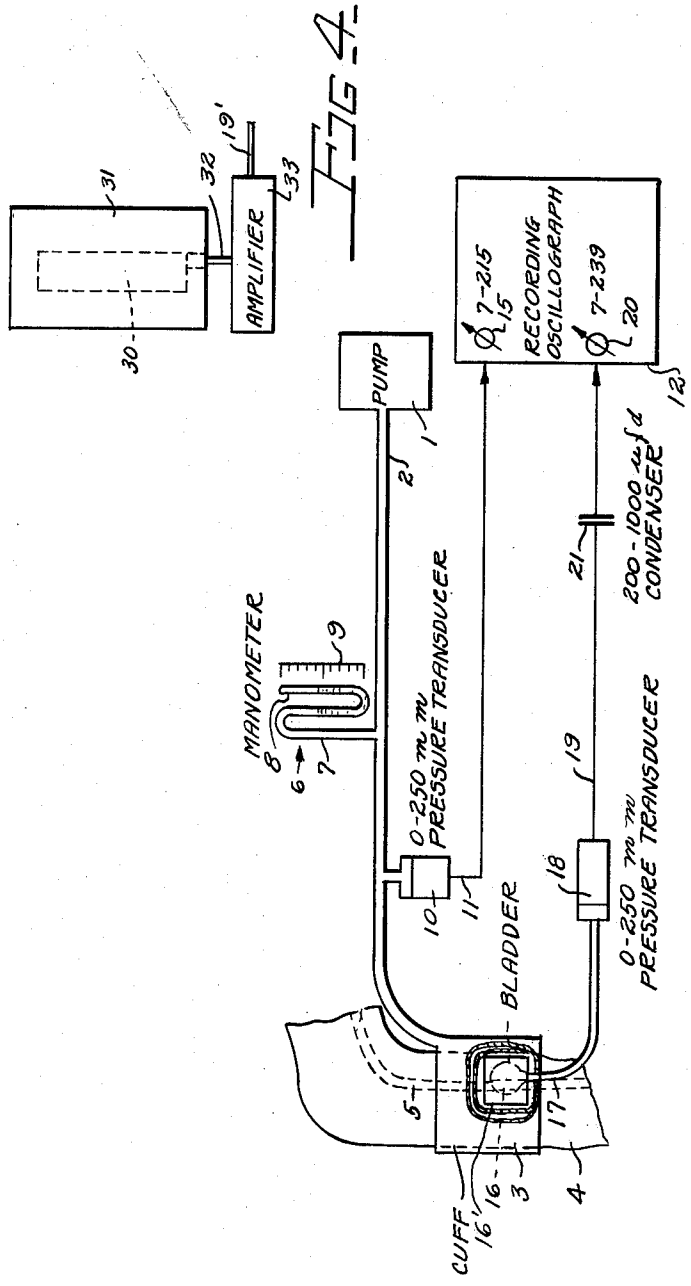


FIG. 1

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3 Sheets-Sheet 2

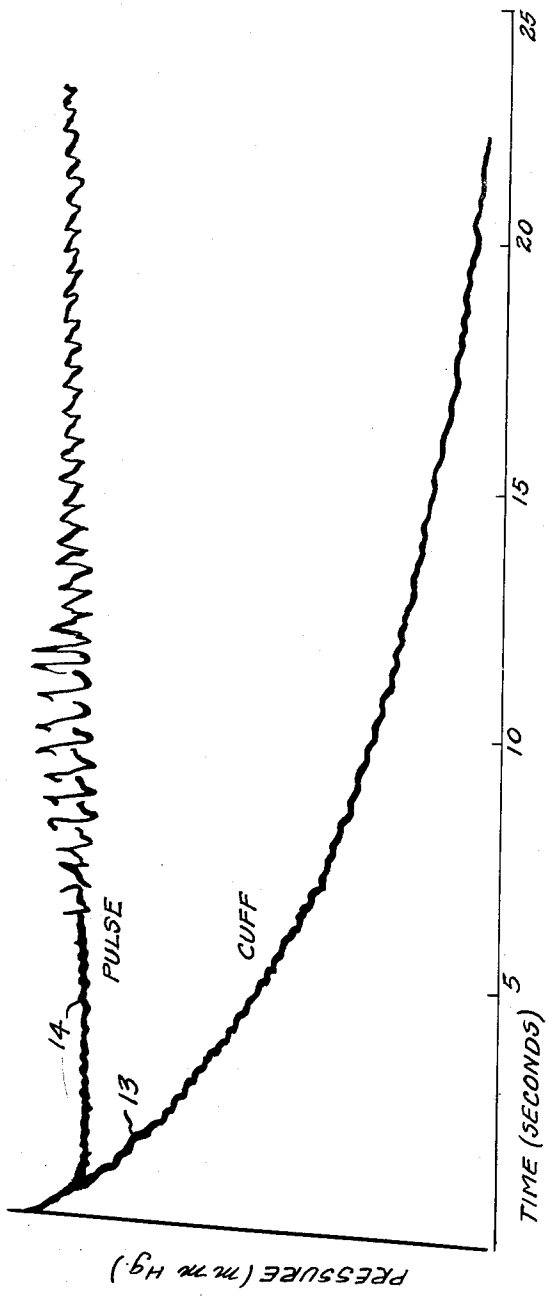


FIG. 2

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Filed May 29, 1956 3 Sheets-Sheet 3

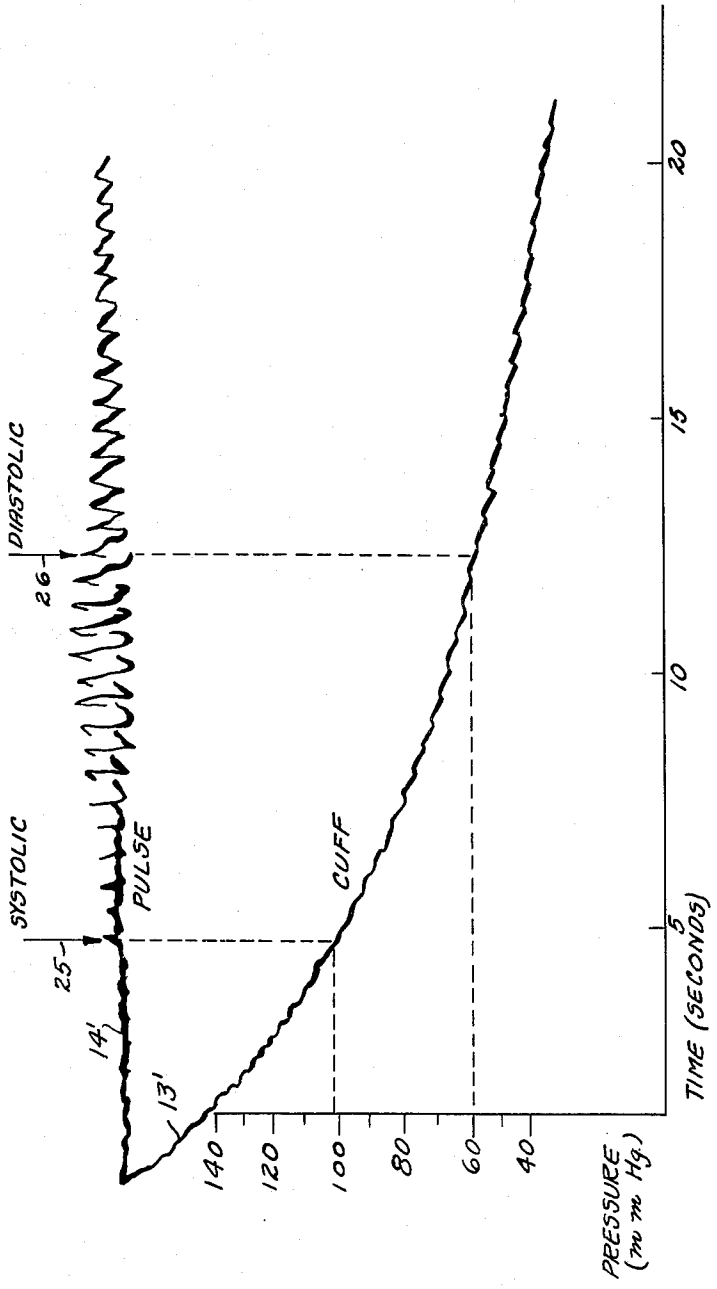


FIG. 3.

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INDIRECT BLOOD PRESSURE RECORDER

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1 Claim. (Cl. 128—2.05)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to us of any royalty thereon.

This invention relates to an indirect blood pressure recorder and more particularly to an improved means and method for taking and recording blood pressure, as well as pulse rate changes and the like.

The indirect taking and the recording of blood pressure readings by the inflated cuff method is well established. In a usual procedure an inflatable cuff is applied over an artery in a man's arm, the cuff is inflated to a pressure in excess of the man's systolic blood pressure and gradually deflated over a period of about 20 seconds, during which time the blood flow approaches normal for that individual. Sounds made by the blood in the artery during the described procedure are commonly detected by the use of a stethoscope. Of particular interest are the sounds at the systolic or peak blood pressure and at the diastolic or minimal blood pressure during the described procedures.

In practicing the above described method the cuff may be made of fabric, rubber, a flexible plastic or the like and may be inflated with air, water or other desired fluid to a predetermined measured and controlled pressure. The pressure within the cuff is commonly measured with a mercury or an aneroid manometer. The deflation of the cuff is commonly accomplished by the manual control of the escape valve during which the sound from the stethoscope is commonly depended upon for indicating the blood pressure at the systolic and at the diastolic pressure extremes. The manual control of the escape valve is characterized by the limitation of a nonuniform linear cuff deflation, which is desirable.

During the cardiac cycle it is of particular importance to detect or to identify that instant at which the artery obstruction which is introduced by the inflated cuff just opens at the systolic pressure and the instant at which the dropping arterial pressure just reaches the diastolic pressure. The sounds of blood flow through the artery during the cardiac cycle as the artery undergoes compression and decompression by the operation of the inflated cuff, both when detected by the stethoscope or recorded, are important sources of information to the experimenter.

The nature of the present invention is the supplying of records of blood pressure which are usable as a basis for the study of cardiovascular responses from circulatory functions, inclusive of heart action. The substance of the present invention is an adaptation of an inflated cuff technique by means of a pump or a bulb for inflating the cuff with a mercury manometer indicating controlled pressure and inclusive of a first pressure transducer connected with a recording oscillograph for recording the pressure within the inflatable cuff. A pressure sensitive device is positioned between the inflatable cuff and a skin surface overlying an artery from which mechanical data is to be derived and a second pressure transducer picks up and converts the arterial pulse into an electrical signal which is applied preferably through a capacitor to the same recording oscillograph where a tape is printed. The tape produced by the recording oscillograph shows on a time basis, both the cuff pressure and the arterial pressure rise and fall accurately and permanently recorded.

As the terms are used herein systolic pressure is defined as the point at which systemic arterial pressure is just sufficient to overcome the pressure within the inflated cuff. In analyzing the recorded pulse waves which are produced by the apparatus contemplated hereby, the first abrupt increase of the amplitude of the pulse wave, together with its change in shape, is taken as the point of systolic pressure and the point of diastolic pressure is recognized by its form change and by its decrease in amplitude. At the systolic pressure point the pulse also is characterized by a wider separation of the ascending and the descending strokes of the curve. A pressure sensitive device overlying the brachial artery in the arm and beneath the inflatable cuff permits the detection of pulses as they appear and disappear with pressure alterations within the cuff.

The blood pressure recorded which is contemplated hereby is used on human subjects in studies of the heart and the circulation. It has been used successfully by the Armed Forces in supplying recordings taken from subjects on the human centrifuge, in high altitude pressure chambers and the like.

An object of the present invention is the collection and the preservation of records indicating the cardiovascular status of a subject, particularly during the changes of acceleration and during high altitude flight where cardiovascular responses are all important. The records so provided are a graphic presentation of arterial blood pressure and pulse rate for purposes of study, comparison, and illustration.

This device provides for the automatic recording of blood pressure, and pulse rate changes using the generally accepted, recognized and well established inflated arm cuff method.

In practicing the present invention preferably an electric motor operated pump is used to inflate the cuff sufficiently to occlude the brachial artery in the human arm. The motor may be replaced by a rubber bulb if desired. The cuff is then allowed to deflate slowly preferably at a substantially linear, uniform rate during which the pressure changes with time are made a permanent record in a recording oscillograph.

An illustrative embodiment of the present invention is shown in the accompanying drawings wherein:

FIG. 1 is a diagram of an apparatus contemplated hereby as installed on a human arm;

FIG. 2 is a reproduction of an oscillograph recording of an actual pulse wave above a cuff pressure curve on time-pressure coordinates using the equipment shown in FIG. 1;

FIG. 3 is a reproduction of another oscillograph recording where an actual pulse wave above a cuff pressure curve is presented on coordinates of time in seconds along the abscissa and of pressure in millimeters of mercury along the ordinate; and

FIG. 4 is a modification of the invention substituting a strain gage for an inflatable balloon shown in FIG. 1 of the drawings.

The equipment embodying the present invention and represented in FIG. 1 of the present drawings comprises a preferably automatic pump 1 which supplies under pressure a fluid such as air, water or the like through a hollow tube 2 to an inflatable cuff 3. The cuff 3 is shown encircling a member or an extremity such as a human arm 4 to which blood pressure pulses are conducted through a brachial artery 5. Magnitudes of pressure within the cuff 3 and within the hollow tube 2 preferably are made directly visually observable by means of a glass

walled mercury manometer **6**. The manometer **6** has one leg **7** opening directly into the pressure tube **2** and has a second leg **8** which is sealed at its end remote from the tube **2**. The mercury meniscus of the manometer is read directly projected against a scale **9**, in indicating the magnitude of pressure within the cuff **3**. The manometer **6** is used both in calibrating the system and in providing direct readings during experimentation upon a subject. A first pressure transducer **10** has a blood pressure receiving end which opens directly into the pressure tube **2** and an output end from which an electrical lead **11** extends. The first pressure transducer output electrical lead **11** is connected to a recording oscillograph **12**. The first pressure transducer output signals cuff pressure curves **13** and **13'** which are reproduced in FIGS. 2 and 3, respectively, of the accompanying drawings.

The pressure system of the pump **1**, the pressure tube **2**, the cuff **3**, the manometer **6** and the pressure end of the transducer **10**, preferably has a safe pressure range up to at least 250 mms. of mercury. The pump **1** which is contemplated hereby is the subject matter of a patent application now being prosecuted in the interest of the H. L. Klein Manufacturing Company of 481 East 11th Avenue, Columbus, Ohio. The pump **1** control, not shown, is adjusted to perform automatically within 1 or 2 seconds the inflation of the cuff **3** and then to shut off automatically upon reaching a desired pressure of illustratively 240 mms. of mercury, as indicated by the manometer **6**. Pump control then automatically allows the fluid pressure within the system to subside along the curves **13** and **13'** to ambient over the next 22 to 24 seconds of a full time cycle, which illustratively is 25 seconds long. The entire cycle of 25 seconds duration in time is repeated continuously until the procedure is terminated by the operator.

The first pressure transducer **10** illustratively may be a Gauer-Wetterer miniature manometer, which is described in the publications: the journal Science, for October 6, 1950, page 404, and in the journal Circulation, volume 3, page 390; a pressure transducer manufactured by and commercially available from Statham Laboratories, Inc., Los Angeles, California under Patent Nos. 2,036,458 and 2,059,549; or the like. The Gauer-Wetterer pressure transducer described herein has a rubber diaphragm over a piston head at the fluid pressure end of the transducer for the purpose of confining fluid at the input end of the transducer.

The pressure values picked up by the first transducer **10** are conducted by the transducer electrical output lead **11** to the recording oscillograph **12**, where they are recorded on a tape produced by the oscillograph as the cuff pressure curves **13** and **13'**, along with the pulse wave curves **14** and **14'**, respectively, in FIGS. 2 and 3 of the drawings. The recording oscillograph **12** illustratively may contain a 7–215 galvanometer **15**, which has a sensitivity of 13 microamperes for each inch of the tape, or a galvanometer of similar sensitivity. The recording oscillograph **12** illustratively may be made by the Consolidated Engineering Corporation, or by Wm. Miller Instruments, Inc., both of Pasadena, California.

Interposed between the cuff **3** and skin overlying the brachial artery **5** of the arm **4**, is an inflatable fluid filled balloon or bladder **16**. Preferably a thin rigid plate **16'** is interposed between the bladder **16** and the cuff **3**. The plate **16'** reduces the elasticity of the system and provides a more accurate response on the tape produced by the oscillograph **12**. The balloon or bladder **16** is shown as connected by a hollow tube **17** with a second pressure transducer **18**. The second pressure transducer **18** has an electrical output signal lead **19** preferably capacitively coupled through a series connected condenser **21**, with the recording oscillograph **12**. The oscillograph **12** also contains a 7–239 galvanometer **20** with the sensitivity of 4 microamps per inch of tape.

The bladder **16** and the hollow tube **17** preferably may be made of a polyethylene plastic, rubber or the like, and preferably contain an incompressible fluid, of which boiled water is a satisfactory example and which fluid provides a direct hydraulic ram between the skin overlying the brachial artery **5** and the thin sheet rubber diaphragm which covers the piston head within the transducer **18**. The direct current component of the electrical signal output from the transducer **18** preferably is blocked by the condenser **21**, which may have an illustrative capacitance of 200 microfarads. The use of a condenser of a range of from 200 to 1,000 microfarads, connected in series between the transducer **18** and the oscillograph **12**, is preferred. In the event a miniature manometer is used, a preferred type is back loaded through a constriction so that only the alternating current component of the blood pressure signal is transformed into movements of the diaphragm, since a carrier wave is not blocked by a condenser.

Pulse waves of arterial blood surging in the brachial artery **5** are transmitted by direct mechanical conduction to the hydraulic fluid which is confined within the balloon **16** and within the tube **17**. The pulse waves in turn are applied to the pressure transducer **18** and produce displacements of the transducer diaphragm. Displacements of the transducer diaphragm initiate electrical signals which are conducted between the electrical conductor **19** and into the oscillograph **12**, for presentation upon the tape produced by the oscillograph. The pulse waves appear on the oscillograph tape as shown in the curves **14** and **14'** of FIGS. 2 and 3 of the accompanying drawings.

The tube **17** may be omitted, if preferred, from between the balloon **16** and the fluid pressure end of the transducer **18** for short coupling and for simplifying this arrangement, with the rubber diaphragm closed input tube end of the transducer **18** inserted directly through the wall of the balloon **16**. The resultant structure combines directly the balloon **16** and the transducer **18** in a single unit which is easily and conveniently attached to individual subjects. The short-coupled form of the invention is immediately and accurately responsive in sense and in magnitude to minute pressure changes which are passed from the brachial artery to the fluid within the balloon **16**.

Further simplification of the assembly results in building the balloon **16** into the wall of the inflatable cuff **3**, or attaching the balloon **16** directly to the wall of the inflatable cuff against the skin overlying the brachial artery **5**. The resultant structure provides a single assembly whether the transducer **18** is directly attached to the bladder or is attached to the bladder through a tube **17**, as preferred.

In many of the above arrangements, pressure within the cuff **3** is applied directly to the thin diaphragm of the transducer **10**, and displaces it. The resulting electrical output signal is conducted by the electrical conductor **11** to the oscillograph **12**, where the cuff pressure recordings are applied to the oscillograph tape simultaneously with the recording of balloon or bladder pressure pulse wave recordings.

The use of the condenser **21**, of from 200 to 1,000 microfarads capacity, connected in series in the pulse wave recording output from the transducer **18**, serves to pass alternating current and to block the passage of direct current and thereby to flatten out fluctuations in the base lines **14** and **14'** of the graphs shown in FIGS. 2 and 3 of the drawings. The presence in circuit of the condenser **21** eliminates the large relatively slow drop in pressure within the cuff **3**, while preserving the smaller pulse wave displacements from within the balloon **16**, as indicated in the upper curves **14** and **14'** of FIGS. 2 and 3, respectively, of the accompanying drawings.

The arrows **25** and **26** appearing in FIG. 3 of the drawings indicate respectively the systolic and the diastolic

configurations of the arterial blood pulse force patterns of the brachial artery **5**, as they appear on the tape of the oscillograph **12** from which readings in pressure in millimeters of mercury may be taken from the ordinate and time in seconds may be taken from the abscissa.

Modifications of the above described means for taking and for recording arterial blood pressures which are contemplated herein, and some of which have been used successfully experimentally in the laboratory, include a metal strain gage **30**. The strain gage **30** is enclosed in a substantially flat envelope **31** of rubber, plastic or metal. The strain gage device provides a substantially flat unit for replacing the balloon **16** between the brachial artery **5** and the inflatable cuff **3**, both when the balloon **16** is separate from the cuff and when it is made integral therewith. Output leads **32** from the strain gage **30** conduct their electrical output to an amplifier **33**, from which leads **19'** conduct signal through the capacitor **21** to the oscillograph **12**, as in the earlier disclosed embodiments of the present invention.

A modification of the strain gage concept, where the strain gage is mounted directly into and to be integral with the cuff **3** to overlie the brachial artery **5**, has the advantage of providing a single assembled cuff unit with a built-in indicator which provides simplified handling, uniformity of arm mountings, a minimizing of connections and a minimum of error arising from manipulations and connections.

The oscillograph numbers 7–215 and 7–239 are Consolidated Engineering Corporation part numbers.

A preferred form of the invention which is disclosed herein and which has been used experimentally as an automatic recording device, has been compared with auscultatory measurements made by trained and experienced physicians with favorable results. In both methods at least 20 seconds were allowed for enough pulse beats to come through for clear detection for both systolic and for diastolic pressures. In making the auscultatory measurements the diastolic pressure was noted in the muffling of sounds and at the disappearance of sounds. Systolic pressure was taken as the point at which the pulse sound was first heard.

It is to be understood that the cuff and bladder arrangement shown in FIG. 1 of the accompanying drawings is an experimentally successful method of operation of the present invention and that changes and modifications described and explained herein may be made without departing from the scope of the present invention.

What we claim is:

An indirect blood pressure recorder for recording blood pressure and pulse rate changes of blood circulating in an artery of an appendage comprising an inflatable cuff positioned around a source of pressure change, cuff inflation means for controlling the extent of cuff inflation, means indicating the extent of cuff inflation, an incompressible fluid-filled hydraulic pressure sensitive ram device overlying the source of pressure change and beneath the inflatable cuff, pressure transducer means receiving its input from the pressure sensitive ram device as changes in hydraulic pressure and converting its received input into electrical signal output sensitive in time and in magnitude, an electrical signal recording means receiving the electrical signal output from the pressure transducer means and recording in time and in amplitude the pressure changes to which the hydraulic pressure sensitive device is subjected, and a single piece thin rigid pressure distributing plate interposed between the pressure sensitive ram device and the cuff for uniformly sustaining pressure throughout its area and thereby modifying the elasticity of the system.

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