

[72] Inventors **Gordon K. Burns**
Colts Neck;
Jeofry S. Courtney-Pratt, Springfield, N.J.
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[73] Assignee **Bell Telephone Laboratories, Incorporated**
Murray Hill, Berkeley Heights, N.J.
a corporation of New York

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Primary Examiner—Delbert B. Lowe
Attorneys—R. J. Guenther and Edwin B. Cave

[54] **SPHYGMOMANOMETRIC METHOD AND APPARATUS**
10 Claims, 9 Drawing Figs.

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[50] Field of Search 128/2.05

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ABSTRACT: Diastolic blood pressure measurement by arterial auscultation is afforded by arresting flow as with a pressure cuff and then applying increasingly negative pressure probes to the cuff generally coincident with each phono- or electrocardiographically ascertained minimum of the heart's pressure cycle, maintaining the negative wave amplitude always in excess of the pulse pressure. Cuff pressure at the onset of Korotkow sound signifies diastolic pressure level. Apparatus is described for unattended, automatic and continuous blood pressure monitoring using this method for diastolic readings. Cuff pressure in one embodiment is held constant as increasingly large negative pressure excursions are applied; in another embodiment cuff pressure is decreased while the negative pressure excursions are held constant in amplitude.

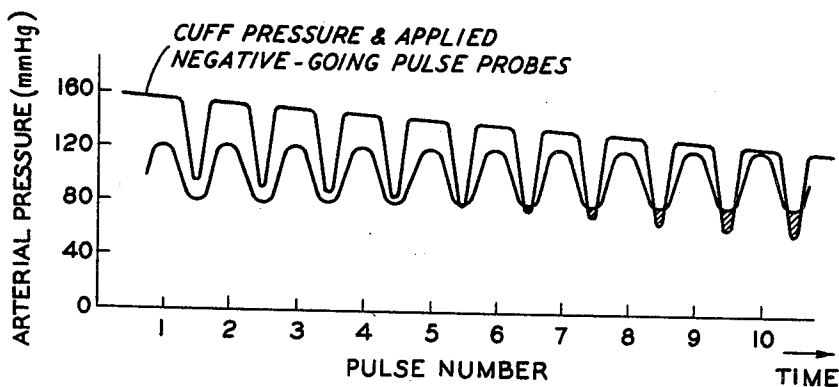
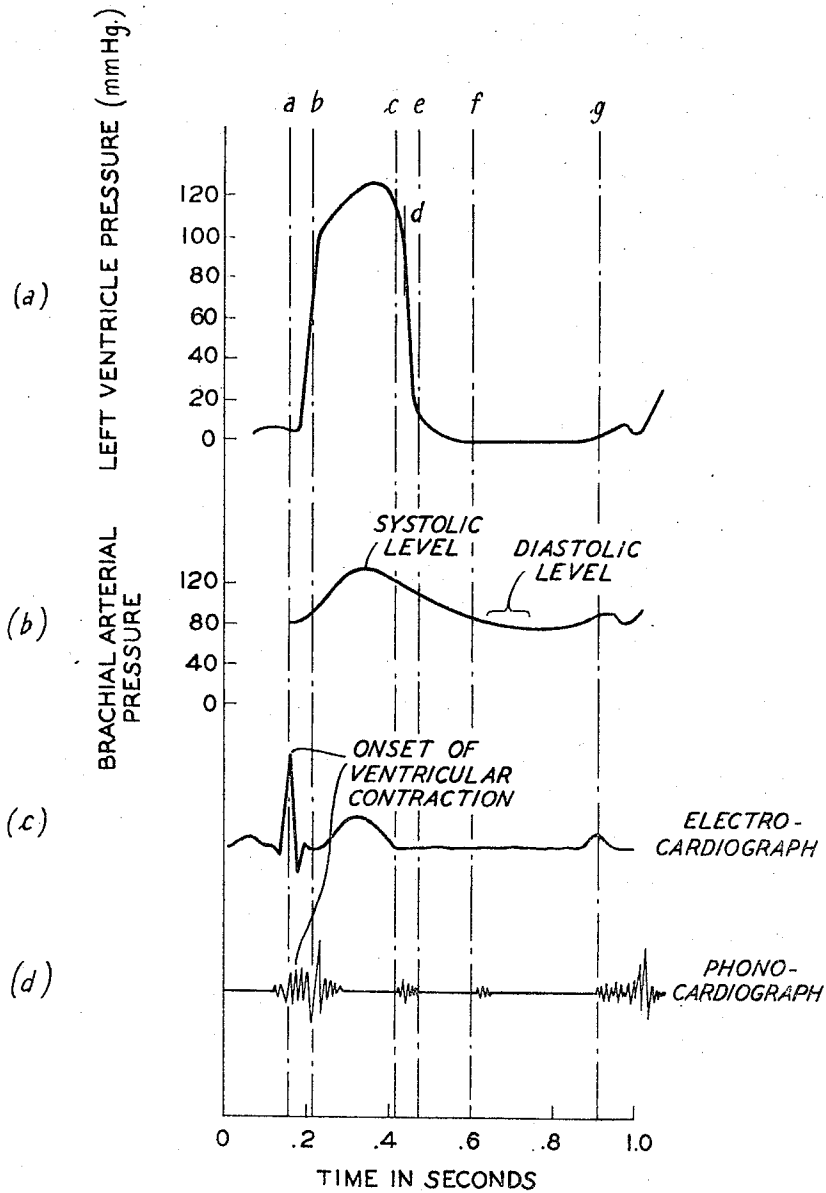
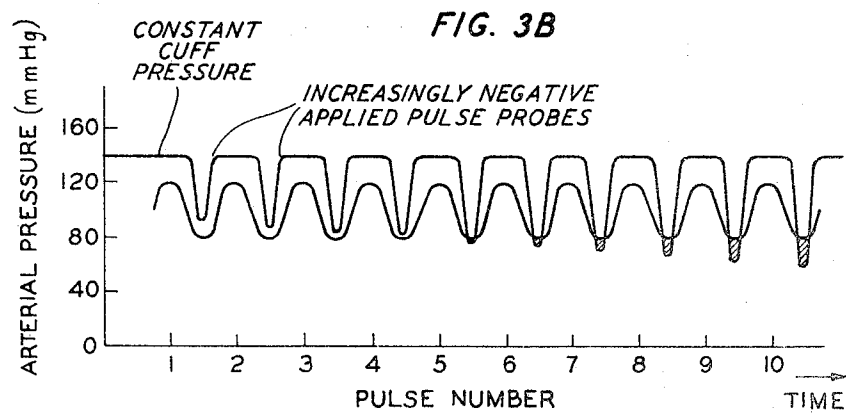
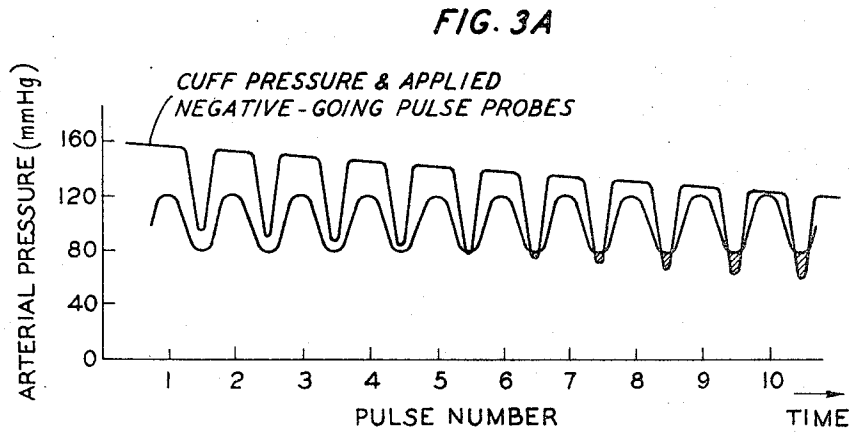
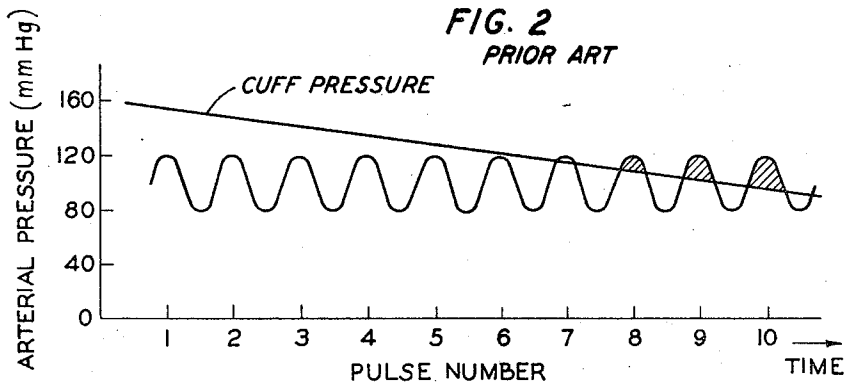


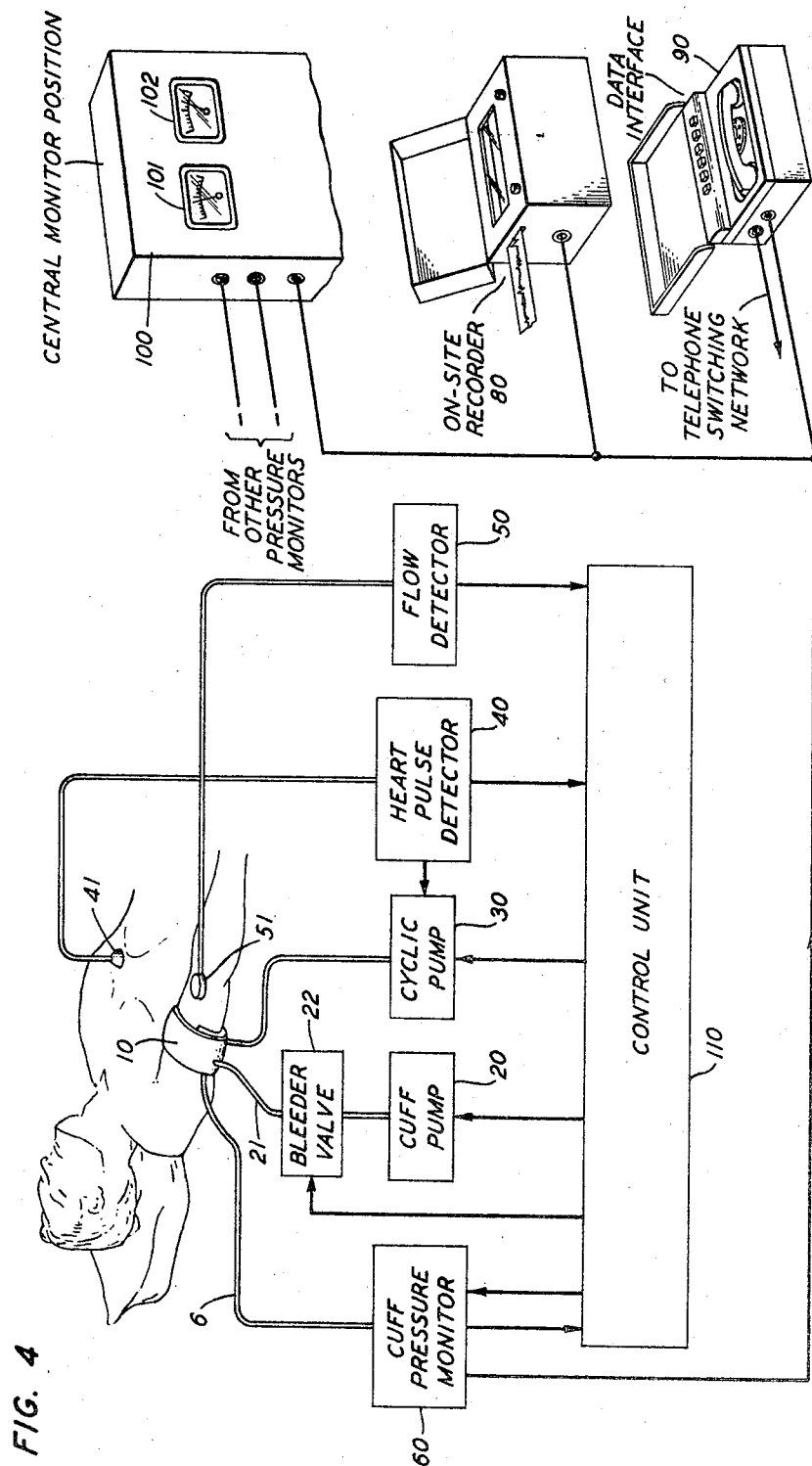
FIG. 1

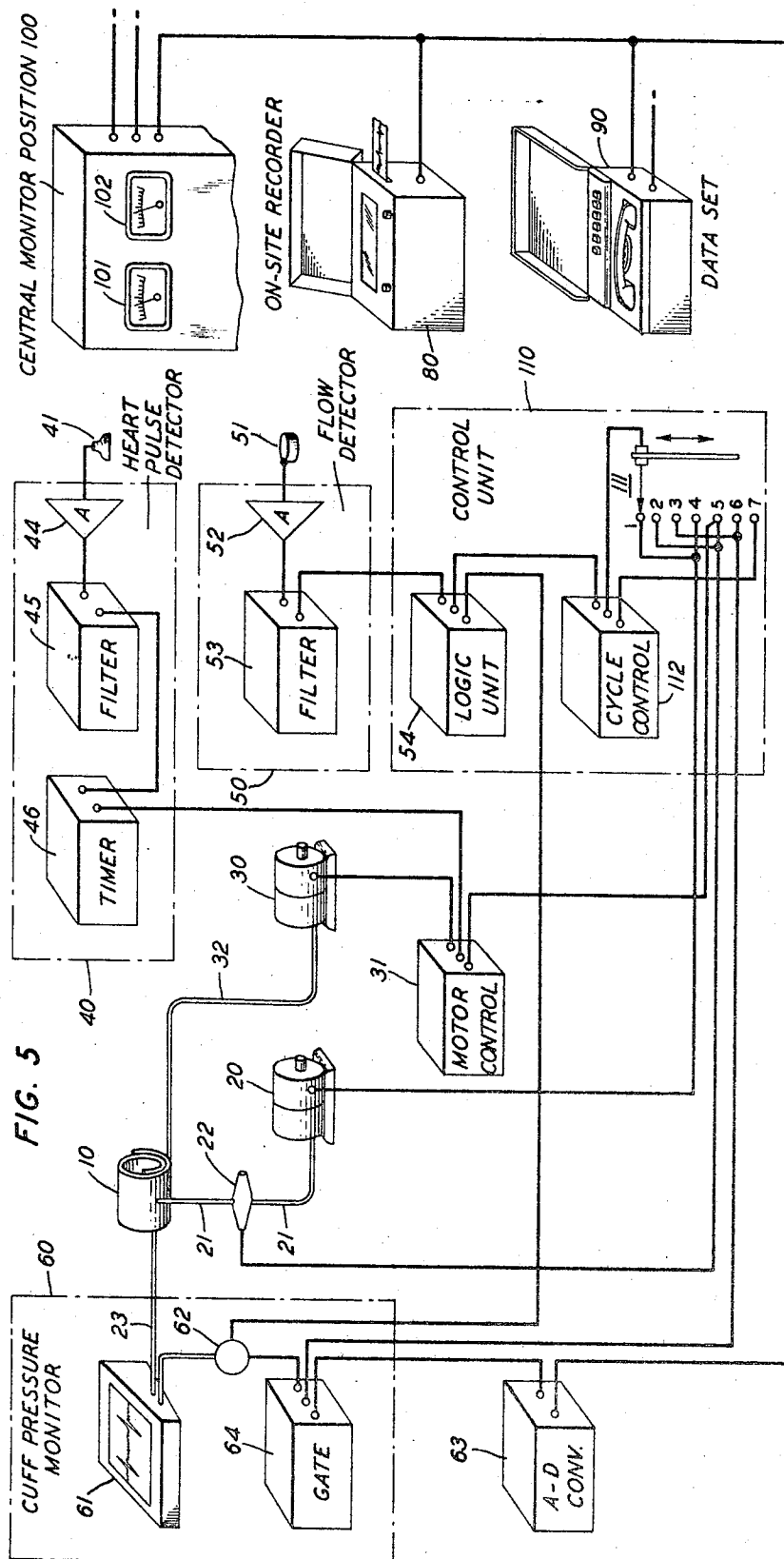


INVENTORS: G. K. BURNS
J. S. COURTNEY-PRATT
BY *Charles E. Grooms*

ATTORNEY







SPHYGMOMANOMETRIC METHOD AND APPARATUS

This invention relates in general to sphygmomanometry; and more particularly to a new method for determining the systolic and diastolic blood pressure by the auscultatory technique.

BACKGROUND OF THE INVENTION

Blood pressure dynamics provide invaluable medical insights in the detection and diagnosis of circulatory and cardiac disorders. Pressure determination is particularly useful, for example, in ascertaining the contractibility of the heart muscle and the distensibility of the ventricles, arteries and veins. As a further example, with continuous monitoring of blood pressure after a major cardiac failure, the oncoming of relapse often can be detected in time for corrective medical action.

Compared with blood flow and blood volume—the other two principal circulatory attributes—blood pressure is the most easily determined and recorded. Yet its accurate measurement by means other than direct catheter insertion into an artery is nonetheless a difficult and exacting task. As the direct method is neither convenient nor altogether safe, its employment is reserved usually for exigent human cardiopulmonary diagnostic work; and hence the various indirect blood pressure measurement methods predominate by far in most practice.

Of these, the auscultatory method is most commonly employed clinically. The basic elements for manual practice of this method are the familiar inflatable rubber arm cuff connected to a pump and to a manometer, and a stethoscope. The method relies on detection of the Korotkow sounds observable during relief of constriction of an artery subjected to a varying pressure applied from without, and their correct interpretation as criteria for the systolic and the diastolic pressure points. Normal arterial blood flow is essentially inaudible; but if an artery is completely constricted as by an inflated cuff and then relieved enough to allow slight reopening of the arterial lumen, a distinct rhythmic tapping sound commences. The onset of these tapping sounds, as heard through the stethoscope, for example, signifies the point of systolic pressure which is then read from the manometer. As cuff pressure is further reduced, the sound alters markedly in both quality and intensity. Finally, just prior to disappearing, the arterial sound is faint and muffled. The manometer pressure at the time of complete disappearance of this muffled sound reflects the diastolic pressure.

Although the initial arterial sounds corresponding to the systolic pressure point usually are readily detectable either by a human listener stethoscopically or through numerous electromechanical arrangements, it is extremely difficult to detect accurately the point at which the muffled sounds corresponding to the diastolic pressure level disappear. This is particularly so with respect to automated sphygmomanometric schemes, a wide variety of which are found in the prior art.

Many such schemes, for example, convert the Korotkow sounds heard as the cuff deflates into a varying electrical signal which is amplified and then interpreted. Insofar as diastolic pressure detection is concerned, however, this approach involves an inherently uncertain distinguishing of assumed background noise from the desired end-point muffled arterial sounds which connote the diastolic pressure point. Other methods rely on the detection of apparently characteristic sounds lying in a low-frequency band and occurring during the arterial pulse pressure interval to provide indices of the systolic and diastolic pressures. Another attempted remedy of the detection problem involves extremely sensitive pickup devices for converting the arterial pulse into an electrical signal.

These and other known prior art schemes do not overcome, however, the basic problem of detecting with certainty against a background of noise and perturbations the critical diastolic pressure signified by the disappearance of all arterial sound.

Accordingly, one object of the invention is to improve the capability of sphygmomanometers to correctly detect the Korotkow sound corresponding to the diastolic blood pressure.

A further object of the invention is to reduce the need for human attending of a convalescing cardiac patient.

A further object of the invention is to make possible a preferred system for automatic and continuous monitoring of the systolic and diastolic pressures of a patient and for their transmission to a remote monitoring point.

SUMMARY OF THE INVENTIVE CONCEPT

The basic principle of the invention, broadly, may be practiced by subjecting a selected artery to an applied initial pressure substantially above systolic and then effecting thereupon a gradual applied pressure decrease coupled with the application of a brief, constant, negative-going pressure peak at each minimum of the heart's pressure cycle, this peak having an amplitude in excess of the pulse pressure.

In one exemplary embodiment illustrating the practice of the invention, the heart's pulse repetition frequency is monitored and supplied to a cyclic pump connected to an arm cuff. The pump cycle time is governed by this input. The pump thus applies the mentioned negative-going pressure peak to the cuff coincidentally with the occurrence of successive minima of the heart's pressure cycle. The cuff is deflated, but with its maximum pressure maintained higher than the systolic blood pressure. The cuff's negative-going pressure excursions imparted through the cyclic pump action approach the diastolic arterial pressure, but because of their timing do not interact with the systolic level at all. Hence, a stethoscopic monitoring of the arterial sounds at this point will detect no Korotkow sounds. However, when cuff pressure at the instant of the negative-going excursion is low enough to allow opening of the arterial lumen, Korotkow sounds signifying the diastolic pressure level are detected and the desired manometric reading of the cuff is taken.

Thus, audio detection of an initial blood flow surge in the artery occasioned by the coincidence of the diastolic arterial pressure and the peak of the negative-going pressure excursion in the cuff is readily afforded without the presence of ambiguous background noises so characteristic of the methods which rely instead on detection of the disappearance of sounds.

The invention and other objects, features and advantages thereof will be readily apprehended from a reading of the detailed description to follow of an illustrative embodiment thereof.

DESCRIPTION OF THE DRAWING

FIGS. 1A—1D are graphs depicting certain events in the cardiac cycle;

FIG. 2 is a graph showing conventional detection of systolic pressure;

FIGS. 3A and 3B are graphs illustrating the present detection scheme for diastolic pressure;

FIG. 4 is a schematic block diagram broadly illustrating an exemplary method for practice of the invention; and

FIG. 5 is a more detailed schematic diagram illustrative of the practice of the invention.

GENERAL DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

An insight into the inventive concept may be gained more readily with an appreciation of the basic cardiac cycle, particularly the time-pressure event sequences occurring in the heart and their relationship to the arterial blood pressure fluctuations.

FIG. 1 traces the cardiac events and the resulting pressure in the left ventricle. On the same time scale, the brachial arterial pressure resulting from the cardiac events is traced. Although the left ventricle pressure is shown, the aorta pres-

sure follows similar traces timewise. The vertical time lines *a* through *g* denote, respectively: *a*. onset of ventricular contraction; *b*. end of ventricular contraction and opening of semilunar valves; *c*. end of ventricular ejection and ventricular systole; *d*. closure of semilunar valves and onset of ventricular relaxation; *e*. opening of the arteriovenous valves and onset of ventricular filling; and *f*. and *g*. continued but slower ventricular filling or diastasis, ending with atrial contraction.

The arterial pressure fluctuations are synchronous with the heart beats. Further, since the rate of propagation of the ventricular pulse wave in the heart is from 3 to 4 meters per second and in the limb arteries is approximately 7 to 14 meters per second, for purposes of the present invention the time lag between a cardiac event and its arterial effects may often be neglected. FIG. 1B illustrates the foregoing, showing the occurrence of the systolic arterial pressure concurrently with the contraction or systole of the ventricle. The trough or region of minimum arterial pressure substantially coincides with the end of the resting phase or diastole of the cardiac cycle, and is the diastolic pressure. Certain of the events occurring in the cardiac cycle are represented in the electrocardiogram trace of FIG. 1C; and in the phonocardiographic trace of FIG. 1D. The possible use of these cardiac traces in the practice of the present invention is explained below.

The basic inventive concept may be illustrated readily with the aid of FIGS. 2, 3A and 3B. FIG. 2 depicts the fluctuating pressure in an artery as running from a diastolic of about 80 to a systolic of about 120 mm Hg. As is well known, these pressures as well as their difference (pulse pressure) will vary considerably from case to case, depending upon age, individual health, and other factors. Measurement of systolic pressure is achieved in conventional fashion by completely constricting arterial flow, as with a cuff, and then slowly bleeding the cuff while stethoscopically probing for the onset of Korotkow sounds. Typically, as is illustrated in FIG. 2, no sound is heard at the pulses denoted 1—6; but at pulse 7 the slowly falling cuff pressure briefly coincides with the maximum arterial pressure. A sound connoting blood flow is heard and a concurrent reading of the cuff manometer yields the systolic pressure.

Now the diastolic pressure measurement is taken, in accordance with the practice of the inventive concept, by inflating the cuff to a point in excess of systolic pressure and then gradually reducing cuff pressure while concurrently superimposing upon the cuff pressure a negative-going narrow pressure pulse or wave, in this case having a substantially constant amplitude which is larger than the maximum likely arterial pulse pressure. The negative "probe" is applied to the cuff so as to coincide in time with the minimum points of the arterial pulse as determined, for example, by reference to cardiac cycle events monitored electrocardiographically (FIG. 1C), phonocardiographically (FIG. 1D), or otherwise. The resulting sequence is depicted in FIG. 3A. The onset of arterial flow again is detected stethoscopically when cuff pressure coincides with arterial pressure at the diastolic floor between the fifth and sixth positive heart pulses.

Alternatively, rather than reducing cuff pressure and applying a constant negative-going probe, it may be desirable to maintain the cuff pressure at a constant level in excess of systolic and apply a succession of increasingly negative pulse probes as depicted in FIG. 3B. The result in either case is the same.

FIG. 4 illustrates a system suitable for practice of the present invention. A conventional arm cuff 10 is applied to a patient whose blood pressure is to be measured by the present inventive method. Associated with cuff 10 is a cuff pump 20, pneumatic in the illustration but hydraulic if desired, for elevating cuff pressure to a controlled point above the maximum arterial pressure. Also associated with cuff 10 is a variable or cyclic pump 30 that when suitably synchronized with the repetition rate of the heart imparts to cuff 10 brief negative pressure surges having an amplitude materially larger, for example, 60 mm Hg., than the pulse pressure. The duration of

the negative-going surge produced by pump 30 typically is from 50—100 milliseconds depending upon the duration of the patient's ventricular relaxation.

The duration as well as the correct timing of these surges is determined by a heart pulse detector 40 which monitors the cardiac cycle. Detector 40 may comprise, for example, a phonocardiograph which utilizes a low-frequency sensitive transducer 41 applied to the patient's chest, and suitable amplifying and filtering circuitry to produce an enhanced electrical analogue of the heart sounds. Those sounds occurring at the onset of ventricular contraction—time *a* of FIG. 1D—are prominent, readily detectable and hence suitable as recurrent pulses which are applied to cyclic pump 30 for timing of the negative-going excursions. Other cardiac cycle events, or other event-monitoring methods including electrocardiography, apexcardiography, etc., may of course be employed alternatively to generate the desired indication of the heart's pulses. For example, a sphygmograph could be used to detect the pulsating in an uncontracted artery and this used as a source of timing pulses.

A flow detector 50 including a low-frequency sensitive pressure transducer 51 placed over the brachial artery just below the arm cuff 10 monitors the artery and detects those sounds signifying the onset of arterial flow. In addition, a cuff pressure monitor 60 associated with cuff 10 continuously monitors the latter's pressure and supplies the pressure readings corresponding to the blood systolic and diastolic pressures to any one of several possible output devices. The latter may include, for example, the onsite recording oscillograph designated 80 for recording at the patient's bedside or elsewhere in the hospital the pressure information; the data interface 90 which converts the pressure readings to a form suitable for transmission through the telephone switching network; or a central monitoring position 100 which includes visual displays 101, 102 of the diastolic and systolic pressures received from a selected one of a plurality of cuff pressure monitors servicing different patients.

The basic operation of the scheme shown in FIG. 4 advantageously may be automated with the addition of a control unit 110, hereinafter called "CU". The general functional operation of such a system then is as follows, when implementing the approach illustrated in FIG. 3A.

With the patient recumbent to minimize the effects of hydrostatic pressure and with the arm cuff 10 and transducers 41, 51 in place, CU 110 is activated and turns on cuff pump 20. Pneumatic or hydraulic pressure is supplied from pump 20 to cuff 10 via a flexible nondistensible line 21 which may be of rubber, polyethylene plastic or the like. As cuff pressure increases and the brachial lumen is constricted, arterial sounds are detected by transducer 51. When blood flow is completely arrested, these sounds disappear which occasions a signal to be sent from flow detector 50 to CU 110. On receipt of this signal CU 110 turns off cuff pump 20 and operates a bleeder valve 22 associated with flexible line 21. Bleeder valve 22 operation allows the cuff pressure to decrease substantially along the upper curve of FIG. 2, for example, until it drops to a point at which it just balances the peak portion of the arterial pressure.

At this point flow detector 50 registers the initial arterial sounds, signaling the opening of the heretofore fully constricted brachial lumen and thus the measuring point for systolic pressure. Accordingly, flow detector 50 signals the occurrence of this event to the control unit which promptly directs cuff pressure monitor 60 to read the instantaneous cuff pressure and to supply this reading to user units 80, 90, 100.

When the systolic pressure reading is completed, CU 110 directs cuff pump 20 to reinflate cuff 10, and concurrently signals bleeder valve 22 to close. As before, cuff 10 is inflated and flow detector 50 supplies an indication of when arterial flow is completely arrested. CU 110 receives this indication from flow detector 50, and this time allows the pump 20 to continue inflating cuff 10 until pressure monitor 60 reads approximately 20 to 30 mm Hg. above the pressure at which ar-

terial flow was fully arrested. At this point CU 110 turns cuff pump 20 off, reopens bleeder valve 22 and actuates cyclic pump 30, the latter supplying negative-going pressure excursions to cuff 10. During the time of ventricular relaxation, as determined by heart pulse detector 40, and as cuff 10 is slowly deflated, the cyclic negative excursions finally intercept the valley or minimum points of arterial pressure denoted in FIG. 3. At such time flow detector 50 again registers the onset of Korotkow sounds, signifying opening of the arterial lumen, but, significantly, this time at the diastolic pressure level.

CU 110 receives a signal indicative of diastolic flow from detector 50, and instructs cuff pressure monitor 60 to read the instantaneous cuff pressure and to supply this reading to the user units 80, 90, 100.

Implementation of the procedures illustrated graphically in FIG. 3B follows the foregoing, except that once constant cuff pressure is established, relief valve 20 is kept closed and the increasingly negative pulse probes are generated by pump 30.

DETAILED DESCRIPTION OF AN ILLUSTRATIVE EMBODIMENT

FIG. 5 depicts in somewhat more detail the illustrative embodiment of the invention described with respect to FIG. 4, and in which like numerical designations denote like component parts. The heart pulse detector 40 comprises a pressure transducer 41 applied tightly to the chest. Transducer 41 may be of the type employing a rubber sheet contact portion hydraulically connected to a movable piston. Generally suitable alternatives to a pressure transducer include strain gages, piezoelectric crystals, capacitance transducers, light and photocell arrangements, and others.

The heart beat pulses received by transducer 41 are converted to an analog electrical signal that is applied to an amplifier 44. The latter may, for example, be a direct-coupled transistor amplifier especially sensitive to frequencies of 2—100 c.p.s., and operated Class C. The enhanced heart-pulse signal from amplifier 44 is supplied to a filter 45. Advantageously, filter 45 is designed to pass only heart sounds—particularly the sounds of ventricular contraction, which as explained below are here relied upon for timing pulses—while otherwise blocking spurious body noise and any electrical ambient disturbance.

The output of filter 45 is a recurring brief pulse, essentially as shown in FIG. 1D. In the instant embodiment, as the pulse output of filter 45 happens not to coincide with the occurrence of the ventricular relaxation period of interest, it is necessary to insert a time delay through a timer 46. The delay must be sufficient to shift the pulse backwards in time so that it will occur substantially in the middle of the period between the vertical lines *f* and *g* in FIG. 1 which essentially bracket the ventricular relaxation period. Timer 46 may be any of numerous conventional delay circuits including, for example, a gate-opening "one-shot" triggered by the leading edge of the ventricular contraction pulse, an RC network, or others.

The output of timer 46 is a pulse applied to a motor control unit 31 associated with cyclic pump 30. Unit 31 is adapted to vary the cycling time of pump 30 so as to effect the coincidence of the pump's negative excursion with the receipt of the timing pulse from timer 46. This cycling time variation can be effected, for example, by varying the speed of pump 30, or by various other well-known control methods.

Pump 30 itself must be constructed so as to produce a negative-pressure pulse with a selected constant amplitude in excess of the usual approximately 40 mm Hg. pulse pressure, say, in the vicinity of -60 mm Hg. The pump pulse time width must be less than the period of ventricular relaxation, which of course varies with individuals and specific health. As a median, however, this period of ventricular relaxation may be taken as being of approximately a 200 to 300 milliseconds duration; and hence the duration of the negative pulse produced by pump 30 should be about one-quarter to one-half of that, or 75—150 milliseconds. With these rather rapid pressure rise

and fall times, care must be taken in a pneumatic system design to insure its rapid response in these short times without introducing pressure transients that may interfere with system operation.

The flow detector 50 depicted in FIG. 5 consists of a pressure transducer 51 similar to transducer 41 and suitable for intimate contact with the human skin surface directly above an artery. As only the Korotkow sounds corresponding to onset of arterial flow following complete arterial constriction must be detected in the practice of the instant invention, transducer 51 should be selected for its sensitivity to the characteristics of these sounds only and not to extraneous bodily and other ambient noise. The output of transducer 51 is supplied to an amplifier 52. The output of amplifier 52 is suitably filtered in filter 53 to further attenuate extraneous arterial and bodily sounds and to pass only those sounds corresponding to the onset of arterial blood flow following the equilibrium between blood pressure and cuff pressure.

In the operation of the embodiment described, it is useful for detector 50 to be able to distinguish among (1) disappearance of arterial sounds with increasing cuff pressure; (2) the onset of arterial sounds in the absence of negative excursions; and (3) the onset of arterial sounds in the presence of negative excursions. This recognition may be supplied by a suitable logic unit 54, having as inputs the amplified and filtered arterial sound detected by transducer 51 and an indication of cuff pressure from monitor 60. Logic unit 54 may be a pulse memory circuit, for example, which recognizes the coincidence of a disappearing arterial sound with increasing (80 mm Hg. or more) cuff pressure as a sign that cuff pressure has increased beyond the systolic arterial pressure. Similarly, the onset of arterial sound with decreasing cuff pressure in the absence of negative cuff pressure excursions is recognized by logic unit 54 as the point at which systolic pressure is to be measured. Finally, the onset of arterial sounds with a decreasing cuff pressure in the presence of negative cuff pressure excursions is recognized by logic unit 54 as signifying the time at which measurement of the diastolic pressure must occur. The recognition of each of the above states is transmitted by detector 50 to CU 110.

Cuff 10 is a strong, inelastic inflatable cloth band connected by indistensible air or hydraulic lines 21, 32, 23 to pump 20, pump 30 and cuff pressure monitor 60, respectively. As seen in FIG. 5, monitor 60 comprises advantageously a conventional pressure oscillograph 61 or other suitable direct-reading pressure gauge located at the site of the patient's bed. Connected to manometer 61, and responding to the pressure variations therein registered, is a suitable transducer 62 for converting the oscillograph pressure variations into a varying electric signal, as for example a voltage, so that each discrete voltage level of the transducer relates to a specific pressure. Transducer 62 may be replaced by other suitable devices as, for example, a digital voltmeter.

The output of transducer 62 is twofold: first, to logic unit 54 for reasons above indicated; and secondly, to one or more user units, examples of which are recorder 80, data interface 90 and central monitor position 100 shown in FIGS. 4 and 5. It may be desirable in some instances to provide an analog-to-digital converter 63 between the transducer 62 and the various outputs, depending on the requirements to be met. Additionally, a gate 64 disposed between transducer 62 and the various user units 80, 90, 100 and under the control of CU 110 allows the output readings of transducer 62 to be selectively supplied to these user units if desired.

CU 110 advantageously includes a cyler 111 and a cycle control 112 which directs the sequence of operations performed by cyler 111 in accordance with inputs received from selected points in the system.

OPERATION

Practice of the inventive concept by the system shown in FIG. 5 follows in general the procedures earlier described for

the operation of the system depicted in negative-going 4. The below-described operations may be achieved through numerous circuit arrangements. Hence, in FIG. 5, functional lines only are set out.

Initially, cycle control 112 is activated and directs cyclor 111 to the position indicated as 1. In this position, control unit 110 supplies power to cuff pump 20 to inflate the cuff 10 through now-closed valve 22. Arterial sound is monitored and processed in flow detector 50 as described. Shortly logic unit 54 detects that arterial blood flow is completely arrested, and supplies this information to cycle control 112. On receipt of this, cycle control 112 allows cuff pressure to increase another 20—30 mm and thereafter shifts cyclor 111 to position 2. In this position, power to the cuff pump is cut off and cuff bleeder valve 22, heretofore closed, is opened. Cuff pressure drops, and when it balances with the peak portion of the arterial pressure, arterial sound is detected by transducer 51 and registered in logic unit 54. Together with its input from transducer 62, logic unit 54 recognizes this state as the systolic pressure point and notifies cycle control 112. In response, cycle control 112 instructs cyclor 111 to shift to position 3. In position 3, bleeder valve 22 is closed and a signal is sent to gate 64 to pass the reading of transducer 62 on to the user units 80, 90, 100.

Immediately thereafter cycle control 112 shifts the cyclor to position 4 wherein cuff pump 20 is reenergized for repeated inflation of cuff 10. Again, cuff pressure increases sufficiently to cause full arterial constriction and hence complete disappearance of arterial sound. Logic unit 54 recognizes this and informs cycle control 112 which now allows pump 20 to continue inflating cuff 10 to an additional 50—70 mm Hg. This point reached, cycle control 112 directs the cyclor to position 5.

In this position, bleeder valve 22 is reopened and cyclic pump 30 is turned on through motor control 31. Motor control 31, once activated, energizes and times motor 30 in the manner already described. Cuff pressure again decreases and the timed cyclic negative excursions finally intercept the minimum arterial pressure. Arterial sounds are detected by transducer 51, processed and supplied to logic unit 54 which together with the input from transducer 62 recognizes this as the point for diastolic pressure measurement and informs cycle control 112. In response, cycle control 112 advances cyclor 111 to position 6. In this position, bleeder valve 22 is quickly closed and cyclic pump 30 deenergized; and gate 64 is opened instantaneously to pass the diastolic pressure reading.

A seventh position is included in control unit 110 as a no-pressure rest position which starts a timing interval within cycle control 112 at the end of which cyclor 111 is returned to position 1 and the entire cycle is repeated.

In summary, the method of the present invention avoids the drawback inherent in known prior art diastolic measurement relying on identifying the point at which arterial flow returns to being completely unrestricted. As noted, this point is far more difficult to detect. The present invention avoids this problem altogether while enabling essentially the same detection scheme to be practiced for measuring the diastolic pressure as for measuring systolic pressure. Considerably more accurate readings are obtained with actually less complex detecting equipment than heretofore used.

It is to be understood that the embodiments described herein are merely illustrative of the principles of the invention. Various modifications may be made thereto by persons skilled in the art.

We claim:

1. A method for determining diastolic blood pressure comprising the steps of:
 - arresting arterial flow with applied pressure;
 - coincident with the occurrences of pulse pressure minima, momentarily relieving the applied pressure by increasing amounts until the relieved applied pressure and the pulse pressure minima overlap sufficiently to permit spurts of arterial flow; and

concurrently with the onset of such spurts, measuring the relieved applied pressure as representing the desired diastolic pressure.

2. A method for determining diastolic blood pressure comprising the steps of:
 - arresting flow in a selected artery;
 - upon the occurrence of arterial pulse wave minima points only, progressively reducing the extent of arrest until the recommencement of arterial flow; and
 - reading the arterial pressure concurrently with the onset of said flow.
3. A method for determining diastolic blood pressure comprising the steps of:
 - subjecting a selected arterial point to an applied initial pressure above systolic;
 - subjecting said arterial point further to an increasingly negative-going pressure pulse applied only at minima of the arterial pulse wave, said negative pulse having an amplitude in excess of the arterial pulse amplitude; and
 - registering the onset of arterial flow following conjunction of an arterial pulse pressure minimum with the peak of a negative-going pressure pulse.
4. A method for the measurement of blood pressure comprising the steps of:
 - applying an initial pressure in excess of systolic to a selected artery through an inflatable cuff;
 - applying to said artery through said cuff a series of narrow negative-going pressure pulses each centered in time at one of a plurality of successive minimum points of the arterial pulse wave;
 - causing the peaks of said negative-going pulses to approach and then intercept successive minimum points by varying the applied cuff pressure;
 - detecting the onset of arterial spurts following said interception; and, concurrently,
 - reading the instantaneous cuff pressure as representing a measure of diastolic pressure.
5. A method in accordance with claim 4 wherein said negative-going pressure pulses are substantially constant in amplitude, and wherein the cuff pressure is varied by bleeding the cuff.
6. A method in accordance with claim 4 wherein said cuff pressure variation is effected by progressively increasing the amplitude of said negative-going pressure pulses while otherwise maintaining said cuff pressure in excess of systolic.
7. Apparatus for measuring blood pressure comprising:
 - a pressure member for the application of controlled constricting force to an artery;
 - a pressure monitor for registering the pressure applied by said member to said artery;
 - means for registering the occurrence of successive minima points of the arterial pulse pressure wave;
 - means for applying to said member an initial pressure in excess of systolic to fully constrict said artery;
 - means for further applying to said member a succession of narrow, increasingly negative-going pressure pulses, each centered in time at successive ones of said arterial pulse wave minimum points, in response to said registration thereof;
 - means for detecting the onset of arterial flow following the abrupt momentary penetration of one of said negative-going pulses through a minimum point of said arterial pulse wave; and
 - means responsive to said arterial flow onset detection for recording the instantaneous pressure registered by said pressure monitor, said recording being a measure of the diastolic pressure.
8. Apparatus for determining diastolic blood pressure comprising:
 - first means for applying pressure to a selected artery sufficient to arrest flow;
 - second means for registering the occurrence of minimum points of the arterial pulse pressure wave;

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third means responsive to each successive said registration for reducing the pressure applied by said first means, said reduction being in increasingly greater amounts causing said arresting pressure to approach, and finally to equal, the value of said diastolic pressure as indicated by the onset of arterial spurts; and

fourth means for indicating the arterial pressure concurrently with the onset of said spurts.

9. Apparatus in accordance with claim 8 wherein said second means comprises:
means for monitoring the cardiac cycle events and for deriv-

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ing therefrom a recurrent timing pulse in rhythm with the arterial pulse;

means for synchronizing the occurrence of said timing pulses with successive minima of the arterial pulse; and
means for transmitting said timing pulses to said third means.

10. Apparatus in accordance with claim 9 wherein said first means comprises an inflatable arm cuff and wherein said fourth means comprises a pressure-indicating device connected thereto.

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