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SPHYGMOMANOMETRIC DEVICES

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This invention relates generally to sphygmomanometric devices and more particularly concerns instrumentation for recording pulse beat and blood pressure conditions and also for monitoring variations in a patient's average or mean blood pressure during surgery or under other critical conditions so as to provide a warning signal whenever pressure lapses or rises dangerously. In the preferred embodiment the instrumentation is miniaturized so as to be completely portable whereby it may be carried on the patient to provide a continuous record of blood pressure and pulse beat when the patient is physically active or otherwise required to be on the move. The invention is herein illustratively described by reference to its presently preferred embodiment; however, it will be recognized that certain modifications and changes therein with respect to details may be made without departing from the underlying essentials involved.

An additional object herein is to achieve the above-mentioned purposes with novel apparatus which is reliable, versatile and adapted for use with practical electric circuit techniques. Still another object is to provide instrumentation adapted for producing a permanent visible record which can be conveniently viewed and accurately interpreted.

Still another object is to provide such apparatus which records on a continuously moving tape in such a manner that the rate of movement of the tape may be made very slow and the amount of power required to effect the recordings minimal, thereby further reducing the power consumption and size requirements of the apparatus.

A specific object is a new and improved sphygmomanometric device which, while critically monitoring the patient's vitality, as during surgery, is inherently stabilized or biased so that transient conditions do not produce false warnings of lapses or excesses of blood pressure, but only dangerously prolonged excesses or lapses of the mean or average blood pressure are capable of doing this.

In accordance with one feature of the invention applied to a recording type instrument, a continuously moving recording film is advanced past a plurality of styli one of which is activated momentarily with each "nth" pulse or heart beat, "n" being an integer of the order of between five and twenty, for example, and another such stylus being activated periodically with each recycling response of a blood pressure impulse integrating circuit. The integrating circuit accumulates an incremental electric charge with each pulse beat, which incremental charge is proportional to a value representing blood pressure, such as systolic pressure, and when the total accumulated charge reaches a certain value the circuit discharges and activates the recording stylus and at the same time conditions itself for a repeated cycle of charge accumulation. Upon developing the film and projecting the same optically for enlargement upon a viewing screen, a significant analysis of the patient's condition may be made by noting variations in the frequency of the pulse beats and in the mean of blood pressure, the latter being computed by dividing the number of integrator circuit discharges by the number of heart beats in a given time interval. In this way the effects of different types of physical activity on the patient's blood pressure and pulse rate may be readily determined for use along with other data, recorded on the same film if desired, in diagnosing the patient's physical condition.

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In still another embodiment the time-averaged, mean blood pressure condition may be measured and utilized to indicate danger points to a surgical team or otherwise. This is done in one illustration by providing circuits which count the integrating circuit discharges and also the pulse beats and produce voltages proportional to the count rates, which voltages are then applied to a comparison circuit which takes the ratio between them as a measure of mean, time-averaged blood pressure, and which operates an alarm or other indicator whenever such ratio exceeds a certain maximum safe value or drops below a certain minimum safe value.

These and other features, objects and advantages of the invention will become more fully evident from the following description thereof by reference to the accompanying drawings.

FIGURE 1 is a simplified diagram showing a fragmentary length of recording film whereon pulse beat markings and blood pressure integrator circuit discharge markings have been made for diagnosis.

FIGURE 2 is a simplified block diagram of a monitoring system for providing such a film record and for providing a warning indication, audible or otherwise, whenever the time-averaged blood pressure mean value passes out of a predetermined safe range.

FIGURE 2A shows in simplified form a representative combined integrator and integrator recycling circuit.

Referring to the drawings, the preferred recording medium comprises a film strip 10 of transparent plastic material suitably treated with a radioactive emission-sensitive coating which can, upon exposure, be developed and fixed to form a permanent record image contrasting with the transparent background of the film. The film may be incorporated in a polygraph type recording instrument in which a number of different types of data may be recorded continuously on the film as it moves in the recorder past the radioactivated tips of recording scribes or styli. The styli tips may either bear continuously against the film in order to leave a continuous trace thereon or may be normally retracted, as in the present case, and momentarily advanced into contact with or proximity to the film whenever a mark is to be made. If the film moves very slowly, as is desirable in a miniaturized portable recorder, resolution between successively adjacent marks requires a certain minimum time interval between markings. In this instance, one series of marks P are made on the film at intervals representing not every pulse beat, but every "nth" pulse beat so as to achieve the necessary physical separation between successive marks. With the film driven at constant speed, the spacing between successive marks will then represent "n" times the average time interval between successive pulse beats occurring during a given interval. If the number of such marks made on the film in the series P in any interval dt is within certain limits, the patient is presumed to be normal.

A second series of marks, I, produced on the film represent the individual discharges of a blood pressure integration circuit to be described. These occur substantially at the instant of a pulse or heart beat but not necessarily at the instant of one of the individual marks in the series P, since the latter marks are not made on every pulse beat.

By dividing the number of marks in series I by the number of marks in series P within a given time interval, say dt , the numerical result is representative of time-averaged or mean blood pressure during that interval.

Referring to FIGURE 2, it will be recognized that the blood pressure transducer 12 and the heart beat or pulse beat detector 14 may comprise any of different suitable devices (conventional or otherwise) for converting these physical phenomena into electrical signals. The blood pressure transducer, for example, may comprise a device

which, with each pulse beat, produces a voltage or current impulse of a magnitude proportional to the systolic pressure. The heart or pulse beat detector may comprise a transducer which produces a voltage or current impulse of any convenient magnitude with each heart beat or pulse beat in the patient. The blood pressure impulses are applied to a linear integrator circuit 18 of any conventional or suitable form in which a charge increment is accumulated (i.e., on a storage condenser or other storage element, as is well known) proportional in value to the magnitude of the applied blood pressure-related electrical impulse. This linear integrator circuit may, for instance, comprise a conventional operational amplifier type integrator in which linear integration is performed and in which a storage interval of any desired duration may be achieved by appropriate design.

In association with or forming a part of the linear integrator is an integrator recycler circuit 20 with an adjustable limit point or value. The output of the linear integrator 18 is applied to the input of the integrator recycler 20 and when the integrator voltage reaches a predetermined or preset value the recycler operates to discharge the storage condenser or other storage element in the integrator 18 and to condition the circuit for starting another cycle of integration. As shown in FIGURE 2A the integrator 18 may comprise an operational amplifier and storage condenser, and the recycling circuit 20 may comprise an isolation amplifier controlling a switch connected to short across the storage condenser and thus discharge it the instant its voltage rises to a certain value. This will occur at the instant of a pulse beat, when the condenser charge is being incrementally increased.

The discharge of the integrator circuit produces a sudden transient in its output which is differentiated by the differentiator comprising the condenser 22 and the resistance 24, according to well known techniques, so as to deliver a sharp pip or voltage impulse to the recorder unit 26 which comprises a stylus actuator. Thus, the stylus is actuated into contact with the sensitive film 10 each time the integrator circuit 18 is recycled by the circuit 20, and a mark is made on the film at the stylus location at that instant.

Depending upon the patient's systolic pressure and pulse beat frequency, the recurrence rate of the marks I on the film will vary. A patient with a high systolic pressure will, of course, cause a greater number of marks I in a given time interval dt than a patient with a low pressure, but one who has the same heart beat rate as the first-mentioned patient. In a typical design the marks I are caused to occur less frequently than the pulse beat marks P.

In order to permit the film to move very slowly, and thus store a large quantity of data on a film of given length, and in order to conserve electrical energy, which is an important objective in the case of a miniaturized portable device which is battery energized, the invention records only every " n th" pulse beat. This is accomplished by passing the output pulses from the detector 14 through a frequency divider or counter circuit 28 which is set to produce an output for every " n th" input pulse. Such output is applied to the stylus actuator 30 in order to actuate the related stylus so as to produce a mark on the film. Typically, every tenth (the number may vary) pulse beat will be recorded in this manner and by so doing the successive marks P produced on the film will be spaced apart and separately identifiable, whereas otherwise, with a slow-moving film, they would be run together in a substantially continuous, unbroken line and it would be virtually impossible to detect variations in pulse beat and relate them to different types of physical activity or emotional conditions of the patient.

After the film record has been made showing the patient's condition over a period of time and through a succession of experiences, the film may be developed and

projected by conventional viewing apparatus onto an enlarging screen so that the diagnostician may then perform an analysis which will lead to useful information.

If the apparatus is to be used during any critical period such as during surgery or during a time when the patient is on a critical list and needs to be carefully attended, as by the administration of drugs or the like controlling blood pressure or pulse rate, an audible or other warning device may be employed which indicates that the blood pressure condition has risen above or dropped below safe limits. This may be done, for example, by feeding the output of the differentiator 22, 24 to a counter circuit 32 of any suitable or known type capable of producing an output voltage which is proportional to the count rate from the linear integrator 18. Thus, this voltage is proportional to the mean systolic pressure of the patient, averaged over a time interval which depends on the effective time constant of the integrator-recycler circuit and of the counter circuit 32 itself, and multiplied by the pulse beat rate of the patient during that interval. In order to eliminate the latter factor (i.e., pulse beat rate), the output of the frequency divider 28 (or of detector 14) is fed to a second counter circuit 34 which produces an output voltage proportional to the pulse beat frequency. These two voltages are then applied to a voltage divider 36 which produces an output voltage which is proportional to the ratio thereof and thereby eliminates the pulse beat frequency as a factor, leaving only a response directly related to time-averaged blood pressure, which is then applied to a voltage-sensitive warning device 38 capable of responding in any desired manner to systolic pressure rising above a safe upper limit or dropping below a safe lower limit.

Inasmuch as the counter 32 responds to the output of the linear integrator 18, which in turn produces an accumulated charge on a recycling basis, transient blood pressure changes of very short duration have no effect on the voltage-sensitive warning device 38. However, if the mean systolic pressure changes over a significant period of time, which may be of the order of a few seconds, more or less, then a warning response is produced.

These and other aspects of the invention will be evident to those skilled in the art based on the present disclosure of the preferred embodiments.

I claim as my invention:

1. A sphygmomanometric device comprising transducer means operable to convert blood pressure into a succession of electrical impulses synchronous with pulse beat and variable in magnitude with such pressure, transducer means operable to convert pulse beats into electrical impulses, integrator means connected to the first-mentioned transducer means and operable to integrate the blood pressure impulses, means to recycle the integrator means and produce an impulse therefrom each time the integrated value therein exceeds a predetermined value, and means responsive to such recycling impulses and to the second-mentioned transducer means impulses.

2. The device defined in claim 1, wherein the last-mentioned means comprises a recording device in which the pulse beat impulses and the recycling impulses are recorded on a common time base.

3. The device defined in claim 2, wherein the recording device includes record strip moved at constant speed and the pulse beat impulses and recycling impulses are marked in time-spaced succession thereon in parallel series relationship.

4. The device defined in claim 3, and a frequency divider operatively interposed between the last-mentioned means and the second-mentioned transducer means to cause response of the former only to every " n th" pulse beat.

5. The device defined in claim 1, wherein the last-mentioned means comprises means operable to divide the integrator recycling rate by the pulse beat rate and pro-

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duce an output signal proportional to the ratio, and warning means responsively connected to the latter for producing a warning signal in response to said ratio passing a predetermined value.

6. A pulse beat detector and recorder comprising a recording strip with means to advance the same at a slow and substantially constant rate, stationarily mounted scribe means operable to produce a mark thereon of a thickness to merge with adjacent similar marks if operated at a patient's normal pulse beat rate, transducer means operable to convert pulse beats into electrical impulses, and frequency divider means interposed operatively between the transducer means and scribe means to operate the latter on every n th pulse beat where " n " is an integer greater than one.

7. A pulse beat detector and recorder comprising a recording strip with means to advance the same at a slow and substantially constant rate, stationarily mounted scribe means operable to produce a mark thereon of a thickness to merge with adjacent similar marks if operated at a patient's normal pulse beat rate, transducer means operable to convert blood pressure into a succession of electrical impulses synchronous with pulse beat and variable in magnitude therewith, means to integrate said impulses, means to recycle the integrator and produce an impulse therefrom each time the integrated value therein, representing a plurality of said first-mentioned impulses, reaches a predetermined value, and means to operate said scribe means by said last-mentioned impulses.

8. A pulse beat detector and recorder comprising a recording strip with means to advance the same at a slow and substantially constant rate, two stationarily mounted scribe means each operable to produce a mark thereon of a thickness to merge with adjacent similar marks if operated at a patient's normal pulse beat rate, transducer means operable to convert pulse beats into electrical impulses, frequency divider means operated thereby to divide the pulse beat frequency by the factor " n ," where n is an integer greater than one, means connecting said frequency divider to one of said scribe means to operate the latter on every n th pulse beat, transducer means operable to convert blood pressure into a succession of elec-

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trical impulses synchronous with pulse beat and variable in magnitude therewith, means to integrate said impulses, means to recycle the integrator and produce an impulse therefrom each time the integrated value therein, representing a plurality of said first-mentioned impulses, reaches a predetermined value, and means to operate the second scribe means by said last-mentioned impulses.

9. A sphygmomanometric device comprising transducer means operable to convert blood pressure into a succession of electrical impulses synchronous with pulse beat and variable in magnitude with such pressure, transducer means operable to convert pulse beats into electrical impulses, integrator means connected to the first-mentioned transducer means and operable to integrate the blood pressure impulses, means to recycle the integrator means and produce an impulse therefrom each time the integrated value therein exceeds a predetermined value, and means responsive to such recycling impulses.

10. The device defined in claim 1, wherein the last-mentioned means comprises means operable to divide the integrator recycling rate by the pulse beat and produce an output signal proportional to the ratio.

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