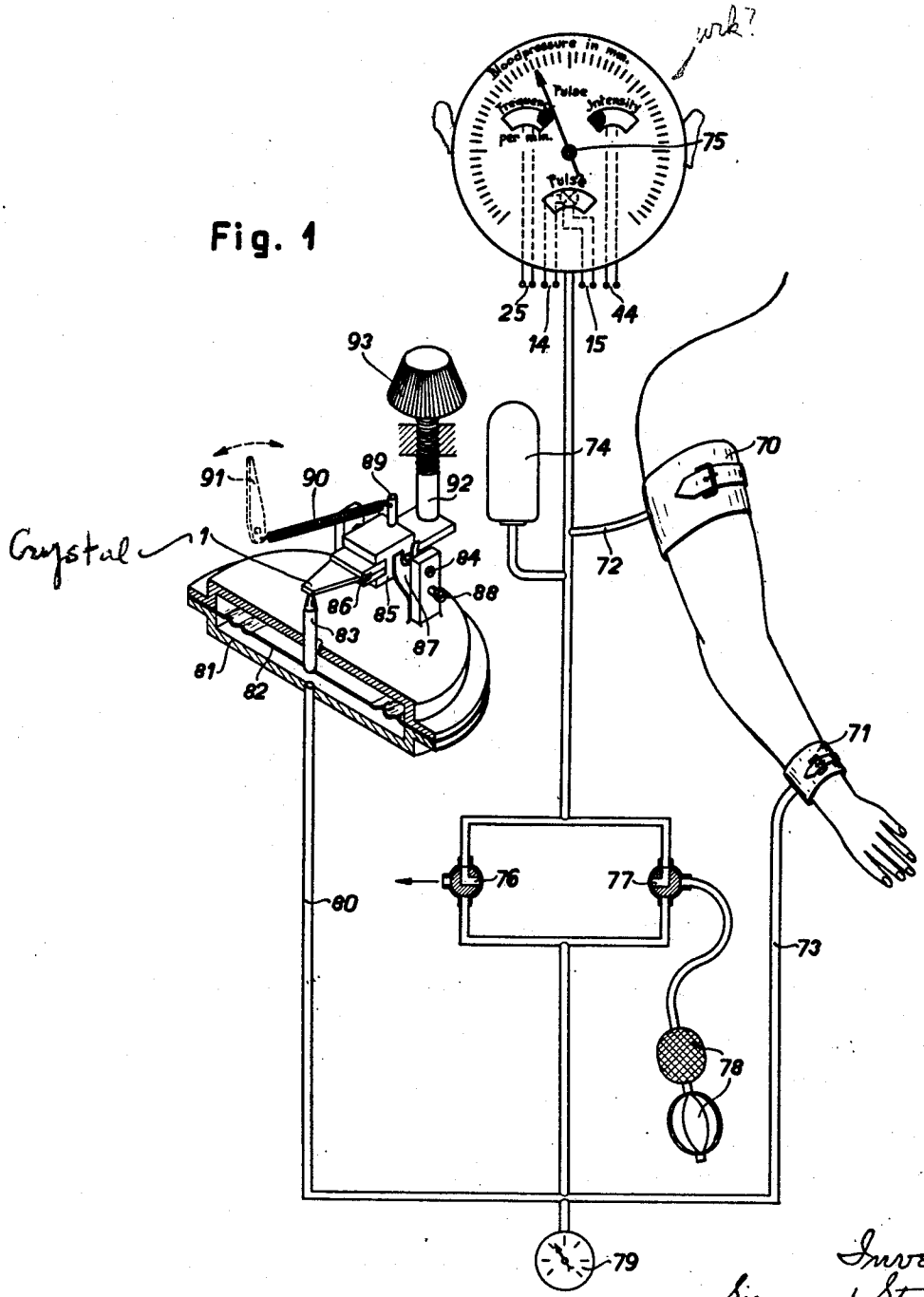
March 19, 1940. S. STRAUSS ET AL 2,193,945

APPARATUS FOR MEASURING AND SUPERVISING THE HEART ACTION

Filed April 12, 1937 2 Sheets-Sheet 1

Fig. 1



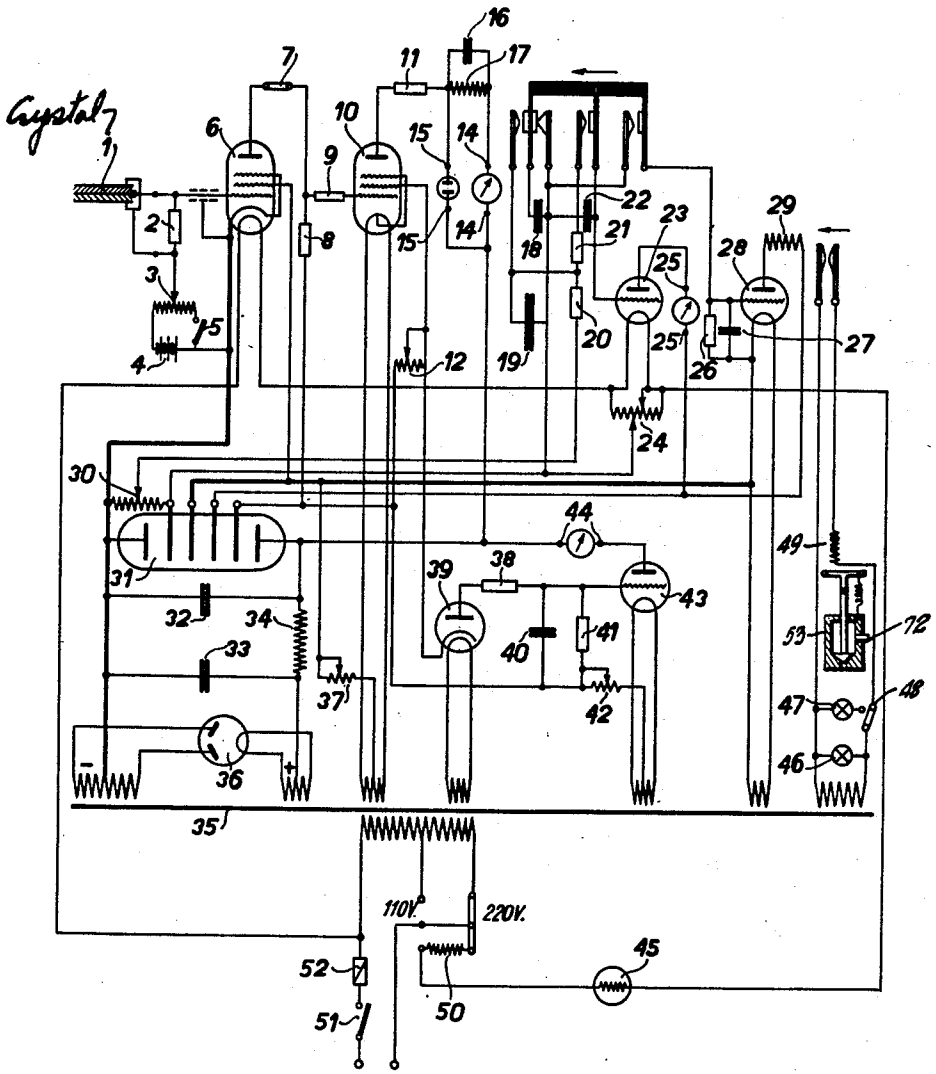
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Fig. 2



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APPARATUS FOR MEASURING AND SUPERVISING THE HEART ACTION

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13 Claims. (Cl. 128—2.05)

The object of this invention is the provision of a device for constantly supervising the blood-pressure and also, if desired, for simultaneously measuring the frequency and the intensity of the pulse. A supervision of this kind is of great importance, especially in the case of surgical operations, in order to take immediately the necessary measures, which in many cases may save the life of the patient, if the blood pressure falls to a dangerously low value. It is usual to measure the blood pressure by means of a compression-bag or cuff applied to the upper arm of the patient, inflated by a hand-pump and connected to a manometer. If the pulse becomes imperceptible at the wrist of the arm being tested, this signifies that the pressure in the bag is equal or greater than the pressure of the blood in the compressed blood-vessels. In many cases, it is difficult to detect the palpitation of the pulse with the finger and requires, in the case of surgical operations, a specially trained assistant who merely supervises the pulse. It has been proposed to pick up the pulse, for instance on the wrist, by means of a microphone and to transmit the impulses to a loud speaker over an amplifier. But in such arrangements, difficulties are encountered because the microphone picks up disturbing noises which are also amplified and given out by the loud speaker together with the pulse beats. Acoustic feedback and howling also may easily occur and interfere. It has also been proposed to arrange a compression bag or cuff on the upper arm, said bag being connected to a manometer and to a motor-driven pump, and to pick up the pulse by means of a microphone arranged below in the bend of the arm, to amplify the impulses and to employ the amplified impulses in combination with a switch to switch the pump-motor on and off periodically. If in this known device (according to German patent specification No. 512,430) when the pulse vanishes, the pressure in the compression bag rises due to the fact that the pump continues to work until an alarm circuit is closed. This arrangement, however, is very complicated and has not only the disadvantages of all the devices using a microphone as a pick-up, but moreover the drawback that, if the pulse ceases, the motor driven pump continues to work, so that the pressure in the compression bag increases in a dangerous manner, unless further complicated safety devices are provided.

The object of the present invention is to avoid these drawbacks. According to the invention, two compression bags are provided, the first of which is, applied, for instance, on the upper arm, and receives a measured pressure, while the second is applied to a blood vessel, for instance to the artery on the wrist and receives the same pressure or a slightly higher or lower pressure. The pulse in this blood vessel, which may be stopped by the inflation of the first bag, controls volume changes of said blood vessel and of the whole adjacent body tissue and variations of the air pressure in the second bag. These variations are transmitted pneumatically to a manometric chamber in which they cause displacement of the manometric diaphragm. According to the invention the movements of the diaphragm deform a piezo-electric crystal and are thereby transformed into electric pulsations, which are employed to supervise the pulse beats and the heat action.

The drawings show by way of example an embodiment of the invention. Fig. 1 shows schematically the two compression bags or cuffs and the pneumatic devices to connect the same to the measuring and indicating devices. This figure also shows in sectional perspective view the device for transforming the air pressure variations into electric impulses. Fig. 2 is a wiring diagram of the electric arrangement for measuring and supervising the characteristic values of the pulse.

In Fig. 1, 70 and 71 are the two compression bags or cuffs which are of well known design. The first bag or cuff 70 is applied for instance to the upper arm and is adapted to stop the circulation of the blood to an artery, for instance on the wrist, where the second cuff 71 is applied. The compression cuffs or bags may be, of course, also applied to other parts of the body, the first bag 70 being always arranged nearer to the center of the blood circulation system and the second near to the periphery of the same. The two bags 70 and 71 are connected for instance by means of conduits 72, 73 with separate conduit systems. The conduits 72, 73 may be ordinary thin flexible rubber tubes, which may be sterilized and may have considerable length (up to 20 meters), so that the device may be employed in the sick room or operation room in a very convenient and aseptic manner. The conduit system connected to the first cuff 70 is connected to a manometer 75 and preferably to an air vessel 74. The latter has the purpose to compensate or smooth out small variations of pressure occurring if the tube 72 and especially the air-pressure bag 70 is accidentally compressed. The manometer 75 indicates the blood pressure

or its lower limit and has a large dial. Within the field of vision of said dial the dials of other measuring instruments for the characteristic values of the pulse are arranged. This combination indicator is preferably arranged on a standard and so positioned that the operating surgeon is able to observe it easily, in order to be informed of the heart action condition of the patient at a glance.

The second compression bag or cuff 71 is connected by the conduit 73 and the conduit system 80 to a manometric chamber 81 having a resilient diaphragm 82. Either conduit system may be selectively connected alternately by means of a three way cock 77 to a pump 78, or by way of three way cock 76 to the atmosphere, and the conduit system connected with cuff 70 is connected to the air vessel 74.

In operation, after the three-way-cock 77 has been properly adjusted, the conduits 73 and 80, cuff 71 and the manometric chamber 81 are put under pressure by means of the hand-operated pump 78. The amount of this pressure is made preferably lower than the blood pressure and may be read on the manometer 79. The pulse causes pressure variations in the bag 71 which are transmitted through tube 73 and conduit 80 to the manometric chamber 81 and cause mechanical vibrations of the diaphragm 82 corresponding to the pulse beats. In order to transform these movements into electric impulses, a microphone of any known design and circuit connection could be used, for instance a capacity microphone or a carbon compression contact. It has been found, however, that a piezo electric crystal, for instance of Seignette salt, is especially adapted for this purpose. Said crystal is deformed by the movement of the diaphragm and generates considerable electric voltages. This crystal is however very easily breakable and delicate and is therefore arranged in a novel socket adapted to avoid any damage. This socket will be described later in detail and also the manner in which the generated electric impulses are employed to directly indicate all the important characteristic values of the pulse beats.

In order to measure the blood pressure, the bag 70 is inflated (the cocks being set accordingly) until the pulse vanishes, that is to say, no more electric impulses are to be observed. The blood pressure may then be read upon the dial of the manometer 75. During the surgical operation the pressure in 70 is lowered to a certain value, say 10 mm. less, so that the impulses occur again. If the blood pressure drops below this value, the impulses will cease again and after a certain lapse of time an alarm signal is given in a manner described later in detail. Simultaneously with this alarm signal an air escape valve 53 may be opened. This valve is connected by a conduit with the tube 72 and therefore causes a slow pressure drop in cuff 70 until the impulses occur again.

The crystal 1 is carried by a socket or clamp 86, which is supported in a piece 85. This piece is pivotally supported by pivots 84 on two extensions of the manometer casing 81. According to the invention, the pivoting movement may be effected only against a certain frictional resistance caused by a spring 87 which is adjustable by means of a screw 88 and acts, so to say, as support of the crystal 1, said crystal being acted upon on its point by the rod 83 attached to the diaphragm. The crystal is held against said rod by means of a spring 90, the tension of said spring being just capable of overcoming the frictional resistance. In order to adjust said spring, a regulating device 91 of any design is provided. If the blood pressure drops heavily making necessary a pressure drop in the bag 71, the connecting rod 83 of the diaphragm is displaced. Due to the design according to the invention just described, the crystal follows the rod 83 under the influence of the spring 90 and constantly remains in contact with the rod 83. Therefore, displacements of the rod 83 with respect to the crystal have no influence because said crystal cannot lose contact with the rod. The screw 92 with the milled head 93 makes it possible, to separate the crystal from the rod 83 when desired, for instance, for transporting the apparatus. It is, however, not possible to press the crystal against the rod 83 by hand. This can only be done by the spring 90. In this manner it is made impossible to break the crystal, even by careless manipulation.

As shown in Fig. 2, a very high leak resistance 2 of about 20 megohms is connected in parallel to the electrodes touching the crystal 1. One side of the crystal and the leak resistance is connected to a potentiometer 3 bridging a biasing battery 4 (of about 4 volts) which is connected to the cathode of the first tube 6 and which may be disconnected by means of the switch 5 if the device is not in use. The other side of this parallel group (crystal and leak) is connected by means of a shielded conductor to the grid of tube 6. This tube is preferably a, so-called, high frequency pentode which as far as possible is free from residual gas, and has an indirectly heated cathode, the grid being well insulated, and is led to the outside at the apex of the glass bulb. In the plate circuit of this tube are arranged short-circuited terminals 7 for the connection of a measuring instrument, and the operating resistance 8. The voltage across this resistance is fed through a stabilizing resistance 9 in direct connection with the grid of the second tube 10. This tube 10 is a directly heated power pentode, such as is commonly employed to actuate a loud speaker. The cathode of this tube, that is to say the center-tap of its heating coil, is connected over a variable resistance 37 with logarithmic characteristic to a point of fixed potential. This point is positive with respect to the cathode of the first tube, and negative in relation to the plate potential which is applied to the operating resistance 8. Thus, considering the voltage drop in 8, the correct negative grid bias for the tube 10 is obtained. This tube works as an anode bend rectifier and amplifier. The potentials are kept constant by a voltage divider of low ohmic value or in a more efficient and reliable manner by a glow-discharge-voltage-divider 31. This voltage divider is fed by a transformer 35 over a full-wave rectifier 36 and filtering devices (condensers 33, 32 and filter resistance 34). The plate circuit of tube 10 includes a limiting resistance, the relay coil 17 shunted by a condenser 16, and a milliammeter with the terminals 14. The voltage drop across 17 and this instrument is employed for the operation of a glow lamp with terminals 15. Fig. 1 shows the arrangement of this instrument and of the glow lamp with its connections. These connections are connected with the terminals in Fig. 2 designated by the same reference numbers.

In operation, each pulse stroke generates an electric impulse in the crystal 1. This impulse

is amplified and rectified by the directly coupled amplifier 6, 10, even if it has very low frequency and very flat characteristic as for instance in the case of old or sick persons. Each pulse stroke causes a flash of the lamp across 15, a deflection of the pointer of the instrument between the terminals 14, and an attraction of the armature of the relay 17.

The glow lamp 15 serves to clearly indicate the pulse strokes and further offers the advantage that the voltage drop across the relay 17 and the instrument between the terminals 14 is always kept constant at a value of about 85 volts (i. e. the glow-voltage of the glow lamp). Therefore the operation of the relay and the deflection of the instrument always takes place under optimal conditions. The glow lamp 15 is further advantageous because its use makes possible the connection of an instrument of relatively high sensitivity to the terminals 14, this instrument being protected by the glow lamp which acts as a shunt of relatively low ohmic resistance as the glow discharge starts. The sensitive instrument, however, makes possible an easy and comfortable adjustment of the amplifier by adjusting the grid bias of the tubes. The plate current of the pentode 10 is limited to a desired value by means of the resistance 11.

In order to directly indicate the frequency of the pulse, each operation of the relay, as described in our Patent No. 2,114,578, dated April 19, 1938, connects a small condenser 18 in parallel to a great condenser 19, said great condenser being connected constantly through a high resistance 20 to a potential, which may be exactly regulated by means of the potentiometer 30. Thus, a certain amount of electricity is withdrawn each time from the condenser 19, which is absorbed by short-circuiting the condenser 18, as the relay 17 is restored. Therefore, the potential across the condenser 19 is a function of the number of pulsations per time unit. In order to measure this potential, the same is transmitted over a further relay-contact and a resistance 21 (serving to filter out the pulsations) to a condenser 22, this condenser being arranged between the grid and the center-tap of a filament-potentiometer 24 of a tube 23 acting as a vacuum tube voltmeter. In the plate circuit of this tube, a milliammeter with terminals 25 is arranged, which is calibrated directly in pulse strokes per minute (Fig. 1).

In order to constantly supervise the intensity of the pulse-strokes, the amplifier has a double output circuit. For this purpose, it would be possible to employ two tubes having their grids in parallel, the plate circuit of one of said tubes operating the relay, whilst the plate circuit of the other tube actuates a device for measuring the amplitudes. It is preferable to connect, as shown in Fig. 2, the screen grid of the pentode over a resistance 12 to a positive potential and to transmit the voltage drop across this resistance (said voltage drop being a function of the impulse amplitude) over a rectifier (metal rectifier or diode 39) and, if desired, a filter resistance 38 to a condenser 40 shunted by a resistance 41. This condenser 40 is charged up to the peak voltage of the amplified impulses and this voltage is measured by means of the intensity meter arranged across the terminals 44 in the plate circuit of the voltmeter tube 43. It is possible, by means of the variable resistance 37, to vary the amplification of the tube 10 and thereby to set the pointer of the intensity meter to a predetermined position. In this manner, any abnormal intensity of the heart-strokes is instantaneously made visible. The resistance 42 furnishes grid bias to the tube 43.

In order to give a signal after a certain time delay, if the pulse stops because of a lowering of the blood pressure, two more contacts are arranged on relay 17. At each operation of the relay said contacts connect a condenser 27, shunted by a resistance 26, to a charging potential. This combination 26, 27 is arranged between grid and cathode of another tube 28 and blocks this tube, as long as impulses are occurring, by charging its grid with a negative potential. If the impulses cease the potential flows off and after a certain time, according to the time-constant of 26, 27, the tube becomes conductive. A relay 29 in the plate circuit of tube 28 then closes the circuit of a buzzer 49 which may be disconnected by means of a switch 48. In order to give a warning signal, if this buzzer 49 is disconnected, a pilot lamp is switched on at the same time. The pilot lamp 46 lights constantly and indicates the operating condition of the device.

In order to compensate the influence of variations in the voltage of the mains to the measurements, the heaters of those tubes, which may be effected by variations of the electron emission (such as especially the first stage tube 6 and the voltmeter tube 23), are connected to the mains over a regulating tube 45 comprising iron filaments in an atmosphere of hydrogen; 51 is the main switch (combined with the variable resistance voltage 37), 52 is a safety fuse and 50 a resistance, which if in connection with 220 volt serves as series resistance for the heating circuit of the tubes 6 and 23.

The device may be, of course, also operated by batteries or converters instead of the alternating current mains, and the alterations necessary in this case are evident to any expert skilled in the art.

What we claim is:

1. A device for measuring and supervising the heart action comprising two compression bags, one of said bags receiving a measured pressure and being applied to the body in such a manner that it is adapted to intercept the blood circulation towards an artery to which artery the second bag is applied, the second bag being acted upon by the volume alterations of the artery due to the blood circulation and being pneumatically connected to a manometer having a chamber provided with a diaphragm, a piezo-electric crystal adapted to be deformed by the movement of said diaphragm and to generate electric impulses, a direct-coupled multi-stage amplifier amplifying and rectifying said impulses, a relay in the output circuit of said amplifier, said relay being adapted to shunt at each movement of its armature, a small condenser to a condenser connected for charging to a source of electric potential over a resistance, means to indicate the potential across said charged condenser to thereby measure the frequency of the pulse, and a rectifier connected to the output circuit of said amplifier adapted to measure the peak values of the amplified impulses for indicating the intensity of the pulse strokes.

2. In a device according to claim 1, a glow lamp arranged in shunt to the relay coil and to an indicating instrument in the output circuit of the amplifier.

3. A device according to claim 1, in which the last stage of the amplifier comprises a double

output circuit, one output circuit operating a relay, and the other output circuit the intensity measuring rectifier.

4. A device according to claim 1, in which the last stage of the amplifier comprises a pentode, the relay being arranged in the plate circuit of said pentode, the screen grid circuit of said pentode containing a resistance, the grid of a voltmeter-tube being connected to said resistance over said rectifier.

5. In a device according to claim 1, a variable resistance in the cathode circuit for regulating the amplification factor of the amplifier in order to set the intensity measuring rectifier to a predetermined indication.

6. A device according to claim 1, in which the heaters of the first tube of the amplifier and the voltmeter-tube are arranged in series with a regulating tube.

7. In a device according to claim 1, additional contacts operated by said relay, said contacts operating an alarm device over a time delay device if the pulse strokes cease for too extended a period of time.

8. In a device according to claim 1, additional contacts operated by said relay, a condenser shunted by a resistance arranged between grid and cathode of a tube, said condenser receiving, by means of said additional contacts, a charge negative with respect to the grid at each impulse, and means in the plate circuit of said tube to operate an alarm device.

9. In a device according to claim 1, additional contacts operated by said relay, a condenser shunted by a resistance arranged between grid and cathode of a tube, said condenser receiving, by means of said additional contacts, a charge negative with respect to the grid at each impulse, and means in the plate circuit of said tube to operate an alarm device and to operate a valve relieving the air pressure in the first compression bag.

10. Apparatus according to claim 1, and means for frictionally holding said piezo-electric crystal, and means for resiliently pressing said holding means so that the crystal is resiliently pressed against said motion transmitting connection.

11. Apparatus according to claim 1, and means for frictionally holding said piezo-electric crystal, and means for resiliently pressing said holding means so that the crystal is resiliently pressed against said motion transmitting connection, a hand operable means for lifting the crystal from the motion transmitting connection, said means comprising a one way motion transmission mechanism whereby said means is prevented from applying pressure on said crystal against said motion transmitting connection.

12. Apparatus according to claim 1, a movable socket holding the piezo-electric crystal, a spring pressed against said socket and frictionally holding said socket in position, a screw for applying pressure adjustably on said spring to adjust the tension of said spring against said socket and another spring for resiliently pressing said crystal against the motion transmitting connection to the manometer diaphragm.

13. Apparatus according to claim 1, and a manometer for measuring and indicating the pressure of the first compression bag and having a large indicating dial, the means for indicating the frequency and intensity of the electrical variations of the crystal responsive to the pulse comprising smaller dials arranged within the area of said large dial.

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