

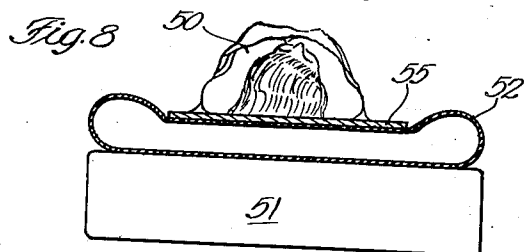
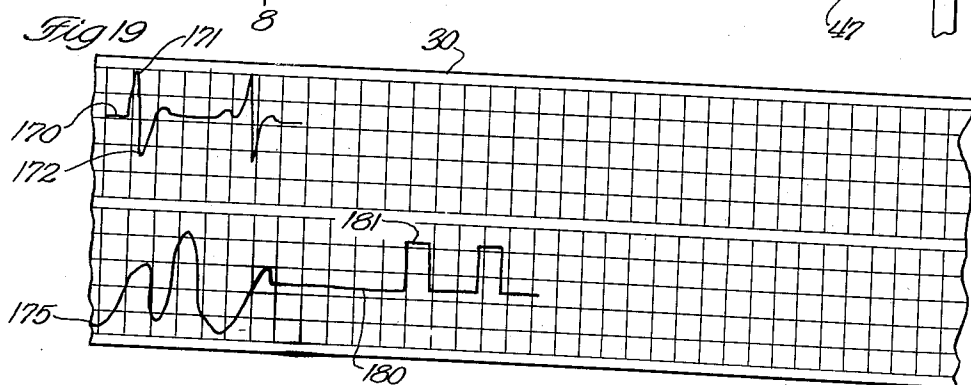
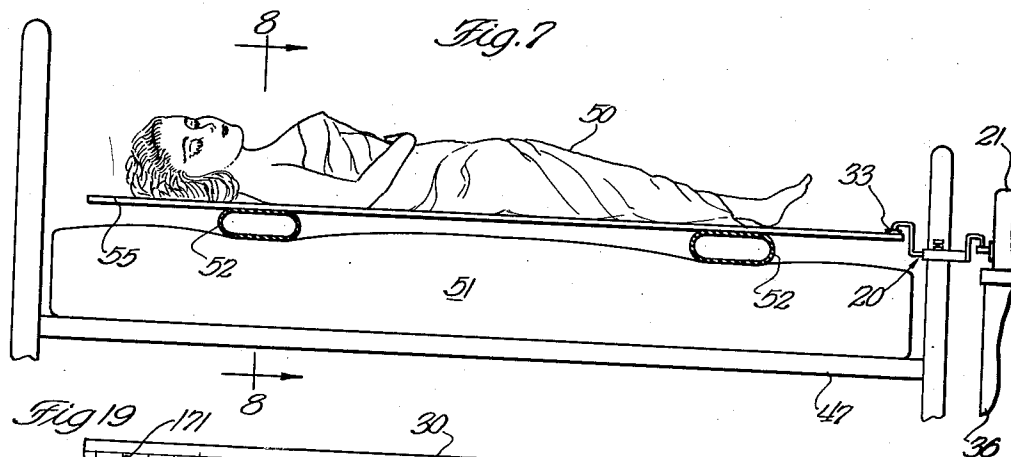
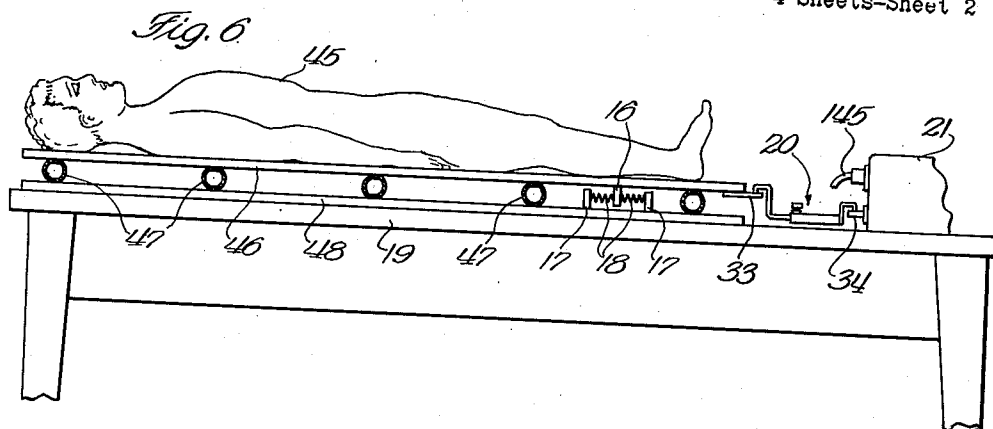
June 8, 1954

M. L. EDWARDS
BALLISTIC CARDIOGRAPH

2,680,438

Filed March 25, 1950

4 Sheets-Sheet 2



INVENTOR.
Miles Lowell Edwards
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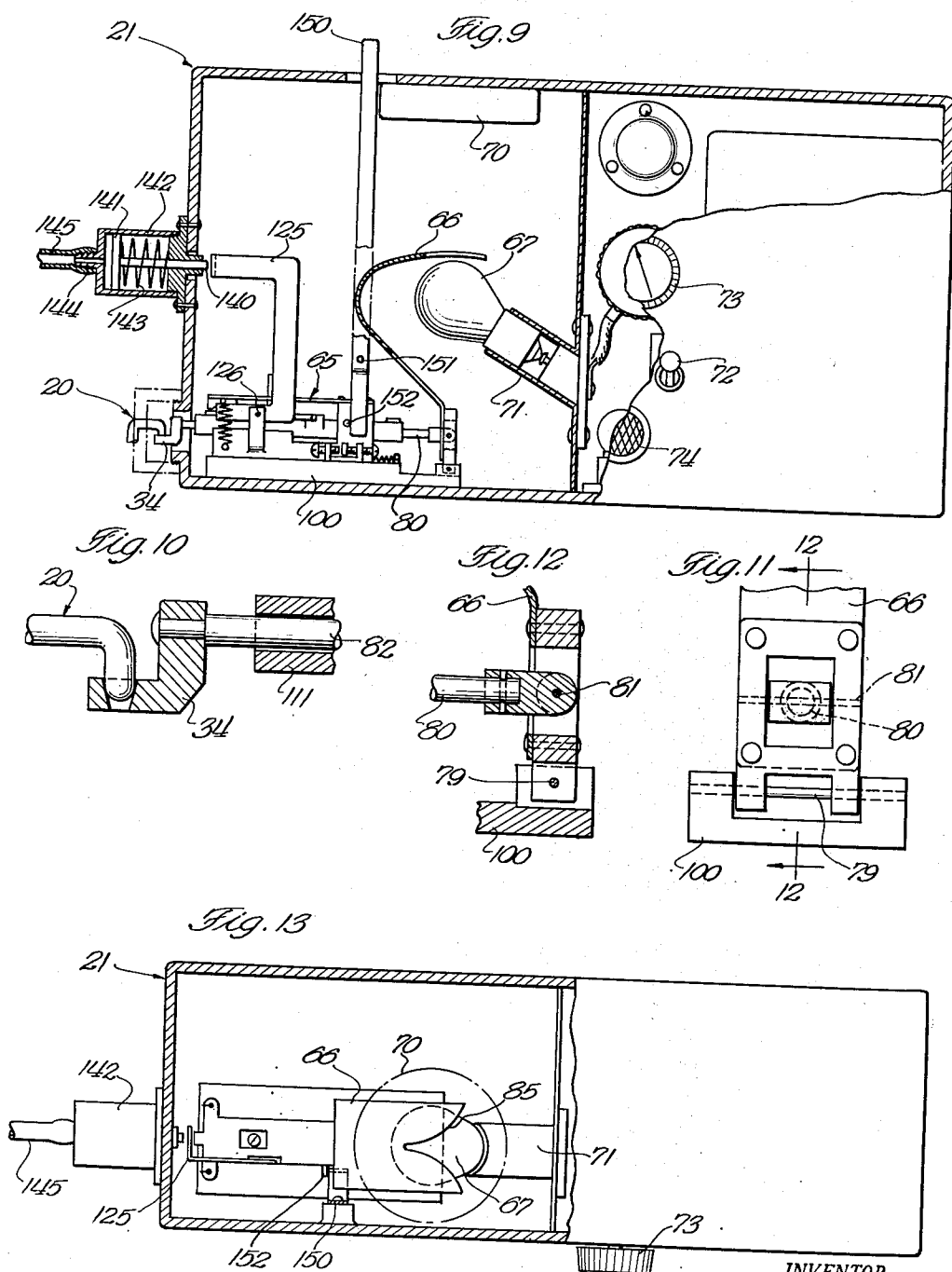
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4 Sheets-Sheet 3



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4 Sheets-Sheet 4

Fig. 14

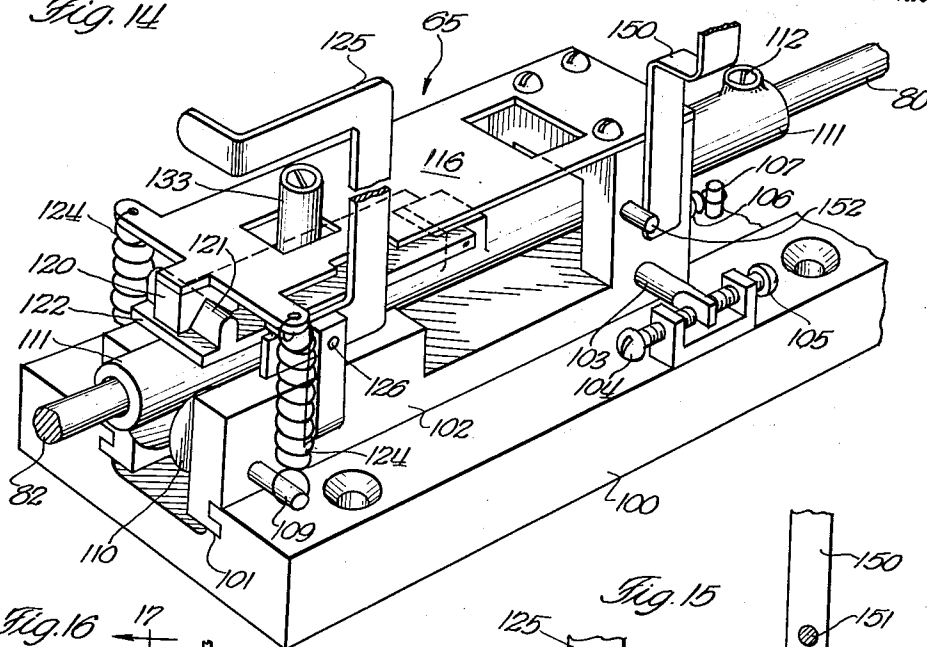


Fig. 15

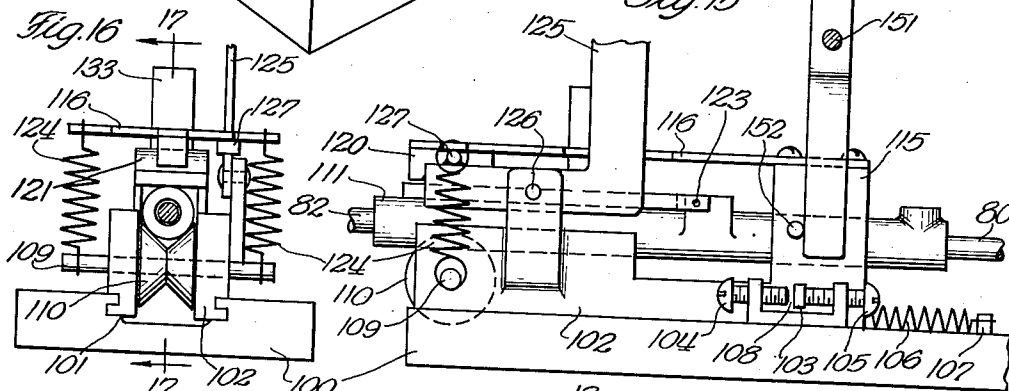
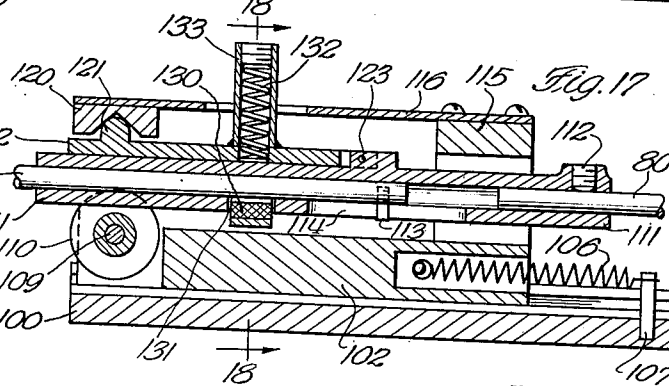
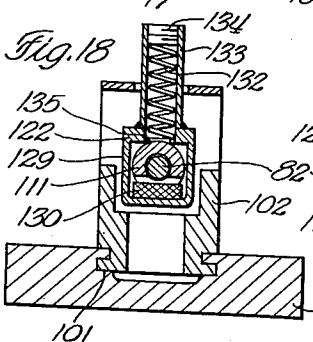
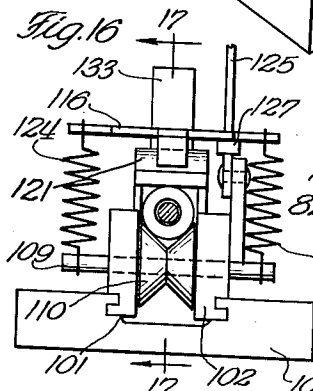


Fig. 16



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UNITED STATES PATENT OFFICE

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BALLISTIC CARDIOGRAPH

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Application March 25, 1950, Serial No. 151,905

17 Claims. (Cl. 128—2.06)

1

This invention relates to improvements in apparatus for recording the ballistic effects produced by pulsations of the heart and the rhythmic movements of the blood in the human body.

The most common and elementary clinical tests employed for investigating a patient's heart action and blood circulation involve the use of the stethoscope, the counting of the heartbeat frequency, and measurement of the arterial blood pressure. More recently, the electrocardiograph has been devised to record graphically the nature of the rhythmic change of certain electrical characteristics of the body which are synchronous with the heartbeat. Such procedures reveal different aspects of the phenomenon of heart action and circulation of blood in an individual, but they are not useful to indicate the rate of flow of blood, which flow in ample volume is necessary to maintain life and well-being in the human body. The usual pulse count, blood pressure measurement and indication of electrical transients in the body may indicate the apparent vigor of the heart's effort, but they do not reveal whether the heart is operating effectively and accomplishing its purpose as a pump to produce the necessary rate of flow in the arterial and venous systems. It is believed, for example, that defective valve action, in particular, may exist in the heart without being detected by such tests. Unusual sounds may be heard in the stethoscope but the limitations of this instrument are well recognized. Ballistic methods have been proposed, but known apparatus heretofore developed for the purpose has been cumbersome and expensive, difficult to adjust and use, and the results generally included considerable error and distortion from various disturbances which could not be eliminated.

General objects of the present invention are, therefore, to provide an improved ballistic cardiograph apparatus which is reasonably compact and portable, which may be adapted for use with patients who cannot be removed from bed, which is easy to adjust and use, and which is relatively inexpensive and at the same time capable of greater accuracy and precision than existing apparatus.

Particular objects are to provide improved apparatus which is sensitive to any vibratory movement produced by pulsations of the heart and the rhythmic movements of the blood stream of a patient, and which will eliminate substantially all undesired disturbances, and to provide a sensitive mechanism to respond in true linear relation to minute movements of the cen-

2

ter of gravity of a patient produced by the resultant ballistic effects of such pulsations and blood stream movements.

Other objects are to provide novel and improved supporting means for the patient to provide relatively frictionless freedom of movement in a horizontal direction; to provide elastic restraining means for the supporting means to eliminate disturbing movements and to introduce a nominal centering force; to provide an improved translating device for converting minute movements into measurable, directly proportional variations in an electrical output circuit; to provide apparatus of the type described which is suitable for use with a conventional electrocardiograph recording machine; to provide convenient means for calibrating the record produced by such machine; to provide novel mechanism for centering the responsive mechanism of the translating device; and to provide novel means for releasing the responsive mechanism during periods of patient unrest.

General principles

Certain features of the present apparatus may be used without other features, but it is preferred to use the improved translating device in conjunction with novel supporting means for the patient to obtain the desired response and eliminate disturbing movements. Thus, the patient should be disposed in a reclining position upon a rigid floating support having substantially frictionless freedom of movement in one direction. It is desired that the floating support shall faithfully follow any movement of the center of gravity of the patient in the said direction, but it is also desired to include a slight frictional force, such as a rolling friction, to furnish a nominal dampening effect.

The support is connected in a novel manner with mechanical and electrical components of the apparatus to magnify and record such movements in a curve drawn relative to a time axis on a moving tape. To avoid relative movement or vibration between the center of gravity of the patient and the floating support, the support must be rigid and of relatively small mass in comparison with the mass of the patient.

In order to prevent a gradual drift of the support in one direction or the other, and to prevent long period disturbing movements, such as respiration, from continually shifting the pulse curve back and forth on the paper, it is necessary to apply some restoring force to the support in addition to the mentioned frictional re-

straint without critically impairing the desired ballistic response. To effect the return movement toward a centered position the frictional dampening force is insufficient; the restraining and restoring force must be elastic or the equivalent. It is recognized that any elastic or other restoring force for this purpose will establish a natural vibrating frequency of the oscillating mass comprising the patient and support. Such restoring force must, therefore, be adjusted to keep this natural frequency lower than the range of heartbeat frequencies in order to avoid resonance at the fundamental natural frequency, or any harmonic, of the potential oscillating mass.

It is found that the slight ballistic effects of the relatively slow shifting of the center of gravity of the body from respiration can effectively be eliminated by suitable centering springs without appreciably affecting the response to the ballistic effects of the heart action and blood stream. It is also recognized that such systolic and diastolic action of the heart does not produce a simple ballistic effect in any particular direction relative to the orientation of the body, but it is found that there is a measurable resultant movement of the center of gravity of the body in a longitudinal direction which is useful for the present purpose. The present apparatus is designed to provide freedom for this movement, and to provide a sensitive, convenient, responsive mechanism for recording the movements over a period of time, for clinical use.

When the human body is subjected to any sudden force, or impact, it behaves as an elastic medium, and a train of vibrations is initiated at the natural frequency of the body, as when a tuning fork is struck. Such vibrations have been observed by disposing a fresh cadaver on a rigid stationary support and holding a sensitive vibration pick-up against the bottoms of its feet. If the body is tapped on the head with a single stroke, a train of vibrations will appear clearly on a graphic record produced from this vibration pick-up device. Vibrations of this nature are produced in a living body by heart action. The graphic records made by previous known ballistic methods have recorded these trains of damped vibrations to such an extent following each impulse from the heart that the heart action itself was obscured and could not be analyzed satisfactorily. In the present apparatus, such vibrations of different parts of the body relative to its center of gravity are effectively isolated from the recording mechanism, and the only movement fed into the amplifying system is the longitudinal movement of the center of gravity of the body resulting from the vector sum of the ballistic effects of the heart and the pulsating blood streams throughout the body.

For a theoretical analysis of the ballistic mechanics involved, let it be assumed that a living body is disposed at rest, horizontally, on a frictionless horizontal surface, free of all other external contact. Such a body forms a closed system having a center of gravity which remains stationary and cannot be moved horizontally by any muscular effort of the body itself, though parts of the body can move relative to other parts. When the heart contracts, quantities of blood are moved in different directions away from the heart and, since the heart is not at the center of gravity of the system, the center of gravity of the system is thereby shifted rela-

tive to the body, considering the body as a frame carrying a network of pipe lines. However, with a frictionless support the actual movement in space is that of the body frame and its center of gravity because, as stated, the center of gravity of the whole system, including the blood, cannot move. This is the movement to which the present apparatus is intended to respond, and all mention of the center of gravity of the body in the specification and claims refers to the body frame and pipe line network as distinguished from the stationary center of gravity of the whole body system. Energy losses from friction tend to reduce the amount of movement in a mechanical apparatus but do not alter the principle of operation.

The term "ballistic" is thus employed to describe the response of the present cardiograph to the movement, or recoil, of the center of gravity of the patient's body frame, tissue, and pipe line network when a quantity of blood is propelled or moved suddenly within the body by heart action. The term "ballistic" distinguishes the response to such ballistic movement from response to electrical manifestations of heart stimuli, response to variations in the blood pressure, and response to vibratory movements of some part of the body relative to its center of gravity.

Other objects and advantages will become apparent, and the invention will be better understood with reference to the embodiments illustrated on the accompanying drawings and described in the following specification. It is to be understood, however, that the drawings are not intended to limit the invention, as various changes may be made in the construction and arrangement of parts without departing from the spirit of the invention. Also, as hereinabove pointed out, advantages may be obtained for certain purposes by using some features of the invention without others.

In the drawings:

Figure 1 is a side elevation view of a preferred embodiment of the complete apparatus of the ballistic cardiograph wherein the patient is supported on metal rollers;

Figure 2 is a bottom plan view, on a reduced scale, of the floating panel under the patient in Figure 1;

Figure 3 is an enlarged detail view in side elevation view of one of the rollers shown in Figure 1;

Figure 4 is an end elevation view of the roller shown in Figure 3;

Figure 5 is an enlarged sectional view showing the construction of the connecting link between the floating panel under the patient and the translating device;

Figure 6 is a side elevation view of a different form of support employing inflated rubber rollers;

Figure 7 is a side elevation view of a modified form of floating support to be used on a bed or other conventional structure;

Figure 8 is a cross sectional view taken on the line 8-8 of Figure 7;

Figure 9 is a longitudinal sectional view of the translating device shown in Figures 1, 6 and 7;

Figure 10 is an enlarged detail view showing the connection between one end of the link in Figure 5 and the translating device shown in Figure 9;

Figure 11 is a fragmentary elevation view of the light shutter shown in Figure 9;

Figure 12 is a sectional view taken on the line 12—12 of Figure 11;

Figure 13 is a top plan view of the translating device with parts of the cabinet broken away;

Figure 14 is an enlarged perspective view of the clutch and centering mechanism shown in Figure 9;

Figure 15 is a side elevation view of the clutch mechanism shown in Figure 14;

Figure 16 is an end elevation view of the clutch mechanism;

Figure 17 is a longitudinal sectional view taken on the line 17—17 in Figure 16;

Figure 18 is a cross sectional view taken on the line 18—18 of Figure 17; and

Figure 19 illustrates a combined electrocardiogram and ballistic cardiogram.

Support for the patent

In Figure 1, the patient's body 10 rests upon a lightweight but rigid panel 11 of plywood or the like, having freedom of movement in a longitudinal direction. This panel is intended to function as a floating table, or support, having free response to any movements of the center of gravity of the body in one particular direction, such as longitudinal, without responding to any movements of one local part of the body relative to another part. For this purpose, the under side of the panel 11 is equipped, as shown in Figure 2, with a plurality of short metal rails 12 to support the panel on grooved rollers 13. Rollers 13 are mounted on anti-friction ball bearings (not shown) on short shafts 14 which are supported on a base board 15 for use on a rigid level table 19. The moving parts of this support, comprising panel 11, rails 12, and rollers 13, have relatively small combined mass relative to the mass of the patient's body 10 to eliminate any relative movement or oscillation between the body 10 and panel 11 resulting from inertia effects. In an operative embodiment the panel 11 and rails 12 weigh fifteen pounds. A less weight in these parts would be desirable if it could be obtained without loss of rigidity, but 15 to 20 pounds is considered satisfactory.

The under side of panel 11 is further equipped with a depending lug 16 positioned between a pair of spaced abutments 17 on the base 15. A pair of light coil springs 18 are seated between the abutments 17 and opposite sides of the lug 16 to center the panel resiliently in a definite position, while, at the same time, offering relatively little restraint to the freedom of its longitudinal movement.

The spring force exerted by the springs 18 upon the panel 11 is an important consideration to the proper functioning of the apparatus. The natural frequency of oscillation of the panel 11 with the body 10 thereon must be lower than the range of heartbeat frequencies in order to avoid resonance at the fundamental or any harmonic of the natural frequency. The minimum spring tension is determined by the consideration that the tension should be great enough to center the panel and body and to prevent movement of the panel in response to respiration. A spring rate of the combined springs of $4\frac{1}{4}$ pounds per inch is found to satisfy both conditions for a patient of average weight, but a lower spring rate is desirable, provided it satisfies the stated condition for minimum spring tension. With this spring rate and a fifteen pound panel, the natural frequency for the spring and mass combination shown in Figure 1 varies from 45 cycles per

minute for a body weighing 100 pounds, to thirty cycles per minute for a body weighing 180 pounds, which values are less than the usual pulse frequencies of the patients. These values were determined experimentally. With a heavier individual, the natural frequency would be slightly less than thirty cycles, and the same spring rate would be satisfactory, provided that it was sufficient to prevent response to respiration. Respiration movements can, of course, be suspended temporarily by holding the breath, but it is preferred to allow the patient to breathe naturally.

Longitudinal movements of the panel 11 are transmitted through a connecting link 20 to an electrical translating device designated generally by the numeral 21. The purpose of the device 21 is to convert the minute movements of the panel 11 into electrical voltage or current fluctuations in linear relationship in an output circuit 22 which is connected with one of the input circuits of a conventional electrocardiograph 25 or other suitable electrical oscillograph type of instrument.

Electrocardiographs are ordinarily equipped with a cable 26 carrying a plurality of different input circuits 27 for transmitting electrical impulses simultaneously from different sources. The output circuit 22 is connected to one of these circuits. The translating device 21 is energized by means of an extension cord 28 and the cardiograph is energized by an extension cord 29. The function of the electrocardiograph 25 is to draw a curve or a series of curves on a moving tape 30 to indicate graphically the voltage or current fluctuations introduced into the input circuits 27 relative to a time axis extending longitudinally of the tape. In the present arrangement, the curve traced by the signals received from the output circuit 22 have ordinate values corresponding to the longitudinal movements of the panel 11 in direct ratio. Since the output circuit 22 utilizes only one of the plurality of input circuits 27, the other input circuits may be used to obtain simultaneous electrocardiograph records, or for any other purpose.

The construction and arrangement of the link 20 is shown in Figure 5. One end of the panel 11 is equipped with a projecting metallic plate 33 and the translating device 21 has a movable element with a similar plate 34 projecting therefrom. Each of these plate members is equipped with a conical socket 35, and the device 21 is preferably supported upon a table 36 so that the plate 34 may be disposed adjacent the plate 33 and at approximately the same level for convenient interconnection of these two members by the link 20.

The link 20 comprises a pair of telescoping rods 37 and 38 having rounded end portions 40 to seat in their respective sockets 35. The central parts of the rods 37 and 38 are preferably offset below the ends 40, so that the link will hang by gravity in a stable position, as shown. After the patient has been placed upon the panel 11 and the translating device 21 has been moved into position adjacent the foot of the panel, the link 20, with set screw 41 loosened, is dropped into place, allowing the telescopic connection between the rods 37 and 38 to make the proper length adjustment between the two sockets. Then the two rods 37 and 38 are made integral and rigid by tightening the set screw 41, so that any longitudinal movements of the panel will be transmitted directly to the plate 34 of the translating device without lost motion. The sockets 35 and rounded ends 40 permit a satisfactory universal joint type of connection to be made between the

plates 33 and 34, even though these plates may be somewhat out of alignment and on slightly different levels.

In Figure 6, the patient 45 is supported on a rigid panel 46 which is similar to the panel 11 in Figure 1, except that it is not equipped with the rails 12. The under surface of the panel 46 is made smooth and flat, and rests upon a plurality of inflated rubber rollers 47. These rollers rest upon the smooth and flat top surface of a second panel 48 on the table 19. Springs 18 center the panel 46 as in Figure 1, and are stiff enough, acting in conjunction with the elasticity of rollers 47, to prevent response to respiration.

Figure 7 shows a modified form of supporting means for a patient 50 who cannot be removed from the bed 51. Inflated cylindrical rubber tubes 52 are placed transversely across the mattress to support the rigid lightweight panel 55. The tubes 52 and panel 55 can be placed on the mattress and the patient 50 transferred thereto with a minimum of disturbance. The tubes 52 are preferably larger than the tubes 47 in order to hold the panel 55 above the mattress when the mattress is depressed under the tubes. Both types of tubes constitute elastic and pneumatic cushion means to support the rigid members 46 and 55 for horizontal movement in a longitudinal direction. The tubes 52 are only partially inflated, so that they will be considerably flattened under the weight of the patient, as shown. With this shape of cross section, and with the proper wall thickness in the tubes, the tubes themselves will have the desired centering effect and will prevent response to respiration, making the springs 18 unnecessary. Centering springs may be added, however, if necessary.

The tubes 52 preferably extend beyond the side edges of the panel 55, so that the ends of the tubes will bulge up as shown in Figure 8. When the tubes are deformed to this shape, they offer more resistance to rolling, particularly under the very minute movements imparted to the panel 55 by the ballistic effects of the pulse action. Longitudinal movement of the panel tends to compress the tube wall on one side of the tube and slightly stretch it on the other side beneath the panel. Shear stresses are produced in the rubber tube in the projecting end portions. For very minute movements, the combination of compression, tension and shear forces in the rubber produce the necessary amount of restraint and have the desired centering effect, by virtue of the elasticity of the rubber itself, without impairing the freedom of movement of the panel to respond faithfully to longitudinal movements of the center of gravity of the patient.

With the arrangement shown in Figure 7, the table 36 with the electrical equipment may be brought directly to the patient in a conventional bed, in cases where the patient cannot be moved to the equipment. The ballistic cardiogram may be obtained easily and quickly without any sacrifice of sensitivity and without endangering a very weak patient.

The rolling friction which occurs in the metallic or pneumatic roller supporting system provides sufficient dampening of the system to prevent unwanted movements. These movements may be caused by respiration of the patient, or by overshooting of the elastic centering force from inertia. It is found that the rolling friction has the desired dampening effect with minimum interference to the free movement of the body and supporting panel under the cardiobal-

listic effects produced in the patient's body, which effects it is desired to utilize as the source of the input signal for the oscillograph recording mechanism.

The characteristics of the present type of support shown in Figures 1, 6 and 7 are to be distinguished from the characteristics of direct support of the body on a stationary table top. In the latter case the body tissue bearing on the table top establishes a resilient connection between the main mass of the body and the table in which neither the spring rate nor the dampening can be controlled. Any ballistic impulse in such body excites two different types of vibration in the body. There is a movement of the center of gravity of the body relative to the support and also a movement of different parts of the body relative to each other, both movements tending to start trains of vibrations. With such support, a vibration pick-up cannot be applied to the body to respond solely to the original ballistic impulse and reaction.

With the present support, relative movements of parts of the body are not transmitted to the floating support. The support can respond only to movements of the center of gravity of the body, and the dampening effect and elastic centering force acting on these movements can be controlled to eliminate resonance conditions and to eliminate body disturbances from other than cardio-ballistic causes.

Translating device

Figure 9 is a sectional view illustrating the construction of the translating device 21. This device contains a special clutch mechanism 65 for transmitting the longitudinal movements of link 20 to a shutter or occluding device 66 which controls the amount of light from electric bulb 67 which may fall on the light sensitive cell 70. In the illustrated embodiment, the cell 70 is of the self-generating type, and the output circuit 22 shown in Figure 1 merely connects the voltage generated by the cell to the input circuit of the electrocardiograph 25. Other known types of circuits may be adapted to the purpose of varying the signal in the output circuit 22 in accordance with the movements of the link 20 without imposing any restraint upon such movements.

The light bulb 67 is mounted in a socket 71 which is energized from the supply source 28 through a switch 72 and rheostat 73. The signal intensity in the output circuit 22 may be adjusted at its source by varying the temperature of the filament in bulb 67 by the rheostat 73, in addition to the conventional controls provided in the usual cardiograph apparatus 25. A pilot light 74 is connected with the light circuit to provide a visual indication when the light is turned on.

Figures 11, 12 and 13 illustrate details of construction of the occluding shutter 66. The shutter is pivotally mounted on pin 79 to swing in a vertical plane when it is moved by a rod 80 having one end pivotally connected with the shutter by means of the pin 81. When the apparatus is in operation, the clutch mechanism 65 effects a direct mechanical connection between the rod 80 and a rod 82 shown in Figure 10 which carries the plate 34 to support one end of the link 20.

The pin 81 is quite close to the pin 79 in order to magnify the movement of the upper end of shutter blade 66 which is disposed between the light 67 and light sensitive cell 70. The upper end

of the shutter is notched on a double curve 85 which is calculated in accordance with the known characteristics of the cell 70 to give proportional electrical response in the output circuit 22 with respect to the distance of movement of link 20.

The clutch device 65 will now be described with particular reference to Figures 14 to 18. The base member 100 is equipped with longitudinal ways 101 for a sliding frame 102. On one side of the frame 102 is a stop pin 103 projecting between the ends of a pair of opposed stop screws 104 and 105 on the base 100. A spring 106 on the frame 102 has an outer end anchored on pin 107 to hold the frame normally in its rearmost position as viewed in Figure 14, with the stop pin 103 engaging the rear stop screw 105. In this position there is a small gap 108 between the other side of stop pin 103 and the front stop screw 104, as indicated in Figure 15.

The front end of frame 102 as viewed in Figure 14 carries a transverse shaft 109 for a grooved roller 110. This roller is adapted to support a cylindrical tube 111 having a set screw 112 at its rear end to secure it to the rod 80. The rod 82 which carries plate 34 has an easy sliding fit in the tube 111 and is equipped with a guide pin 113 extending into slot 114 in the tube to prevent rotation of the rod and limit the travel of the rod to prevent it from becoming separated from the tube.

The rearward end of sliding frame 102 comprises a bridge 115 upon which is secured a forwardly extending spring plate 116. The forward free end of spring plate 116 carries a centering block 120 having an inverted V-shaped notch to engage a transverse rounded upstanding lug 121 on a plate 122 which is pivotally connected by pin 123 with the tube 111. The center of this notch is in the vertical plane of roller shaft 109. The centering block 120 is normally held in contact with the lug 121 by means of springs 124, but it may be raised out of engagement with the lug by means of lever 125. Lever 125 is pivotally mounted on frame 102 by means of pin 126, and is provided with a small lug 127 to engage and lift the forward end of spring plate 116 when the upper end of lever 125 is pressed in a rearward direction.

Plate 122 carries a stirrup 129 having a pad of friction material 130 forming a clutch element which projects through a slot 131 in the under side of the tube 111 to engage the rod 82. Clutch element 130 is urged upward into clamping engagement with the rod 82 by means of a spring 132 housed in a vertical tube 133 which is integral with the plate 122. The upper end of this spring seats against an adjustable stop screw 134, and the lower end extends through an opening 135 in the plate 122 to bear against the tube 111.

In order to maintain the parts normally in their rest or centered position as shown in Figure 17, the springs 124 must exert sufficient spring force to overpower and slightly compress the spring 132. With the tube 111 thus centered, the rod 80 is adjusted under set screw 112 to place the shutter 66 in Figure 9 in a median position, so that approximately half the sensitive surface of the cell 70 is shaded from the rays of the light source 67. Once made, this adjustment does not have to be changed. Movement of the shutter 66 in one direction then increases the lighted area of the cell 70, and movement in the other direction decreases the lighted area to produce current variations in the output circuit 22 proportional to movements of the rod 80.

In Figure 9 there is also disclosed a convenient

10

device for actuating the lever 125 to operate the clutch mechanism. A plunger 140 is carried by a piston 141 in a cylinder 142 mounted on a wall of the device 21. Spring 143 normally holds the plunger 140 out of contact with the upper end of lever 125. The outer end of cylinder 142 is equipped with a fitting 144 for a rubber tube 145 having a pneumatic bulb 146 shown in Figure 1. When the bulb is squeezed, air is forced into cylinder 142 to drive plunger 140 against lever 125, rotating it in a clockwise direction about its pivot 126.

Figure 9 further shows a lever 150 mounted on a fixed pivot 151. The lower end of this lever is positioned to engage a pin 152 on the sliding frame 102, as shown also in Figures 14 and 15. By means of this lever, the normally stationary frame 102 may be shifted forward until stop pin 103 engages the forward stop screw 104. The amount of this movement is equal to the space, or gap, 108, between the end of stop screw 104 and the adjacent surface of pin 103 when the parts are in the normal position shown in Figure 15, and this gap may be accurately measured and adjusted by a suitable gauge. When the clutch 130 is disengaged, as shown in Figure 17, and the sliding frame 102 moved forward by means of the lever 150, the motion is transmitted through rod 80 to shutter 66 to cause an offset line to be drawn on cardiogram 30 parallel with the base line which is traced when stop pin 103 engages the rear stop screw 105. This provides a convenient and accurate calibration directly on the curve of the cardiogram.

Operation

The patient is placed on one of the supports shown in Figures 1, 6, or 7. After allowing some time for the patient to rest and relax, the link 20 is placed in position to operate the translating device and make the record. In certain cases it may be desired to exercise the patient and then make the record immediately after the exercise.

The parts in the translating device 21 are illustrated in disengaged and centered positions in Figure 17 which is their normal rest position when a record is not in the process of being made. Clutch pad 130 is out of engagement with rod 82, and the latter has free sliding movement in the tube 111. Tube 111 is held in a predetermined or centered position by the engagement of centering block 120 with the lug 121.

When it is desired to trace a ballisto-cardiogram curve, the upper end of lever 125 is pressed rearwardly in Figure 14, by means of bulb 146, causing centering block 120 to be raised by lug 127. Plate 122 and lug 121 follow this movement until the clutch pad 130 bears against the rod 82 with a force determined by the adjustment of spring 132. Further upward movement of the centering block 120 frees the lug 121, and the rod 82 is then clamped in tube 111 to transmit any longitudinal movements from the link 20 directly to tube 111 and rod 80 to actuate the shutter 66. When the bulb 146 is squeezed, the electrocardiograph machine 25 is operated to make the graphic record. The shutter will be actuated in response to movements of the link 20 only while the upper end of lever 125 is depressed rearwardly by the action of bulb 146, and when this lever is released the springs 124 return the parts to the Figure 17 position to disconnect the rod 82 from tube 111 and recenter the latter in its normal rest position. This will cause a

11

straight base line to be drawn in the center of the curve area until the electrocardiograph is turned off.

Figure 19 illustrates the type of cardiogram curve obtained with the apparatus shown in Figure 1. The top curve 170 is traced by conventional electrocardiograph equipment, and represents a typical electrocardiogram curve. This curve is obtained by placing electrodes connected with one of the input circuits 27 in contact with spaced points on the body of the patient. This conventional apparatus is not necessary to the invention and is not shown in Figure 1, but it may be used in conjunction with the novel apparatus illustrated in order to trace the two curves simultaneously for comparison. The several input circuits 27 of a conventional electrocardiograph are independent of each other, and present electrocardiograph equipment may include as many as six input circuits for tracing six different curves simultaneously on the record 30. The translating device 21 utilizes only one of these input circuits, thereby leaving the other five circuits available for any other type of simultaneous analysis which may be desired, such as the curve 170.

In the record shown in Fig. 19, the vertical lines are printed on the paper to indicate fifths of a second in time, and the upper and lower peaks 171 and 172, spaced at approximately one second intervals, form a typical electrocardiogram curve. These peaks indicate slight variations in the electrical potential measured between different points on the surface of the body which occur in rhythm with the heartbeat.

The curve 175 resulted from the signal from output circuit 22 in Figure 1 and was traced simultaneously with the curve 170. On the curve 175, the straight horizontal line 180 forms a reference or base line which was traced in the center of the curve area when the tubular sleeve 111 was centered by block 120 with the clutch 130 disengaged as shown in Figure 17. Offset portions 181 were traced while lever 150 was shifted to hold stop pin 193 momentarily against the forward stop 194. Hence, the vertical distance on the chart between the parallel lines 180 and 181 is a measure of the known distance 198 between the end of stop screw 194 and stop pin 193 shown in Figure 15.

When the bulb 146 is squeezed, clutch 130 is engaged to produce the graphic record at 175 of the longitudinal movements of the center of gravity of the patient with respect to the time axis. Portions of the curve 175 above line 180 indicate movements in one direction from the centered position and portions below line 180 indicate movements in the opposite direction from the centered position. The ordinate distances of points on the curve from line 180 bear a linear relation to the amplitudes of said movements at the instants considered, whereby the extent, duration and velocity of any movement of the center of gravity of the patient may be determined from measurements on the chart.

Having now described my invention and in what manner the same may be used, what I claim as new and desire to protect by Letters Patent is:

1. In a ballistic cardiograph, a rigid member for supporting a patient, said member having a small mass relative to the mass of the patient, rollers supporting said member for movement in one direction, a mechanism for indicating a characteristic of said movement, and a link interconnecting said rigid member and said mechanism

for direct response of said mechanism to said member.

2. In a ballistic cardiograph, a rigid member for supporting a patient, said member having a small mass relative to the mass of the patient, elastic rollers deformable under the weight of a patient supporting said member for movement in one direction, a mechanism for indicating a characteristic of said movement, and a link interconnecting said rigid member and said mechanism for direct response of said mechanism to said member.

3. In a ballistic cardiograph, a rigid member for supporting a patient, said member having a small mass relative to the mass of the patient, elastic cushion means supporting said member for relatively free horizontal movement in one direction, a mechanism for indicating a characteristic of said movement, and a link interconnecting said rigid member and said mechanism for direct response of said mechanism to said rigid member.

4. In a ballistic cardiograph, a rigid member for supporting a patient, said member having a small mass relative to the mass of the patient, pneumatic cushion means supporting said member for horizontal movement in one direction, and a mechanism for indicating a characteristic of said movement, such as amplitude, operably connected directly to said member for response to said movement.

5. In a ballistic cardiograph, a rigid member for supporting a patient, said member having a small mass relative to the mass of the patient, rolling friction means supporting said rigid member for movement in one direction, elastic centering means connected with said rigid member to urge said member toward a predetermined position with sufficient force substantially to eliminate response to respiration of the patient, and a mechanism for indicating a characteristic of said movement connected with said rigid member.

6. In a ballistic cardiograph, a rigid member for supporting a patient, said member having a small mass relative to the mass of the patient, pneumatic cushion means supporting said rigid member for horizontal movement in one direction and tending to center said member in a predetermined position with sufficient force substantially to eliminate response to respiration of the patient, and a mechanism for indicating a characteristic of said movement connected with said rigid member.

7. In a ballistic cardiograph, a rigid table, a rigid member for supporting a patient, said member having a small mass relative to the mass of the patient, rolling friction means supporting said rigid member on said table for movement in one direction, elastic centering means connected with said rigid member to urge said member toward a predetermined position, and a mechanism for indicating a characteristic of said movement connected with said rigid member.

8. In a ballistic cardiograph, a member for engaging a patient to be tested, a translating device for converting minute mechanical movements into current variations in an electrical circuit, a socket in said member, a socket in said translating device, and a connecting link having opposite ends resting in said sockets for universal angular adjustment to transmit movements of the patient to said translating device.

9. In a ballistic cardiograph, a member engaging the patient to be tested, a translating device

for producing variations in an electrical signal corresponding to minute mechanical movements, a link for transmitting movements of said member to said translating device, said link being freely suspended between said member and said device, and ball and socket universal joint type connections between the ends of said link and said member and said device operable by the weight of said link to eliminate lost motion in the connections.

10. In a ballistic cardiograph, a member for engaging a patient's body to respond to minute movements of the body, means for varying an electric signal in response to minute mechanical movements, means including a clutch for connecting said signal varying means with said member, and means for releasing said clutch and centering said signal varying means in a predetermined position.

11. In a ballistic cardiograph, a rigid member for supporting a patient, means supporting said member for free longitudinal movement, elastic means for centering said member in a predetermined position, means for varying an electrical signal as a function of mechanical movement, centering means for said signal varying means, a link for connecting said member with said signal varying means, means for adjusting the length of said link to accommodate the centering of said member and said signal varying means, and means actuated by said centering means for said signal varying means for disconnecting said signal varying means from said link.

12. In a ballistic cardiograph and the like, means for varying a signal in an electric circuit to make a graphic record of minute mechanical movements with respect to a time axis, means to center said varying means in a predetermined position, a member responsive to the mechanical movements to be indicated, a clutch for connecting said member with said varying means, and flexible remote operating means for actuating said clutch and centering means.

13. In a ballistic cardiograph and the like, means for recording variations in an electric signal strength with respect to a time axis, means for varying said signal strength in accordance with minute mechanical movements, means to center said varying means, a member to engage a patient for responding to movements of the patient, a clutch for connecting said varying means with said member, means for actuating said clutch and centering means, and means to move said varying means a predetermined distance when said clutch is disengaged for calibrating the record.

14. In a ballistic cardiograph, a member to engage the body of a patient for responding to minute ballistic movements, means to vary an electric signal for indicating graphically the extent of minute mechanical movements, means including a clutch for connecting said signal varying means with said member, means to center said

signal varying member in a predetermined position when said clutch is disengaged, means to move said signal varying member a predetermined distance from said centered position when said clutch is disengaged for calibrating said graphic indication, and means simultaneously to engage said clutch and release said centering means.

15. In a translating device for a ballistic cardiograph and the like, means for varying the strength of an electric signal to indicate the extent and duration of minute mechanical movements, a member for moving said means, centering means engageable with said member, a member responsive to minute ballistic movements of the patient, a clutch for connecting said two members together, and an operating member movable in one direction to disengage said clutch and engage said centering means and movable in the opposite direction to engage said clutch and disengage said centering means.

16. In a translating device for a ballistic cardiograph and the like, means for varying an electrical signal to indicate the duration and extent of minute mechanical movements, a member for actuating said means, centering means for said member, a member responsive to the movements to be indicated, a clutch for connecting said two members together, spring means for disengaging said clutch and engaging said centering means, manual means for engaging said clutch and disengaging said centering means, and means for moving said first member a predetermined distance from centered position when said clutch is disengaged, for calibrating the device.

17. In a translating device for a ballistic cardiograph and the like, a light sensitive element, a light source, a movable shutter between said element and said light source to vary the amount of light received by said element in accordance with the movements of said shutter, a rod for actuating said shutter, centering means for said shutter, a rod responsive to mechanical movements, a clutch for connecting said two rods together to transmit said mechanical movements to said shutter, spring means to disengage said clutch and actuate said centering means, and manual means to engage said clutch and disengage said centering means.

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