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E. SCHWARZKOPF ET AL

ELECTROCARDIOGRAPH

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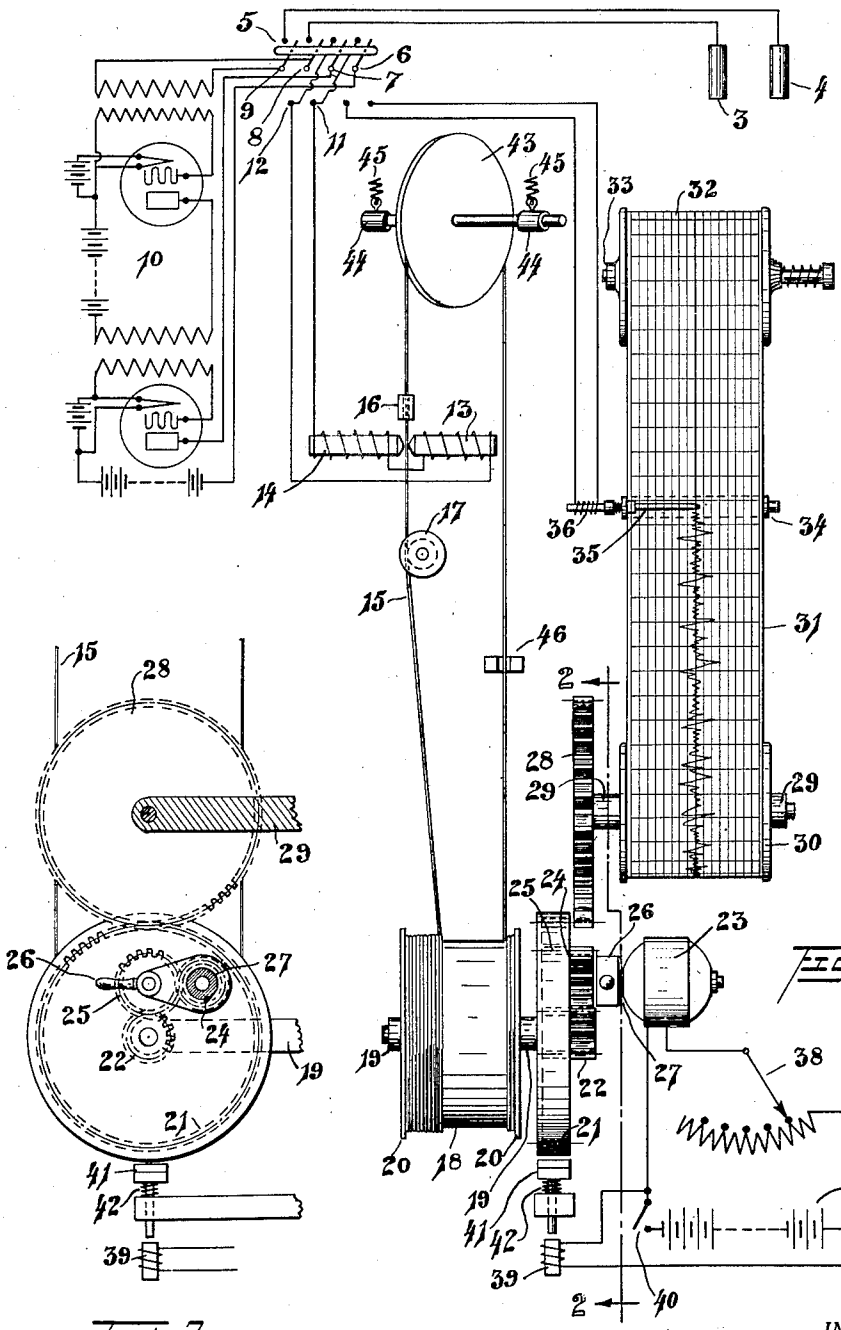

FIG. 1

FIG. 2

INVENTORS.
ERICH SCHWARZKOPF & GERHARD WODTKE.
BY Rudolf Hildebrandt.
ATTORNEY

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ERICH SCHWARZKOPF, OF LONG ISLAND CITY, AND GERHARD WODTKE, OF NEW YORK, N. Y.

ELECTROCARDIOGRAPH.

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Our invention relates to improvements in the electro-cardiograph, an apparatus used in the medical sciences for the registry of minute potential variations between various points of the human body. The apparatus used for this purpose at the present state of the art consists of a galvanometer which is deflected by the impulse of decreasing and increasing currents, a mirror on said galvanometer onto which a small beam of light is trained and a photographic apparatus which registers the movements of the light beam reflected by that mirror on the galvanometer. The swinging part of the galvanometer is of a very delicate construction to eliminate as much as possible a natural momentum of this part. The apparatus requires extreme care in setting up and similar care in handling. Owing to the photographic apparatus used in the procedure its operation has to take place in a fully or partly darkened room which of course affects the nerves of the patient, and abnormal current variations may be observed. The process of development of the photographic record takes a certain amount of time; therefore the record is not available for inspection immediately after it has been made.

The objects of our improvement are:—

1st: To eliminate all fragile parts in the mechanism by a completely electrical registering apparatus in place of the mechanical parts of the galvanometer.

2nd: To overcome all inaccuracies due to the momentum and to the natural frequency of the pendulum.

3rd: To perform all operations under normal lighting conditions.

4th: To have the graphic record on hand shortly after the observation has been made.

Various points of the human body are tapped with electrical connectors to observe the potential variations between these points. Thus the current fluctuations are measured from hand to hand, from the right arm to the left leg, from the left arm to the left leg, or between points located around the heart. To observe, simultaneously, the current fluctuations between several of the above mentioned points, a multiplicity of the apparatus is required. In such a case, owing to its reliability, the use of our improved apparatus becomes still more desirable.

We attain the above named objects by the mechanism illustrated in the accompanying drawing in which—

Figure 1 is the top view of the complete apparatus. The electrical parts are shown schematically. Of the mechanical apparatus only those parts are shown which are required to illustrate directly the functioning of the apparatus. Figure 2 is a sectional sideview of part of the control of the recording mechanism.

Similar numerals refer to similar parts throughout the several views.

The current is tapped from the human body at points 3 and 4 and from there is led to a four-pole double-throw switch 5. The connectors on the hinged levers of this switch, 6, 7, 8, and 9, are connected in pairs to the two ends of amplifying apparatus 10 in such a way that the current goes into the amplifying apparatus from connectors 8 and 9 and the amplified current coming from that apparatus connects to 6 and 7. The amplifying apparatus 10 is a standard apparatus well known to those acquainted with this art. It may be any kind of a multi-stage low or high frequency amplifier as warranted by the circumstances. For simplicity sake, the simplest and oldest multi-stage amplifier is shown in the illustration, i. e. the De Forest two-stage low frequency vacuum tube amplifier.

The two connecting points of switch 5, located next to the points connecting the patient, are connected across to points 11 and 12 of said switch, and from there the current goes to the electromagnetic recording apparatus. This apparatus is constructed on the principle of the Poulsen telegraphone. The connections from points 11 and 12 of the switch lead to two electromagnets 13 and 14 facing each other with a gap between them wide enough to pass thru the steel wire 15. That wire is guided across that point on one side by a stationary German silver sleeve 16, on the other side by a guide pulley 17. The wire drum 18, rotatably mounted in stationary bearings 19, 19 has such a width between the flanges 20, 20 as to accommodate in a single layer as much of wire 15 as is required to make one record. The two ends of the wire are fastened near the two flanges and while the wire reels off on one side it is reeled onto the drum on the other side or vice-versa. Between the reeling off and on the

wire passes over sheave 43 and thru 16, between the magnets and back over the guide pulley 17. The shaft of sheave 43 is rotatably mounted in bearings, 44, 44, which are movable in a direction at right angles to the shaft on drum 18. Tension is applied in this direction to these bearings, 44, 44, by tension springs 45, 45. The sheave 43 is of such diameter and set at such an angle that the bottom of its groove lines up with the one side of the face of the drum 18 on the bottom and with its other side on the top.

As driving means, there are mounted on the shaft of drum 18, an internal gear 21 and a smaller gear 22 inside of it. On the shaft of motor 23, there is a pinion gear 24 which meshes into gear 25 rotatably mounted on lever 26 which in turn is movable on the hub 27 of the motor. Shifting lever 26 in one direction will bring gear 25 into mesh with gear 22, and into mesh with internal gear 21 when shifted to the other side.

When shifted into mesh with internal gear 21, gear 25 will also mesh into gear 28. Gear 28 drives drum 30 which is rotatable in bearings 29, 29. 32 is a roll of chart paper rotatable and under tension on the shaft in stand 33. From there the chart paper 31 passes over the guide roller 34 onto drum 30. Pencil 35 resting on that chart paper is operatively suspended in and is operated by the inductive currents in solenoid 36.

Motor 23 is operated from a current source 37 and its speed may be regulated by a rheostat 38. In parallel with rheostat 38 and motor 23 is connected a relay 39 so that switch 40 will simultaneously start or stop the motor and the relay circuits. Brake-shoe 41 is held by tension spring 42 against the outer rim of the internal gear 21. Actuation of relay 38 will pull the brake-shoe away from the internal gear.

Our apparatus functions as follows:—

When four-pole double-throw switch 5 is thrown up the current impulses from the human body, connected at 3 and 4, pass thru the pair of switch levers on the left of 5, and from there to amplifier 10. After amplification, the amplified current goes to points 6 and 7 of the four-pole double-throw switch 5 and leaves that switch at points 11 and 12, exciting electromagnets 13 and 14.

If, now, lever 26 in the gearing is thrown downward so that the motor is connected thru pinion 24 by way of the idler gear 25 to the gear 22, the throwing in of switch 40 will, on one side, energize relay 39, pulling the brake-shoe 41 away from the rim of internal gear 21, start motor 23 and put drum 18 into rotation. This starts steel wire 15 to reel off on the right side of drum 18, reel onto the other side of that drum and in between it will pass the electromagnets, 13 and 14. According to the well known principles of the telegraphone, the amplified impulses, originating at points 3 and 4 from the patient, will set up a proportionate flux in magnets 13 and 14 and according to the variations of this flux a varying permanent magnetism will be set up in the steel wire 15 as it passes thru the electromagnets. When the desired record of currents has been taken on wire 15, switch 40 is opened, the motor and relay 39 are de-energized, brake-shoe 42 slides against the outer rim of the internal gear 21 and by its breaking power brings the drum 18 to an instantaneous stop.

Thus the record of fluctuations of the currents set up in the patient, is stored in the steel wire reeled up on the left side of drum 18. Now we throw switch 5 down. Currents originating in the electromagnets 13 and 14 will now enter switch 5 at 11 and 12, leave it at 8 and 9 and then enter amplifier 10. The amplified currents will enter switch 5 at 6 and 7 and from there pass thru solenoid 36. If we, therefore, put drum 18 into rotation in a direction opposed to the direction of rotation in which previously the current impulses were registered on wire 15, this wire, with its many small sections of varying permanent magnetism, in passing between the electromagnets 13 and 14 will set up a changing flux in the cores of the electromagnets 13 and 14 and thus induce a fluctuating current in the coils of these electromagnets. This fluctuating current, again passing thru the switch, excites solenoid 36. The field set up in the solenoid will operate pencil 35, movements of which will now be a direct function of the magnetic record on wire 15 as it passes between electromagnets 13 and 14.

If we pass the chart paper 31 below pencil 35 at a speed corelated to the speed at which wire 15 moves past the electromagnets, a chart of the original current impulses will be plotted on the chart paper. Parts 30, 31, 32, 33, 34, 35, and 36 therefore represent a graphic electric recording instrument.

The mechanical action operating the transfer of the magnetic record of wire 15 upon the chart 31, is as follows:—

Lever 26 is thrown upward so that the idler gear 25 meshes into the internal gear 21 and at the same time into gear 28. When motor 23 is started, the power transmitted by way of pinion 24 and idler 25 to the internal gear 21, will rotate the drum 18 in a direction opposed to the previous direction of rotation. The pitch diameter of internal gear 21 being several times larger than that of gear 22 to which previously the power was applied, the drum 18 will now rotate at an inversely proportionate speed, i. e. considerably slower. The gear 28 on drum 30 will rotate that drum at a speed

proportionate to the speed of drum 18. Regardless of the speed of motor 23 there will therefore be maintained a definite ratio of speed between drums 18 and 30. It may be advisable to vary the speed of the motor for the writing down of the record on the chart paper, the running speed of that chart paper being reduced so far as to allow the pencil to follow exactly the fluctuations of the flux set up in 13 and 14 without being impeded by its own momentum.

The first record on the wire 15 having been made at a fixed motor speed and at a fixed speed of drum 18, a fixed number of feet of wire 15 pass the electromagnet per second. As stated before, in writing down the record, the speeds of the chart paper and of the wire are proportionate. Therefore, the paper may be longitudinally divided into sections, representing time units, which allow the direct reading of the correct time intervals on the graph.

The demagnetization of the wire after the record has been written down on the chart is performed as it is done in the case of the telegraphone, i. e., the wire is passed over a permanent magnet 46 or between some electromagnets which are excited from a strong and uniform current source. It is understood that this process does not bring about a demagnetization in the strict sense of the word but rather it uniformly polarizes the wire.

We do not want to limit ourselves to the exact construction of the apparatus as shown in the drawings. As stated before, any kind of a suitable amplifier may be used. So, for instance, we obtain satisfactory results with a four-stage resistance-coupled vacuum tube amplifier.

In the process of recording the current impulses upon a steel wire, we do not want to limit ourselves to the apparatus shown but desire to make use of new developments in this art, since lately the telegraphone has been materially improved upon in foreign countries. This also applies to the driving and control mechanism on the magnetic recorder and to the graphic recording instrument.

To increase the simplicity and the flexibility of the handling of our apparatus, we may add some of the following parts; they have not been shown in the drawings to avoid unnecessary complication: the lever on switch 5 and lever 26 may be mechanically connected so that they operate together. The circuit and the drive will thus be reversed at the same time by one operation.

If a mechanical connection between these parts is not convenient, we may resort to electric interlocking. For instance, switch 5 may have an additional pole controlling relays which operate lever 26.

We also may add an automatic mechanism which automatically opens the motor circuit when wire 15 is nearly reeled off in either direction.

If the operator of the machine desires to observe the fluctuations of the current before and while the magnetic record is taken, a Braun tube may be inserted to bring about direct visibility of the curves.

Having thus described our invention we would like again to emphasize the principal advantage of its use. The record, taken at a high speed by completely electric and magnetic devices which are not subject to mechanical defects, is graphically recorded at a speed so much reduced as to offset all impediments of the writing mechanism. This also allows an analysis of the record and minute inspection of the important sections of it. Our process may be compared to the art of slow motion cinematography but is more flexible. Whereas in that art, the recording speed is limited by the power of the light and by a reciprocating mechanism, the only limitation for taking records in our apparatus is the speed at which the wire may safely pass the electromagnets.

It is evident that this appartus may be used for the observation of all kinds of fluctuating currents.

We claim:—

1. In a device for making a record by differently magnetizing a wire by passing it between two magnets, means for reversing the movement of the wire between said magnets, means for amplifying the current produced by the reverse movement of the wire between said magnets and means for graphically recording the record on the wire in the reverse sense.

2. In a device for making an accurate record of a pulsating weak current by differently magnetizing a wire by passing it between electromagnets, means for reversing the movement of said wire between said electromagnets, amplifying means for said pulsating weak current, means for switching said amplifying means to the current produced by the reverse movement of the wire between said electromagnets and means for graphically recording the record on the wire in a reverse sense.

3. In a device for making a record by differently magnetizing a wire by passing it at a fixed speed between two magnets, shift-gearing for reducing the speed of movement of the wire between said magnets, means for amplifying the current produced by the movement of the wire between said magnets at a reduced speed, and means for graphically recording the record on the wire at that reduced speed.

DR. ERICH SCHWARZKOPF.
GERHARD WODTKE, M. D.