

April 4, 1950

W. D. CANNON ET AL

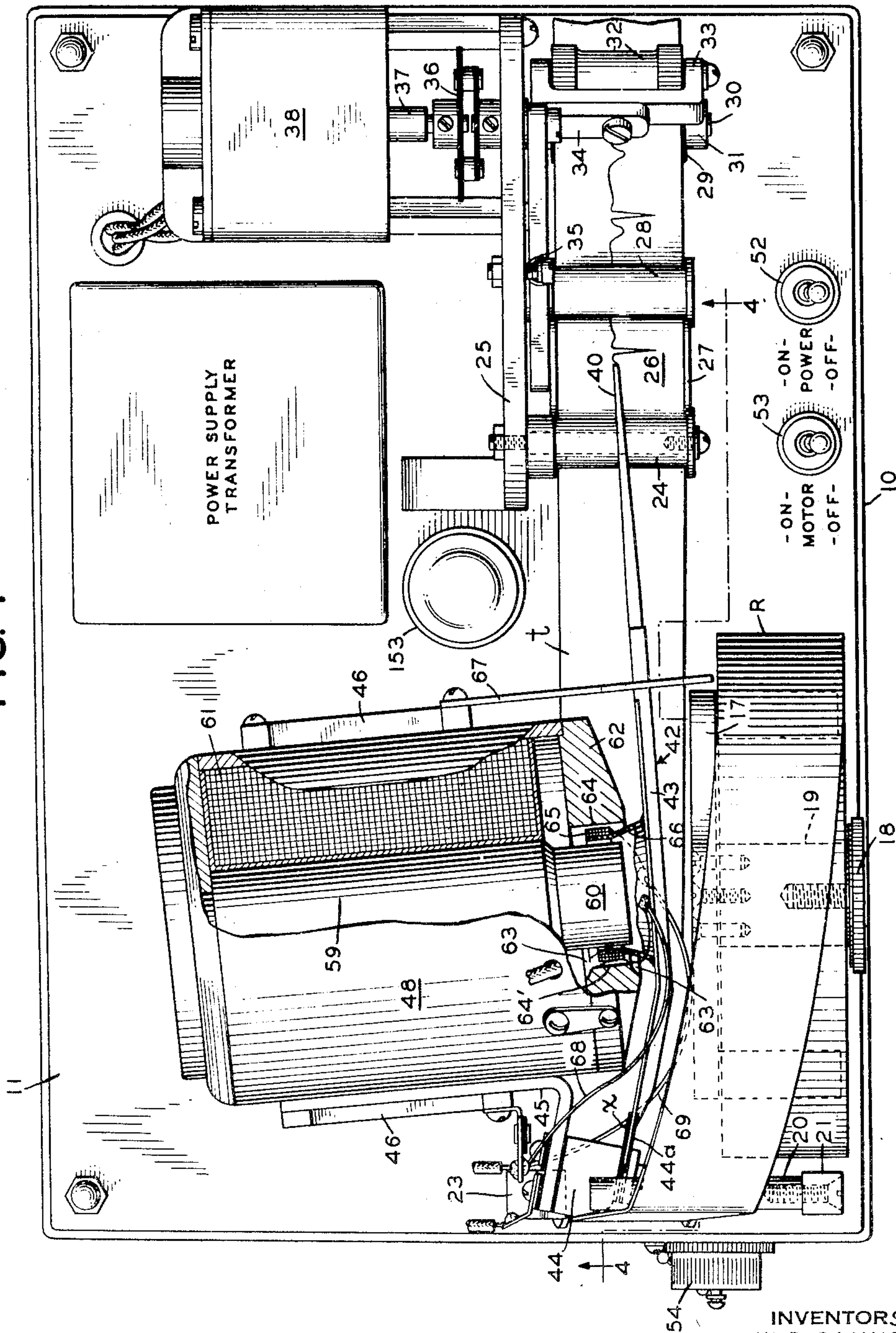
2,502,419

ELECTRICALLY ACTUATED RECORDING UNIT

Filed Feb. 3, 1945

4 Sheets-Sheet 1

FIG. 1



INVENTORS  
W. D. CANNON  
M. CANTOR  
BY *W. F. Pearson*  
ATTORNEY



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W. D. CANNON ET AL

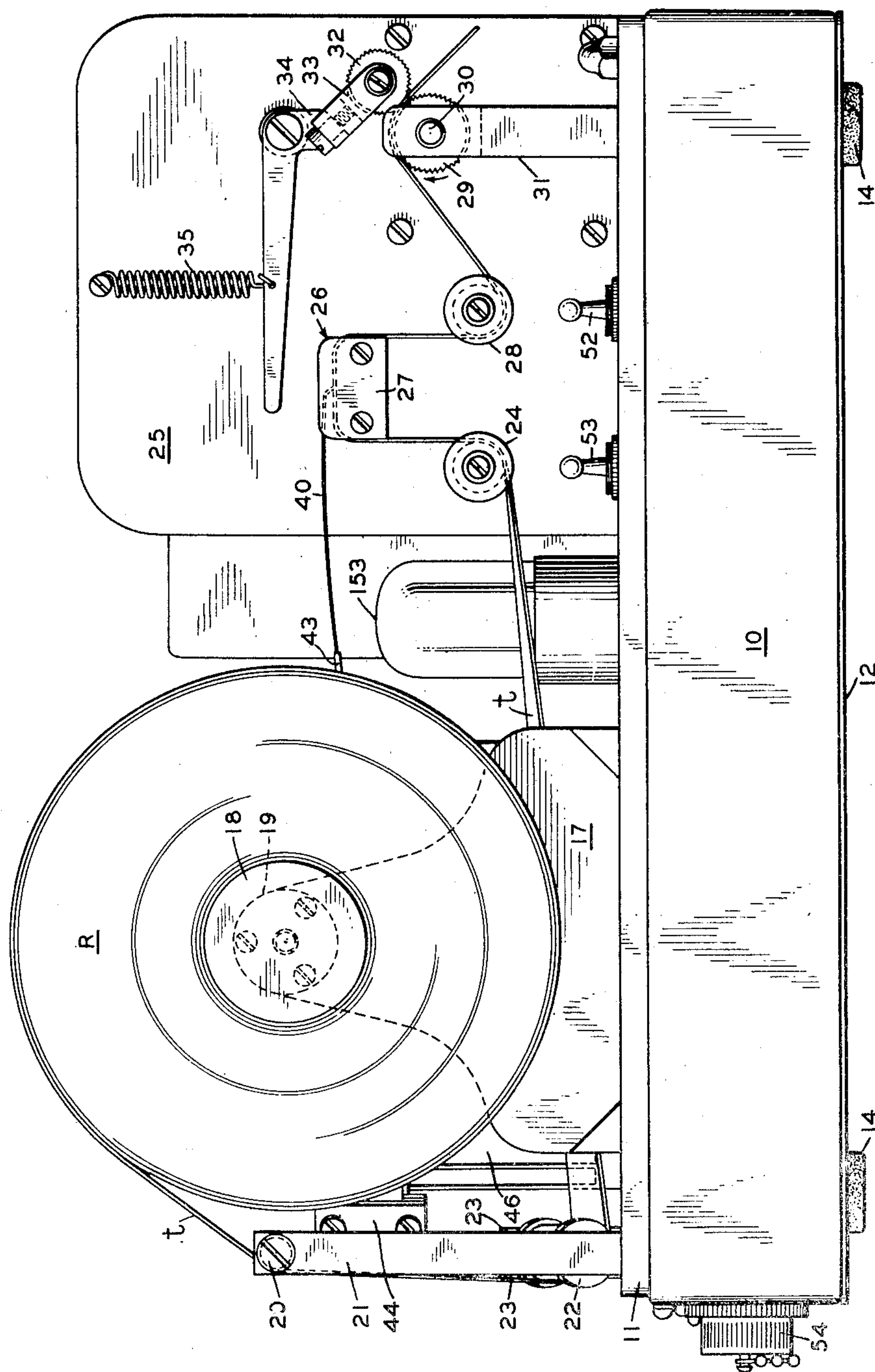
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ELECTRICALLY ACTUATED RECORDING UNIT

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4 Sheets-Sheet 2

FIG. 2



INVENTORS  
W. D. CANNON  
M. CANTOR  
BY *W. F. Preeson*  
ATTORNEY



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W. D. CANNON ET AL

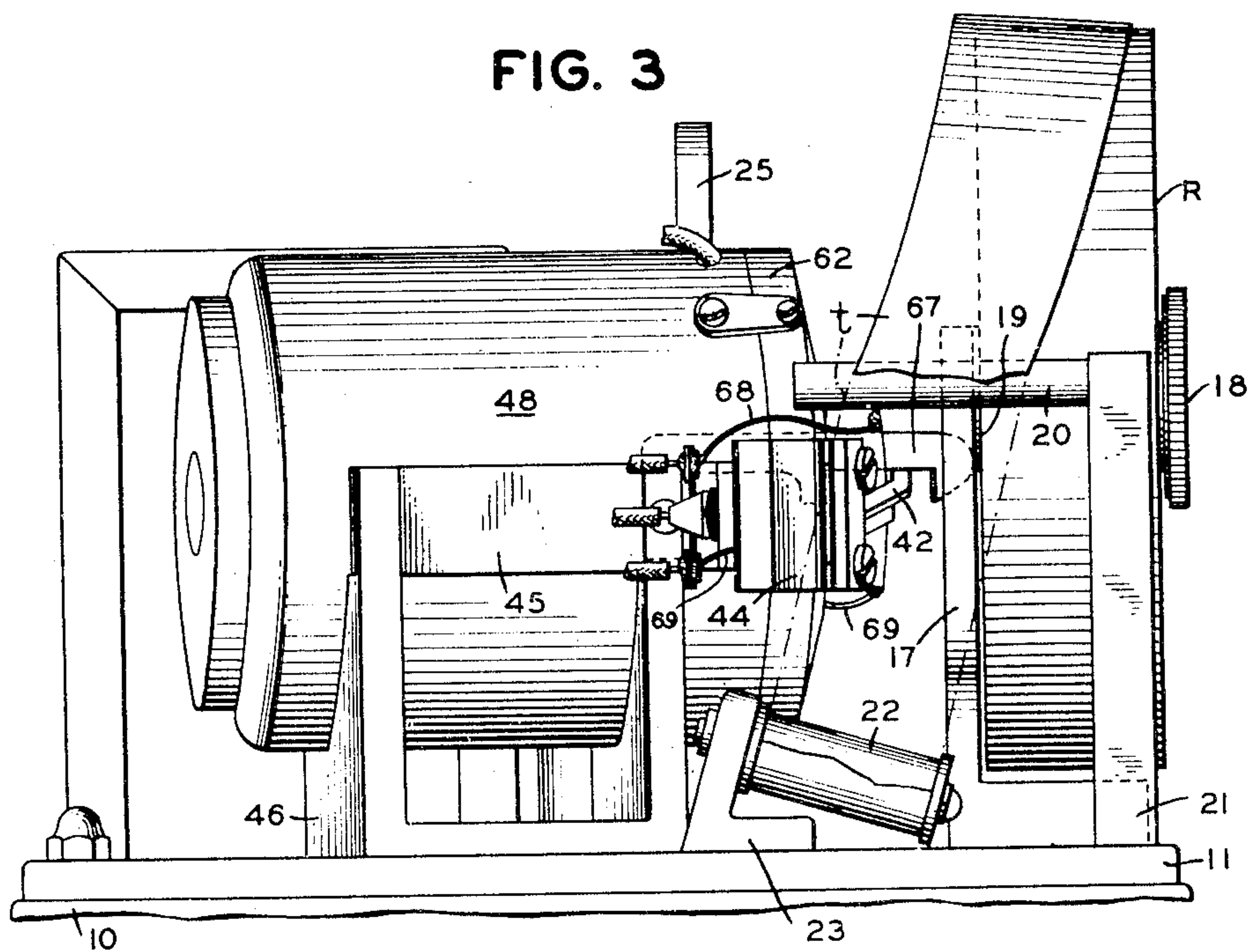
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## ELECTRICALLY ACTUATED RECORDING UNIT

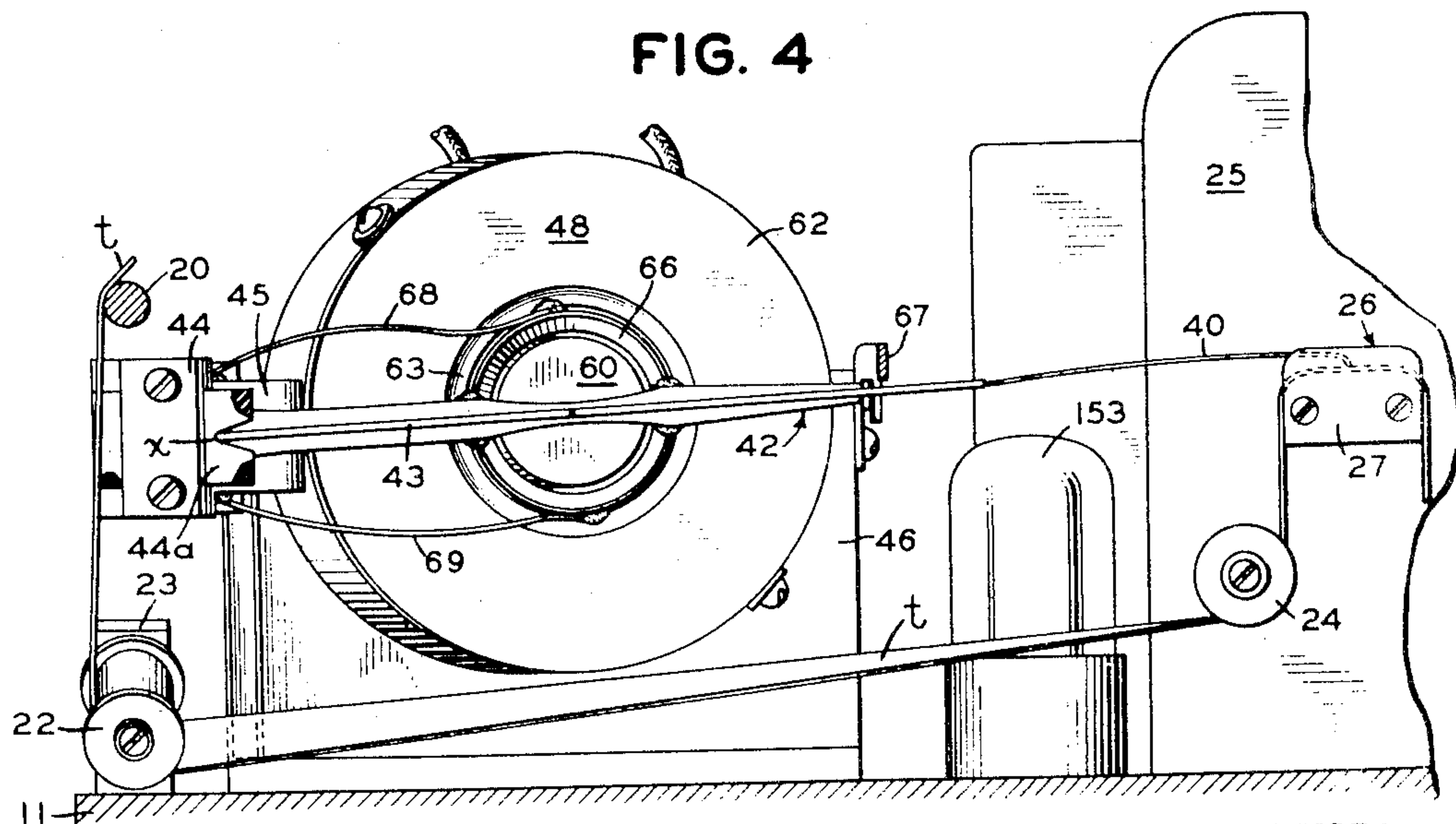
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FIG. 3



**FIG. 4**



INVENTORS  
W. D. CANNON  
M. CANTOR  
BY *W. F. Pearson*  
ATTORNEY



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W. D. CANNON ET AL

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FIG. 5

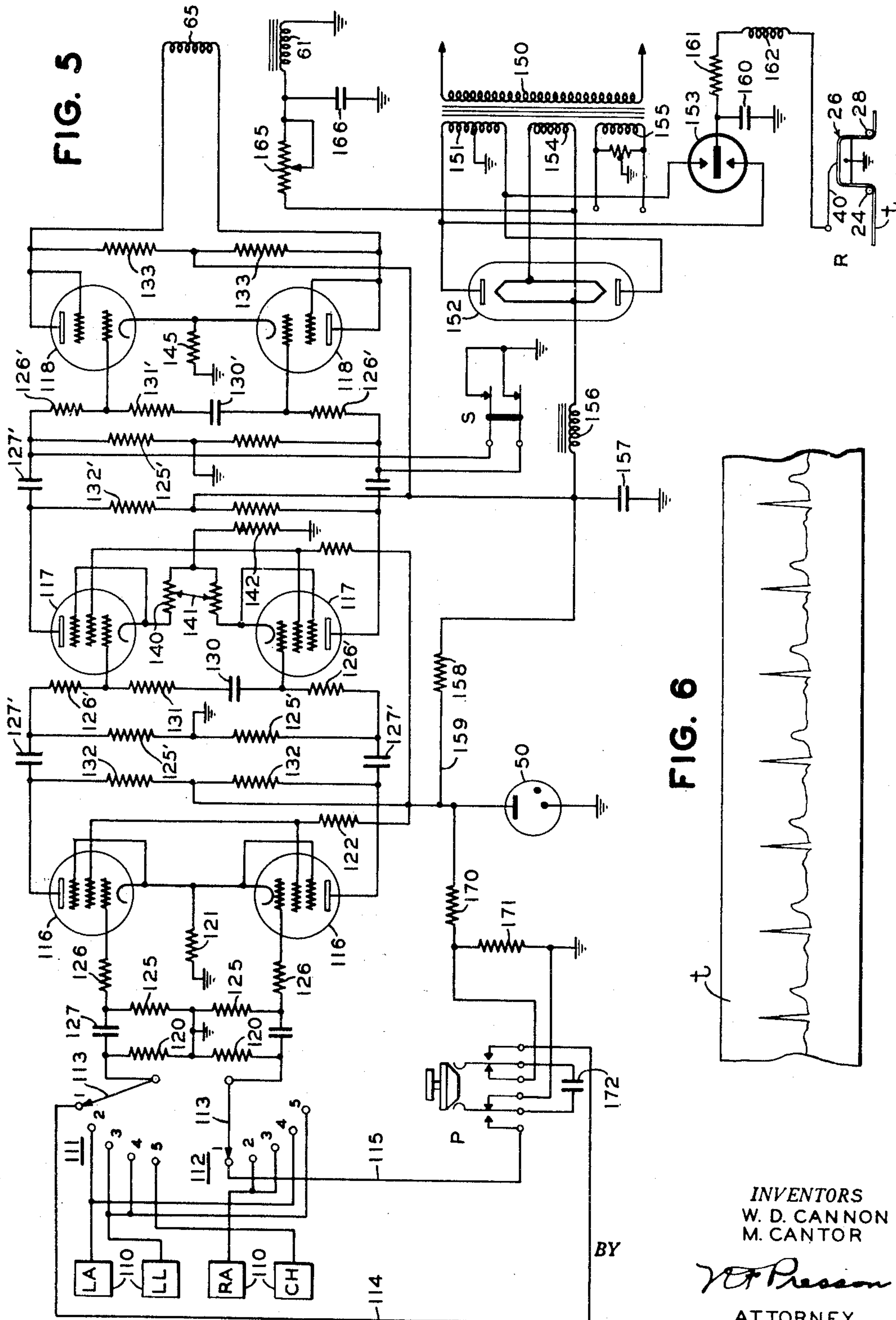
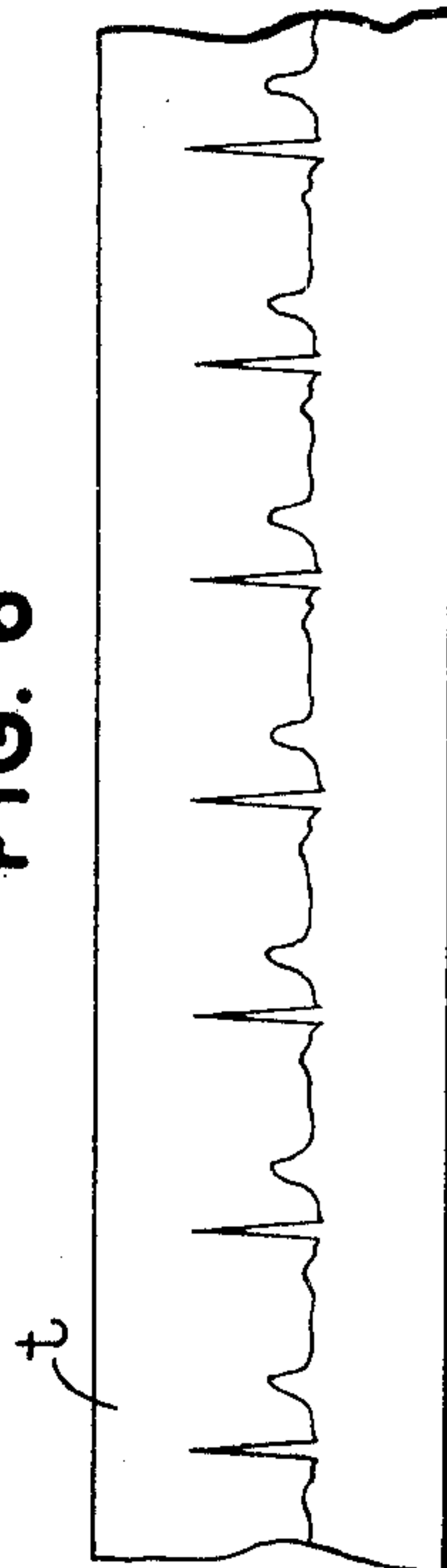


FIG. 6



INVENTORS  
W. D. CANNON  
M. CANTOR

BY *W. D. Cannon*  
ATTORNEY



## UNITED STATES PATENT OFFICE

2,502,419

## ELECTRICALLY ACTUATED RECORDING UNIT

William D. Cannon, Metuchen, N. J., and Michael Cantor, Brooklyn, N. Y., assignors to The Western Union Telegraph Company, New York, N. Y., a corporation of New York

Application February 3, 1945, Serial No. 576,078

11 Claims. (Cl. 346—74)

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This invention relates generally to an electrically actuated recording unit, and more particularly to a unit which enables extremely accurate distortionless recording on electrosensitive recording paper of variable electrical currents of small magnitude over a range of very low frequencies extending from approximately zero to a hundred and fifty cycles. While the device is suitable for the recording of small variable currents from any source, it has particular application in the medical field, for example, in electrocardiographs, encephalographs, and other similar devices for recording electrical reactions resulting from biologic processes.

Heretofore the most common type of such instruments, for example, the electrocardiograph, usually has comprised a sensitive string galvanometer arranged for projecting a beam of light onto moving photographic film. The galvanometer, however, is delicate, easily damaged, and is difficult to repair, and since the operating currents are very minute, the consequent hypersensitivity of the movement has in general precluded the use of recording methods other than photographic. Photographic recording also is objectionable because of limitations imposed upon the construction of the recorder, the imposition of the necessary developing process, and the time consumed therein.

The present invention involves a recording unit which, while extremely sensitive, is rugged and portable, does not depend upon the photographic process, and moreover is direct reading so that the record obtained may be observed during the recording operation. It is also desirable to employ an electrosensitive recording blank which requires no special treatment either before or after the recording operation, and which is unaffected by varying conditions of light, heat, humidity, and the like. One form of a dry electrosensitive recording paper which is suitable for the purposes of the instant invention is a paper such as disclosed in Patents Nos. 2,294,146, 2,294,147, and 2,251,742, although other known types of recording papers suitable for the purpose may be employed. Preferably the conducting paper disclosed in the aforesaid Patent No. 2,251,742 is used since the paper is light in color, is relatively inexpensive, and is adapted for making permanent fine line records at very high speeds from a properly designed and energized electrical stylus.

One of the objects of the invention is an electrical recording unit of the character described which has an electromagnetic moving coil ele-

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ment that is critically damped in a manner to avoid frequency distortion throughout the entire range of frequencies for which the unit is to be used.

Another object is a recorder unit in which the control of the moving coil motional impedance is effected by controlling the flux density of the field of the electromagnetic driving unit for the recording stylus.

A further object is to provide a lateral stylus movement which is linear with respect to the magnitude of the actuating current throughout the amplitude of travel of the stylus, and in which long uniform travel of the stylus is obtained.

Additional objects comprise the matching of the moving coil motional impedance with the output impedance of the associated driving amplifier; to provide a rugged flexible stylus of light construction with a constant current source for energizing the stylus; to align the central plane of the moving coil of the electromagnetic unit with respect to the pivotal or flexing point of the recording stylus arm; and to provide suitable means for quickly and easily calibrating the apparatus prior to a recording operation.

The foregoing and other objects and advantages of the invention will be apparent from the following detailed description, taken in connection with the accompanying drawings, in which:

Fig. 1 is a plan view of an electrocardiograph tape recorder unit embodying the principles of the invention;

Fig. 2 is a front view, in elevation, of the unit of Fig. 1;

Fig. 3 is a view in elevation of the left hand end of the unit as viewed in Fig. 2;

Fig. 4 is a sectional view, taken along the line 4—4 of Fig. 1;

Fig. 5 is a circuit diagram of the electrical system of the recording unit and associated amplifier; and

Fig. 6 shows a length of the electrosensitive tape having a graph recorded thereon by the recording unit of Figs. 1 to 5.

Referring particularly to Figs. 1 and 2 of the drawings, the unit is shown as comprising a hollow mounting base 10 on which is secured a plate 11 on which the various elements of the unit are mounted. The bottom of the housing 10 is closed by a plate 12, and to this plate are secured pads 14 of felt or other suitable material to prevent scratching of the desk or table on which the unit may be placed. On the plate 11 is mounted



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a bracket member 17 having a projecting core member 19 on which is rotatably mounted a roll R of electrosensitive recording tape *t*, such as the lead thiosulphate paper disclosed in the afore-said Patent No. 2,251,742. The roll of tape is slipped over the forward end of the core 19, and is prevented from coming off by a knurled screw 18, there being sufficient clearance between the sides of the roll R and the bracket member 17 and knurled knob 18 to enable the roll of tape to revolve freely about the core. From the roll R the tape *t* passes around a tape guide member 20 supported by an upstanding bracket 21. From the tape guide member 20, the tape passes around a tape guide roller 22 mounted on a member 23 so that the roller is askew with respect to the guide member 20, thereby to deflect the tape, as seen more clearly in Fig. 3, so that the center of the tape will be in proper alignment with the recording apparatus, as hereinafter described.

From the guide roller 22 the tape is passed around a roller 24 which is rotatably mounted on a plate or bracket member 25, Figs. 1 and 2, and thence over a platen 26, the platen having sides 27 secured thereto to maintain the tape in proper position during the recording operation. From the platen 26 the tape passes around the guide roller 28 and thence between knurled feed rollers 29 and 32, the knurled portions of these rollers extending only a comparatively small distance across the edges of the tape so that any indentations formed in the tape by the rollers will not affect the readability of the graph recorded thereon. The feed roller 29 is mounted on a shaft 30 which, at its outer end, is supported by bracket member 31. The pressure roller 32 is carried by a bracket member 33 which is secured to a bell crank 34 that is pivotally mounted on the plate or bracket 25. A helical spring 35 provides the proper resilient tension for the pressure roller 32. The feed roller 29 is driven, through a flexible coupling 36, Fig. 1, from the shaft 37 of a constant speed tape pulling motor 38, which motor may be either the alternating current or direct current type, and energized from a local source of commercial power.

Bearing on the tape *t* is a flexible stylus arm or nib 40 of the lightest possible construction. Preferably, it is composed of a strip of light flexible metal of nickel iron, nickel steel or the like, and has its end turned down and sharpened to provide a stylus point of small diameter where it contacts the recording tape *t*; a diameter of the order of eight thousandths of an inch is satisfactory for fine recording. While the stylus wear has been found to be quite small, nevertheless it is desired to have it replaceable, and the stylus is frictionally inserted within a light weight stylus arm 42, preferably composed of aluminum, the arm having a U-shaped cross section for the pivoted end of the arm, in order to provide the desired rigidity thereto without adding appreciable weight to the arm, the rib portion 43, seen more clearly in Fig. 4, serving to stiffen the arm 42. The stylus arm is secured to a mounting block 44, and is insulated therefrom as shown in Figs. 1 and 3 of the drawings, the mounting block 44 being secured to a bracket 45 which, in turn, is carried by a cradle member 46 that supports the electromagnetic driving unit 48.

The electromagnetic driving unit 48 comprises a cylindrical core 59 composed of material of high magnetic permeability, the core having a forward end 60 thereof which forms a large cy-

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lindrical pole piece for the unit. Surrounding the core 59 is a field winding 61 having a large number of turns. Surrounding the cylindrical pole piece 60 is a cylindrical moving coil 65, having a large number of turns of fine wire, secured to and carried by a circular light weight fiber member 66, the outer end of which is secured to the stylus arm 42 for driving the stylus 40. An intense magnetic field is produced across the air gap by the field winding 61, the magnetic circuit including the outer shell of the unit and an annular ring 62. The operating air gap must be of sufficient width to accommodate the movable coil 65, and must be of substantial length so that the coil 65 at the extremes of its movement will still encounter a magnetic field of uniform strength. To effect this the annular pole piece 65 is formed or cut away at 63 to give a reduced length 64' of air gap on the pivot side of the stylus member 42, so that when the annular coil is actuated to either extreme position such that it is flush with the edge 64, it will also be flush with the edge 64'. The arrangement making more efficient use of the total available flux. This means that the total amount of flux available at the longer edge 64 is somewhat greater than that at the opposite shorter edge 64', and thus makes it possible to increase the damping effect and enable the use of a stronger spring tension with the stylus driving arm 42. It will be seen from Fig. 4 that the rib 43 of the stylus terminates at a point *x*, and that the insulating plate 44a is grooved at this point, so that the stylus arm pivots or flexes at the point *x*. As seen in Fig. 1, this point lies in an imaginary plane that is perpendicular to the longitudinal axis of the coil 65 and which intersects the coil 65 midway between the ends thereof, so that maximum recording movement of the coil may occur before it strikes either of the pole piece edges 64 or 64'. Moreover, the fixed portion of the stylus member 42 is so mounted that the point *x*, Figs. 1 and 4, about which the stylus flexes, and the median position of the free end of the stylus lie in an imaginary plane that is normal to the surface of the recording strip and parallel to an edge thereof at the recording position, so that the end of the stylus 40 in its travel will not introduce appreciable distortion in the recorded graph. Preferably, this plane coincides with the center of the tape *t*. A stylus stop arm 67, Figs. 1, 3 and 4, limits the maximum extent of movement of the stylus in either direction of its travel.

Since the weight of the moving coil comprises a limitation upon the upper frequency to which it will respond, light weight is a paramount consideration. At the same time the coil must be energized by amplifier power tubes whose output impedance is normally of substantial value and preferably without the interposition of transformers. A proper matching of the coil and amplifier impedance necessitates a large number of turns on the coil. In the specific embodiment illustrated this has been accomplished through the winding of approximately 2500 turns of No. 42 enamelled copper wire into a cross section of approximately  $\frac{1}{8}$ " by  $\frac{1}{4}$ ". Aluminum or other wire may also be used for this purpose. The wire is wound upon the circular form 66 of thin fiber or other suitable mechanically strong insulating material.

An amplifier, preferably enclosed within the housing 10, is associated with the recorder for the purpose of amplifying the minute variable



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currents generated by the biologic processes within the body of the subject to a level sufficient to drive the recording unit described. Obviously the amplifier should leave no impression of its own characteristics upon these currents. The amplifier should not pass direct current but should possess a constant gain for frequencies of less than one cycle up to the highest frequency of interest. Also it should be substantially immune to interfering electrical or magnetic fields or power supply noise, and should not be subject to blocking when accidentally subjected to excessive input voltages. Such an amplifier is disclosed in Fig. 5 of the drawings, the circuit also including a unique calibration control.

Referring to Fig. 5 there are disclosed at the upper left-hand portion of the figure a plurality of electrodes 110 for application to various portions of the body of the subject such as the left arm, left leg, right arm and chest in the case of a cardiograph, those electrodes being designated by the letters LA, LL, RA and CH to indicate the various portions of the body of the subject to which they may be applied. The electrodes are connected to banks of contacts 111 and 112, and more specifically to arcuate contacts 2 to 5 of the banks. Contacts 1 of the banks are connected by means of conductors 114 and 115 to a calibrating circuit hereinafter described. The amplifier disclosed is a three-stage, push-pull, resistance-coupled amplifier, the input of which is connected, by a double-contact switch comprising switch blades 113, to the source of potentials to be measured, that is, to pairs of contacts 2 to 5 of the banks 111 and 112. As hereinafter appears, the symmetrical structure of the amplifiers imparts substantial immunity to interfering fields, stray currents and power supply noise which would tend to affect both sides of the amplifier with respect to ground. This cancellation of interference is rendered more effective through the use of the symmetrical, relatively low value resistances 120 across its input circuit, and by the use of the large common resistances 121 and 122 respectively in the connections to the cathodes and screen grids of the first stage. These resistances cause degenerative amplification of the longitudinal currents but do not affect the desired series currents.

The first and second stages of the amplifier comprise pairs of tubes 116 and 117, and the third or power stage of the amplifier comprises a pair of tubes 118, all of these tubes being connected in push-pull relation. Tubes 116 preferably are the type known as No. 6J7; tubes 117 are of the type known as No. 6SJ7; and tubes 118 are of the type known as No. 6Y6; other types of tubes suitable for the purpose may, of course, be employed. For the sake of simplicity, the conventional filaments or heater elements associated with the indirect heated cathodes of the tubes are omitted in the drawing.

In amplifiers of the type illustrated the inter-stage coupling condensers tend to discriminate against lower frequencies, which effect is compensated for by the use of simple resistance-capacity networks connected in shunt which tend to discriminate against the higher frequencies. In such sensitive amplifiers, when potentials of appreciable value are inadvertently impressed upon the input circuit, substantial voltages are impressed upon the grids of the amplifier tubes where they are isolated by the coupling condensers until a sufficient time has elapsed for the charge to leak off through the grid leaks.

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This action is substantially eliminated by inserted large size resistances 126 and 126' in series with the grids of the tubes, in conjunction with the proper choice of grid leak resistances 125 and 125'. The value of each of the resistances 126 and 126' may, for example, be of the order of 200,000 ohms, while the values of the grid leak resistances 125 and 125' will be of the order of one megohm each. These values of the resistances 126 and 126' keep the tube impedance high even when the grid is positive with respect to the cathode, and prevents the condensers 127 and 127' from charging up at this time. In consequence, accidental large voltages which would initially drive the stylus beyond the limits of the recording tape are quickly dissipated so that the stylus immediately returns to the center of the tape to resume accurate and normal recording of the impressed bioelectric potentials.

The size of the coupling condensers 127 and 127' relative to the resistances 125 and 125' is such that the condensers will pass the lowest frequency involved in cardiograph potentials without appreciable distortion. To further improve the amplifier in regard to low frequency response, condensers 130 and 130' and resistances 131 and 131' are inserted across the two grid circuits of the second and third stages.

The plate resistances 132 and 132' in the first and second stages may be of the order of 300,000 ohms; the screen grid resistance 122 of the first stage may be of the order of 400,000 ohms, and the corresponding grid resistance of the second stage may be of the order of one-half megohm. The plate resistances 133 are of lower value because they are in the power stage of the amplifier; a suitable value of these resistances is of the order of 1500 ohms each.

The second stage gain control is obtained by controlling the degenerative feedback without changing the bias on the tubes, and this prevents violent swing of the stylus when a change in gain is made. Resistances 140 with a slider 141 are provided for this purpose, which resistances are connected to ground through resistance 142. Shifting the slider changes the amount of gain, with the maximum gain being obtained when the slider is moved to the left as viewed in the figure. The values of the resistances are proportioned to give the desired amount of control; in the embodiment disclosed each of the resistances 140 and 142 may have a value of the order of 500 ohms. Resistances 121 and 145 are provided in the first and third stages, respectively, to provide suitable cathode bias. The output of the amplifier from the terminal resistances 133 is connected directly to the movable coil 65 of the electromagnetic unit.

Power for energizing the amplifier is supplied from a source of alternating current in transformer winding 150. Associated with this winding are three secondary windings 151, 154 and 155. Winding 151 is connected to the plate circuit of a full wave rectifier 152, the filaments or cathodes of which are energized from the winding 154. The winding 155 supplies current for the filaments or heaters of the amplifier tubes. From the full wave rectifier 152 current is supplied to the plate and screen grid circuits of the amplifier tubes, through a smoothing circuit comprising an inductance 156 and grounded condenser 157. A current limiting resistance 158 is inserted in conductor 115 which supplies current to the plate and screen grid circuits of the first amplifier stage and the screen grid circuits of



the second stage. Connected to conductor 115 is a gas-filled voltage regulator tube 50 which stabilizes the plate and screen grid voltages. If, for example, the voltage in the power supply lead 159 should increase, the increased current passes through the tube 50 without causing any substantial increase or change in voltage drop across the tube.

It is highly desirable to insure uniformity of marking on the sensitized recording paper tape or strip as the stylus is actuated at varying rates of speed depending upon the value of the recorded signals. During oscillation or lateral movement of the stylus, it is apparent that the marking time is much less than when straight-away or relative longitudinal movement alone prevails between the stylus and tape. Fig. 6 illustrates a cardiogram in which uniformity of marking under these conditions of varying contact time is accomplished through the use of a constant current feed to the stylus, and Fig. 5 illustrates how this effect is secured. The stylus energizing current is obtained from transformer winding 151, through a full wave rectifier 153. The direct current output circuit of the rectifier has a grounded filter condenser 160 connected thereto, and the circuit to the stylus 40 has connected in series therewith a resistance 161 and an inductance 162. In the circuit illustrated, the resistance may be of the order of one-tenth of a megohm, and the inductance may have a value of the order of thirty henries or more. A potential of approximately three hundred volts is employed, and under these conditions a current of approximately three milliamperes flows continuously in the stylus circuit, irrespective of the movement of the stylus or the varying resistance of the recording paper, these values obtaining when a recording paper of the type disclosed and claimed in the aforesaid Patent 2,251,742 is employed. If for any reason the tape  $t$  moves very slowly or stops, the impressed voltage is not sufficient to burn or otherwise impair or disfigure the graph or other record, and the record will be represented by a line of uniform density and width.

Current for energizing the field winding 61 of the electromagnetic unit is obtained from the rectifier 152, the circuit including a variable resistance 165, for controlling within close limits the current flowing in the field coil and thus maintain a flux density of predetermined value in the operating air gap to control the moving coil motional impedance and critically dampen the moving coil and stylus to avoid frequency distortion throughout the range of low frequencies applied to the recorder. Preferably the field energizing circuit has a grounded filter condenser 166 connected thereto. Due to the fact that the moving coil motional impedance substantially matches the output impedance of the amplifier, the output circuit of the amplifier may be connected directly to the moving coil 65, as illustrated in Fig. 5, without the interposition of a transformer.

Prior to each recording operation it is desirable to calibrate the amplifier and recording circuit. In accordance with the present invention there is provided a simple calibrating arrangement which requires no batteries to furnish a standard potential, and which is permanently accurate. The voltage across the gas tube 50, connected between the plate supply and ground, is utilized as a source of standard potential. A portion of this voltage is obtained by means of a potentiometer 170, 171, and is used to charge

a condenser 172 which provides a source of unit input calibrating potential whenever conductors 114 and 115 are connected to the input of the amplifier by means of the switch blades or connectors 113, and the calibrating push button P is depressed, thereby connecting the charged condenser across the input of the amplifier. The gain control 140, 141 in the intermediate stage of the amplifier is then adjusted until the desired amplitude of the lateral movement of the stylus corresponding to the unit input potential is obtained. This relationship may, for example, be of the order of one centimeter lateral deflection for one millivolt of applied voltage. When the peak value of the wave form is not equal to a standard or predetermined desired height, the gain control is adjusted until the desired peak values are obtained. The precalibrating voltage applied by the resistances or potentiometer 170, 171 to the condenser 172 cause the condenser to produce a wave form of exponential decaying, thus producing a peak of extremely short duration for calibrating purposes. An on-off recording switch S is provided for the recorder; when the switch is in its closed position shown in Fig. 5, it will be seen that it short-circuits the grid circuits of the last amplifier stage, and that when the switch is moved to its open position, the unit is in condition for recording.

Reference has heretofore been made to the necessity for matching the impedance of the output stage of the amplifier to that of the moving coil of the recording unit, this being of particular importance in connection with the maintenance of proper frequency response. In the absence of damping measures, the moving element of the recording unit will tend to respond more freely at its natural period which normally lies at a frequency near the upper limit of its useful range, which effect in itself is productive of some distortion. At the same time the moving coil produces a back E. M. F. as a consequence of its motion in the magnetic field. This voltage is applied across the amplifier output circuit which consequently acts as a damping impedance. If the amplifier output tubes are of high impedance, the damping is consequently low and the response of the unit to transients will be impaired. On the other hand, if the tube impedance is low, the coil movement will be over-damped and sluggish.

Considerable advantage accrues if an approximate match of the impedance of the amplifier output stage with the motional impedance of the moving coil is brought about through control of the design of the two entities. The motional impedance of the coil 65 corresponds to the back E. M. F. generated by the coil and is controlled in part by the strength of the permanent field in the air gap. It is possible, therefore, to adjust the motional impedance by current control means in the exciting field circuit, and this adjustment is made initially and maintained by means of the resistance 165 hereinbefore referred to, so that efficient and stable operation of the combined amplifier and recording unit is achieved.

The recording device has been described with particular reference to medical applications. The device, however, is of general applicability to any purpose which requires the recording of sensitive current manifestations, or where the currents are of sufficient magnitude the amplifier may be omitted and the recorder unit used alone. Illustrative applications are as a recorder of submarine cable signals, as an oscillograph, or for the recording of atmospheric or other disturbances.



While the invention has been described in connection with a preferred embodiment thereof, it will be understood that various modifications and changes may be made without departing from the spirit and scope of the invention, and the invention therefore is not intended to be limited except as indicated by the scope of the appended claims.

What we claim is:

1. Apparatus for recording variable electrical currents of small magnitude and low frequency on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a fixed portion, a flexible portion and a free end portion for applying marking current to the recording strip, means for applying a source of constant current to the stylus, an electromagnetic unit for driving the stylus, said unit comprising a magnetic core having a circular pole piece, an opposed pole piece surrounding said core and spaced therefrom to form an operating air gap, an energizing field winding surrounding the core and an annular movable coil disposed in the air gap between the pole pieces, support means secured to said stylus intermediate the flexible and free end portions thereof for carrying said movable coil, means comprising a source of constant current for exciting said field winding, and means for applying said variable electrical currents to said movable coil for actuating the stylus.

2. Apparatus for recording variable electrical currents of small magnitude and low frequency on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a fixed portion, a flexible portion and a free end portion for applying marking current to the recording strip, means for applying a source of constant current to the stylus, an electromagnetic unit for driving the stylus, said unit comprising a magnetic core having a pole piece, an opposed pole piece surrounding said core and spaced therefrom to form an operating air gap, an energizing field winding for the core and a movable coil disposed in the air gap between the pole pieces, support means secured to said stylus for carrying said movable coil, means comprising a source of constant current for exciting said field winding, means for applying said variable electrical currents to said movable coil for actuating the stylus, the number of ampere turns of said field winding and the number of turns of said movable coil being such as to generate a back E. M. F. of a value in said movable coil as to critically dampen the moving coil and stylus to avoid frequency distortion throughout the range of low frequencies for which the recorder is adapted.

3. Apparatus for recording variable electrical currents of small magnitude and low frequency on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a fixed portion, a flexible portion and a free end portion for applying marking current to the recording strip, means for applying a source of constant current to the stylus, an electromagnetic unit for driving the stylus, said unit comprising a magnetic core having a pole piece, an opposed pole piece surrounding said core and spaced therefrom to form an operating air gap, an energizing field winding for the core and a movable coil disposed in the air gap between the pole pieces, support means secured to said stylus for carrying said movable coil, means comprising a source of constant current for exciting said field winding, means including an amplifier whose output circuit is connected directly to said movable coil for applying said variable electrical currents to the

movable coil for actuating the stylus, the number of turns of said coil being such as to cause the moving coil motional impedance substantially to match the output impedance of said amplifier to avoid frequency distortion throughout the range of low frequencies for which the recorder is adapted.

4. Apparatus for recording variable electrical currents on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a fixed portion, a flexible portion and a free end portion for applying marking current to the recording strip, means for applying a source of marking current to the stylus, an electromagnetic unit for driving the stylus, said unit comprising a magnetic core having a pole piece, an opposed pole piece adjacent to said core and spaced therefrom to form an operating air gap, an energizing field winding for the core and a cylindrical movable coil disposed in the air gap between the pole pieces, support means secured to said stylus intermediate the ends thereof for carrying said movable coil, means comprising a source of current for exciting said field winding, means for applying said variable electrical currents to said movable coil for actuating the stylus, and means for supporting the fixed portion of the stylus in such position that the flexure point of the stylus substantially lies in an imaginary plane that is perpendicular to the longitudinal axis of said cylindrical coil and which intersects said coil midway between the ends thereof.

5. Apparatus for recording variable electrical currents on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a fixed portion, a flexible portion and a free end portion for applying marking current to the recording strip, means for advancing said strip longitudinally along the stylus during a recording operation, means for applying a source of marking current to the stylus, an electromagnetic unit for driving the stylus, said unit comprising a magnetic core having a pole piece, an opposed pole piece adjacent to said core and spaced therefrom to form an operating air gap, an energizing field winding for the core and a movable coil disposed in the air gap between the pole pieces, support means secured to said stylus intermediate the flexible and free end thereof for carrying said movable coil, means comprising a source of current for exciting said field winding, means for applying said variable electrical currents to said movable coil for actuating the stylus, and means for supporting the fixed portion of the stylus in such position that the flexure point of the stylus and the median position of the free end thereof substantially lie in an imaginary plane that is normal to the surface of the recording strip and parallel to an edge thereof at the recording position.

6. Apparatus for recording variable electrical currents on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a fixed portion, a flexible portion and a free end portion for applying marking current to the recording strip, means for advancing said strip longitudinally along the stylus during a recording operation, means for applying a source of marking current to the stylus, an electromagnetic unit for driving the stylus, said unit comprising a magnetic core having a pole piece, an opposed pole piece adjacent to the first pole piece and spaced therefrom to form an operating air gap, an energizing field winding for the core and a cylindrical movable coil disposed in the air gap between



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the pole pieces, support means secured to said stylus intermediate the flexible and free end portions thereof for carrying said movable coil, means comprising a source of current for exciting said field winding, means for applying said variable electrical currents to said movable coil for actuating the stylus, and means for supporting the fixed portion of the stylus in such position that the flexure point of the stylus substantially lies in an imaginary plane that is perpendicular to the longitudinal axis of said cylindrical coil and which intersects said coil midway between the ends thereof, and said flexure point and the median position of the free end of the stylus substantially lie in an imaginary plane that is normal to the surface of the recording strip and parallel to an edge thereof at the recording position.

7. Apparatus for recording variable electrical currents on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a pivotal portion and a free end portion for applying marking current to the recording strip, means for applying a source of marking current to the stylus, an electromagnetic unit for driving the stylus, said unit comprising a magnetic core having a circular pole piece, an opposed annular pole piece having an inner edge thereof surrounding said core and spaced therefrom to form an operating air gap, an energizing field winding for the core and an annular movable coil disposed in the air gap between the pole pieces, support means secured to said stylus for carrying said movable coil, means comprising a source of current for exciting said field winding, means for applying said variable electrical currents to said movable coil for actuating the stylus, said annular pole piece having its said inner edge formed to provide a shorter length on the side closest to the pivotal portion of the stylus and a longer length on the side farthest from said pivotal portion of the stylus, thereby to increase the total flux effective for actuating said movable coil throughout the extent of its movement.

8. Apparatus for recording variable electrical currents on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a pivotal portion and a free end portion for applying marking current to the recording strip, means for applying a source of marking current to the stylus, an electromagnetic unit for driving the stylus, said unit comprising a magnetic core having a circular pole piece, an opposed annular pole piece having an inner circular edge surrounding said core and spaced therefrom to form an operating air gap, an energizing field winding for the core and an annular movable coil disposed in the air gap between the pole pieces, support means secured to said stylus for carrying said movable coil, means comprising a source of current for exciting said field winding, means for applying said variable electrical currents to said movable coil for actuating the stylus, said annular pole piece having its said inner circular edge formed to provide a shorter length on the side closest to the pivotal portion of the stylus, said edge progressively increasing in length from said closest side to the side farthest from said pivotal portion of the stylus, thereby to increase the total flux effective for actuating said movable coil throughout the extent of its movement.

9. Apparatus for recording variable electrical currents of small magnitude and low frequency on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a pivotal portion and a free end portion for ap-

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plying marking current to the recording strip, a circuit for applying a source of constant current to the stylus, an impedance in said circuit for limiting the current applied to the stylus and an inductance in the circuit to maintain a constant value of stylus current, an electromagnetic unit for driving the stylus, said unit comprising a magnetic core having a circular pole piece, an opposed pole piece surrounding said core and spaced therefrom to form an operating air gap, an energizing field winding surrounding the core and an annular movable coil disposed in the air gap between the pole pieces, support means secured to said stylus intermediate the flexible and free end portions thereof for carrying said movable coil, a circuit for supplying constant current for exciting said field winding, an impedance in said field circuit for regulating the current flowing therein, and means for applying said variable electrical currents to said movable coil for actuating the stylus.

10. Apparatus for recording variable electrical currents on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a pivotal portion and a free end portion for applying marking current to the recording strip, an electromagnetic unit for driving the stylus, said unit comprising opposed pole pieces spaced to form an operating air gap, and a movable coil disposed in the air gap between the pole pieces, support means secured to said stylus for carrying said movable coil, means including a thermionic amplifier whose output circuit is connected to said movable coil for applying said variable electrical currents to the movable coil for actuating the stylus, gain control means in the amplifier circuit, a power supply circuit for said amplifier connected to a source of rectified alternating current, calibrating means comprising a gas-filled voltage regulator tube connected to said power supply circuit to provide a source of standard potential, means including a manually operable switch for driving a predetermined calibrating potential from said source of standard potential and applying the calibrating potential to the input circuit of the amplifier, and means for manually adjusting the gain control until a desired deflection of said recording stylus corresponding to the unit input potential is obtained.

11. Apparatus for recording variable electrical currents on an electrosensitive recording strip, comprising an electrical stylus of low inertia having a pivotal portion and a free end portion for applying marking current to the recording strip, an electromagnetic unit for driving the stylus, said unit comprising opposed pole pieces spaced to form an operating air gap, and a movable coil disposed in the air gap between the pole pieces, support means secured to said stylus for carrying said movable coil, means including a thermionic amplifier whose output circuit is connected to said movable coil for applying said variable electrical currents to the movable coil for actuating the stylus, gain control means in the amplifier circuit, a power supply circuit for said amplifier connected to a source of rectified alternating current, calibrating means comprising a gas-filled voltage regulator tube connected to said power supply circuit to provide a source of standard potential, a condenser and means including contacts of a manually operable switch for charging said condenser from said source of standard potential, means including other contacts of said switch for connecting momentarily the charged



condenser to the input circuit of the amplifier, and means for manually adjusting the gain control until a desired deflection of said recording stylus corresponding to the unit input potential is obtained.

WILLIAM D. CANNON.  
MICHAEL CANTOR.

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