March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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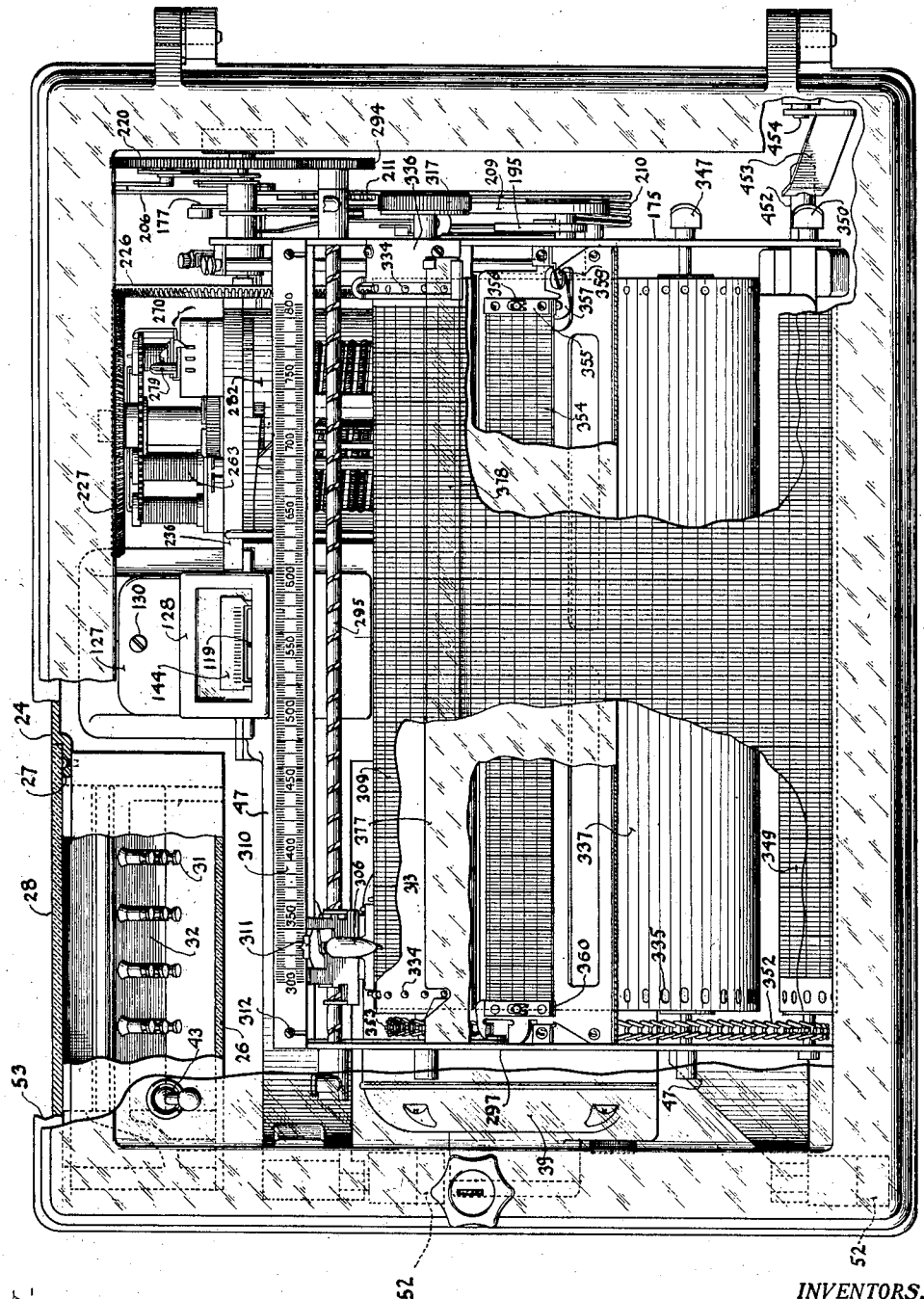


FIG. 1.

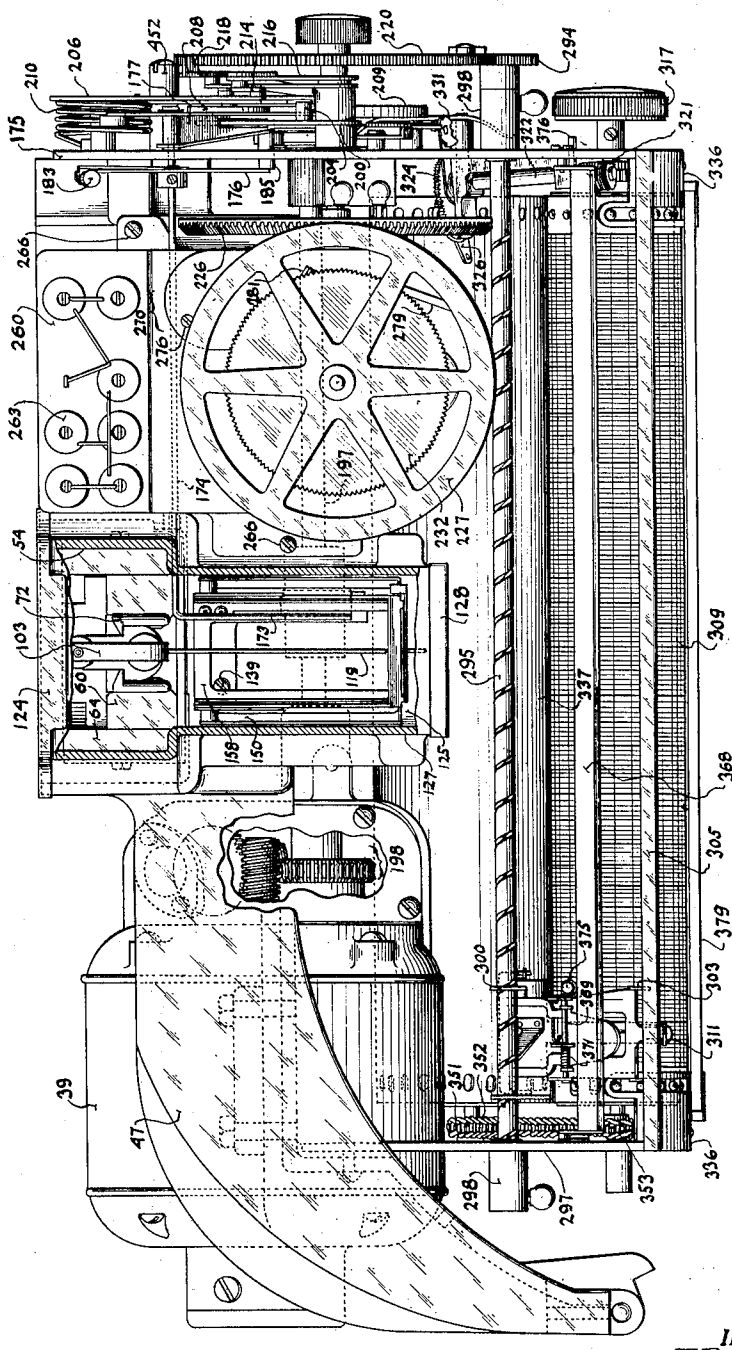
INVENTORS.
T. R. Harrison,
J. E. Kessler,
E. H. Grauel,
BY Louis J. McBane
ATTORNEYS.

March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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FIG. II.



INVENTORS.
T.R. Harrison,
J.E. Kessler,
E.H. Grauel,
BY Louis J. McBare
ATTORNEYS.

March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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FIG. III.

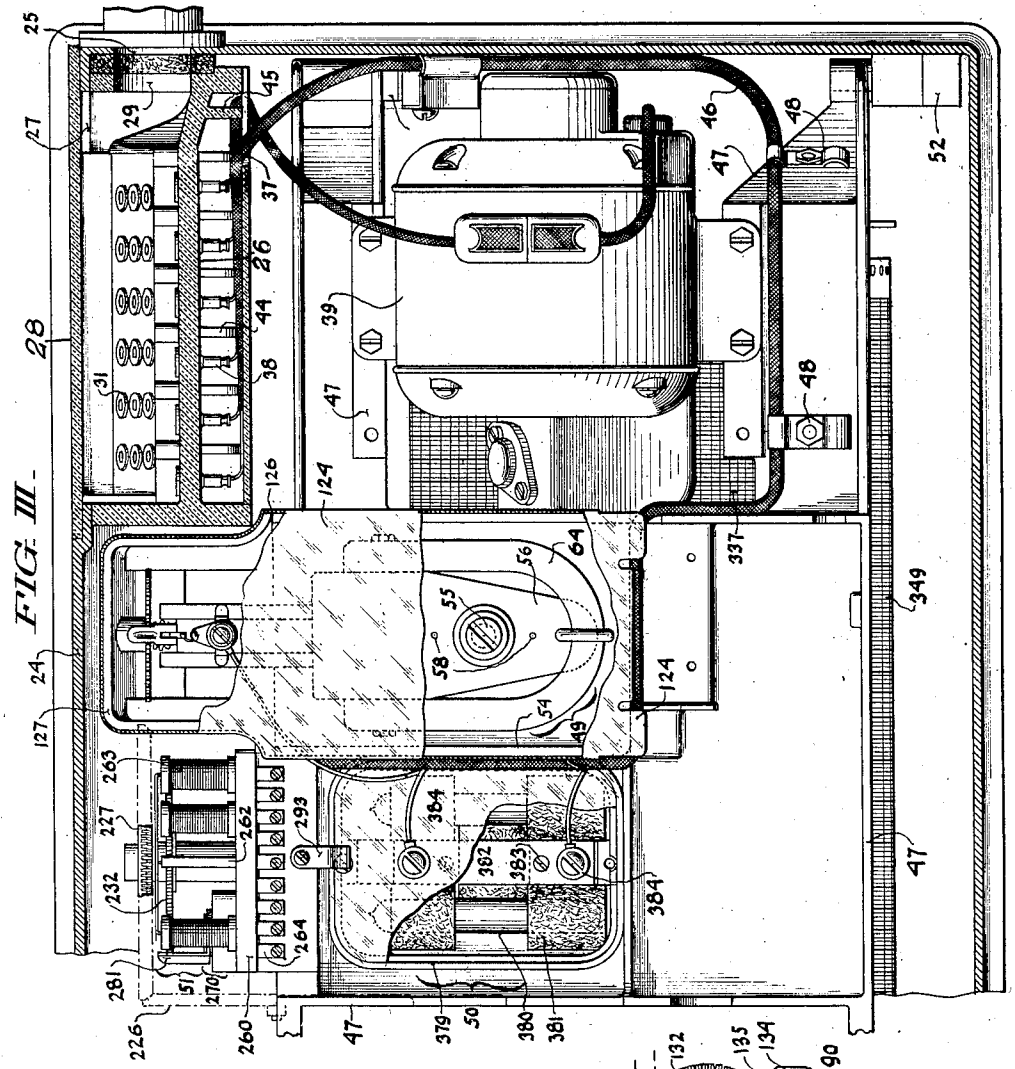


FIG. VIII.

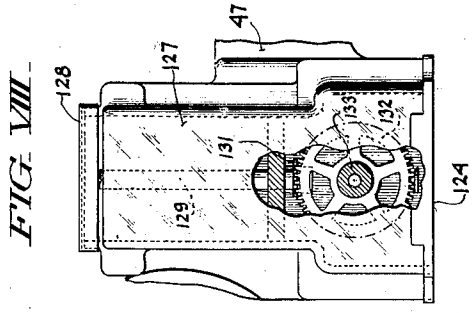
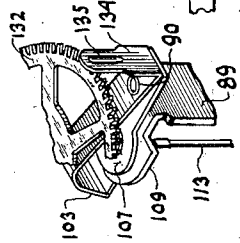


FIG. IX.



INVENTORS.
T.R.Harrison,
J.E.Kessler,
E.H.Grauel,
BY Louis J. McBane
ATTORNEYS.

March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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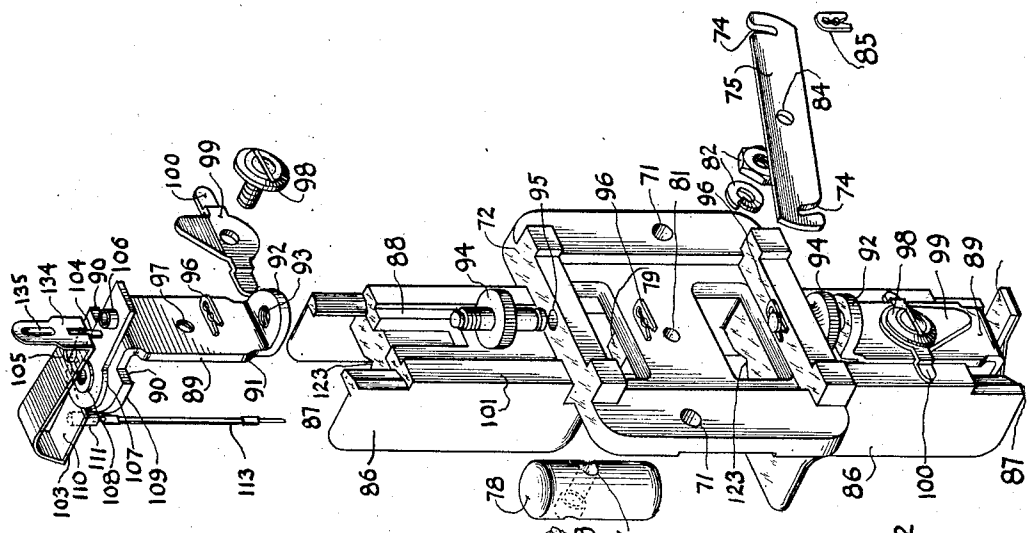


FIG. IV

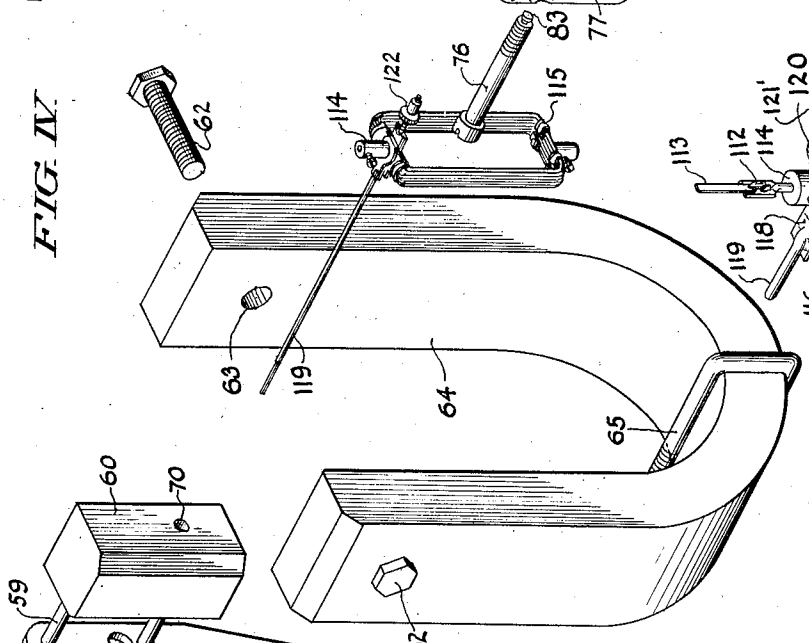
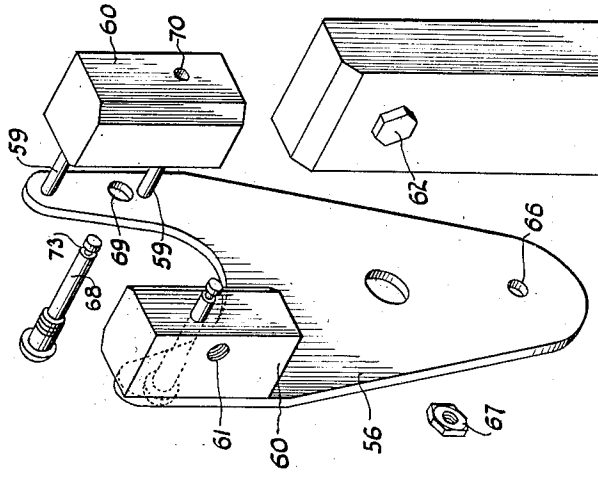


FIG. X



FIG. XI



INVENTORS.
T.R. Harrison,
J.E. Kessler,
E.H. Grauel,
Louis J. McBane
ATTORNEYS.

BY

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MEASURING, INDICATING, AND RECORDING INSTRUMENT

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FIG VII

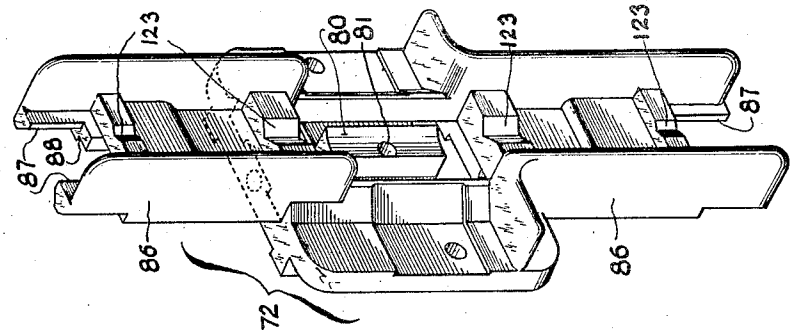


FIG VI

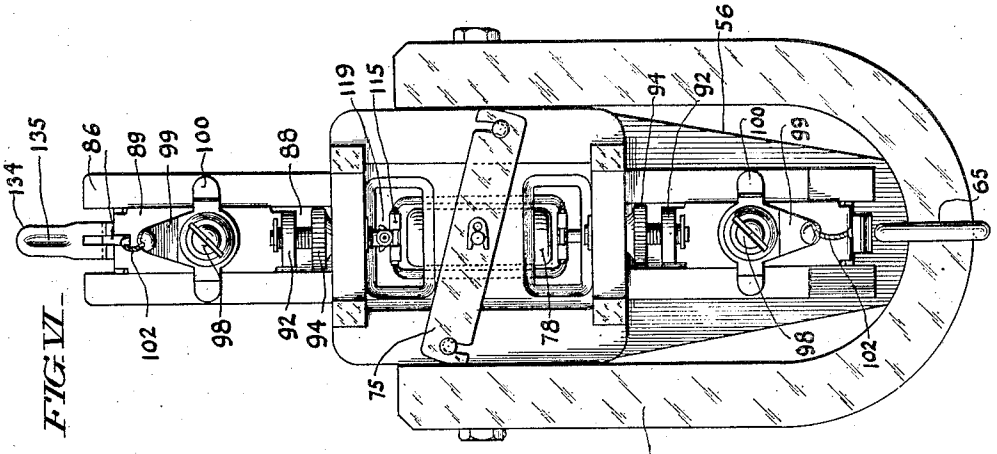
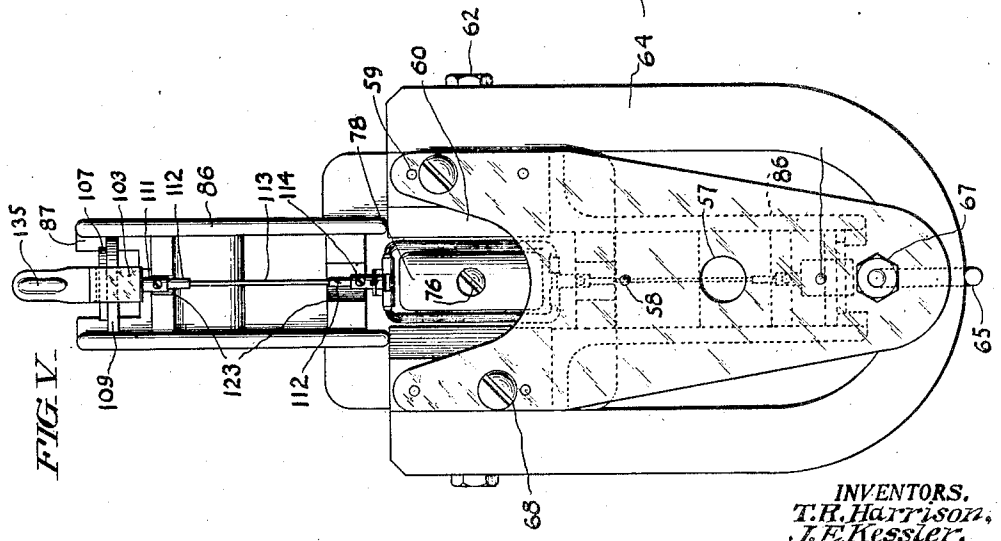


FIG V



INVENTORS.
T. R. Harrison,
J. E. Kessler,
E. H. Grauel,
Louis J. McBane
ATTORNEYS.

BY

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MEASURING, INDICATING, AND RECORDING INSTRUMENT

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FIG. XII.

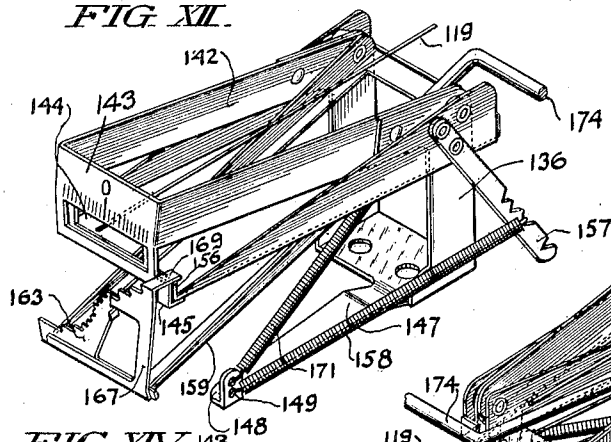


FIG. XIII.

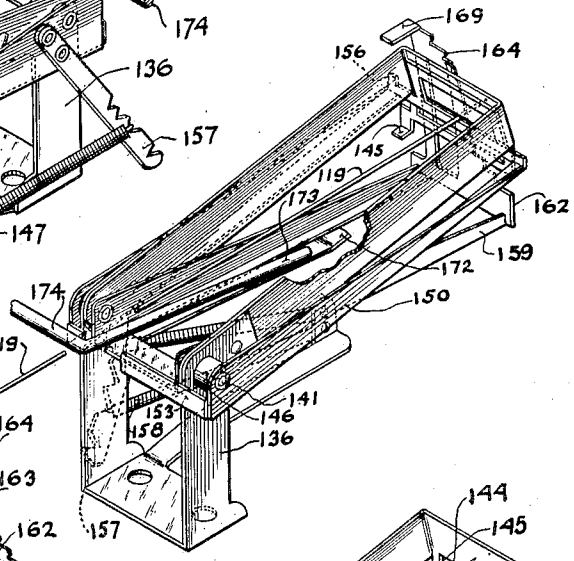
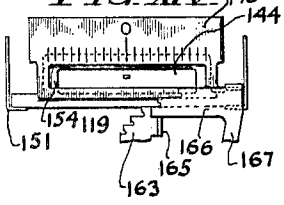
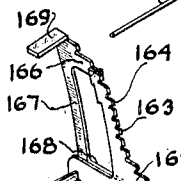


FIG. XIV.





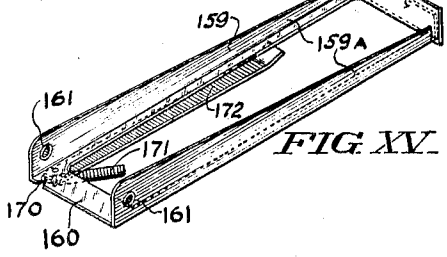


FIG. XV.

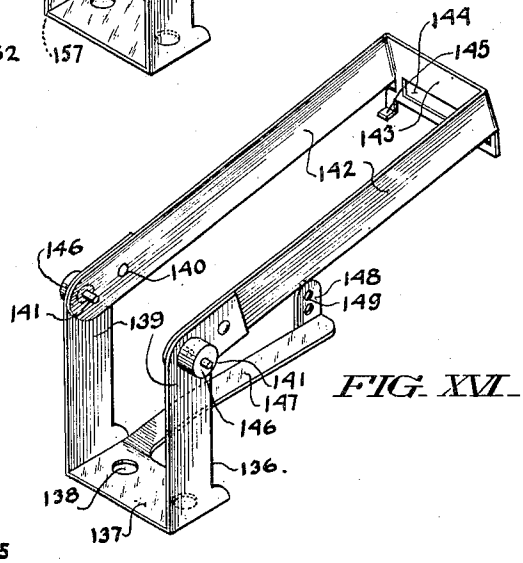
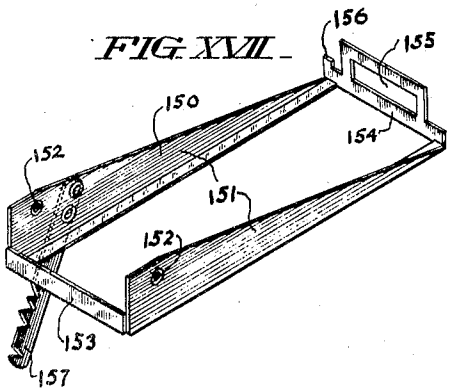


FIG. XVI.

FIG. XVII.



INVENTORS.
T.R.Harrison,
J.E.Hessler,
E.H.Grauel,
Louis McBane
ATTORNEYS.

BY

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FIG. XVIII.

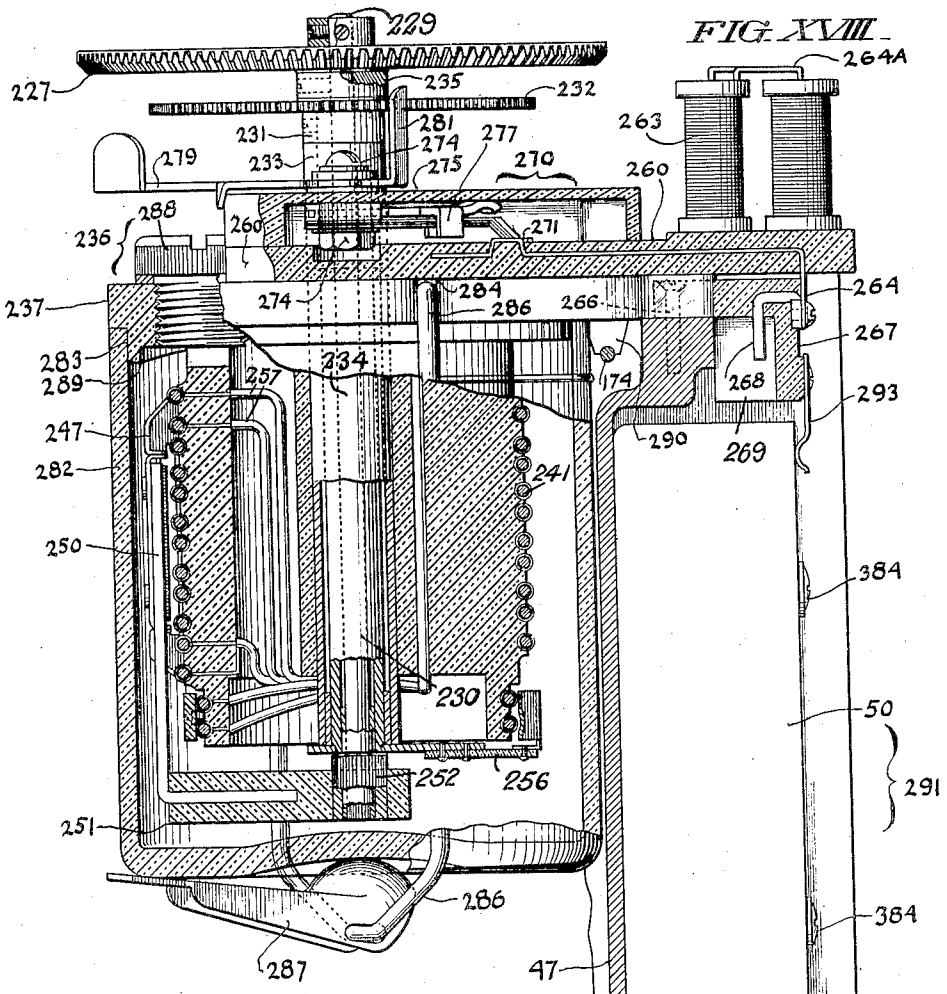


FIG. XXI.

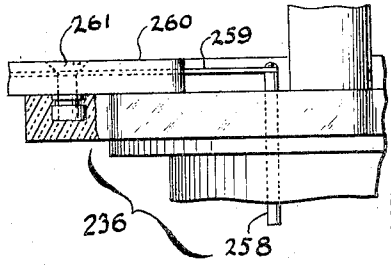
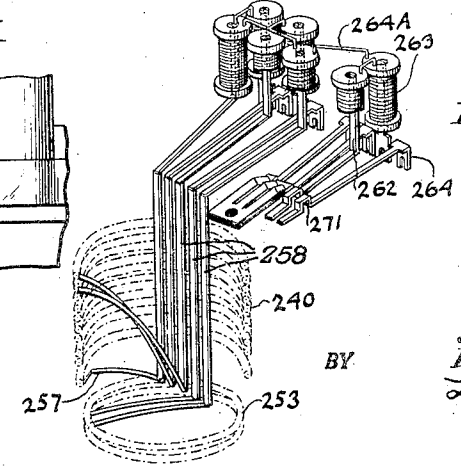


FIG. XXII.



INVENTORS.
T. R. Harrison,
J. E. Kessler,
E. H. Grauel,
Louis J. McBane
ATTORNEYS.

BY

March 14, 1939. T. R. HARRISON ET AL 2,150,502

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FIG XX

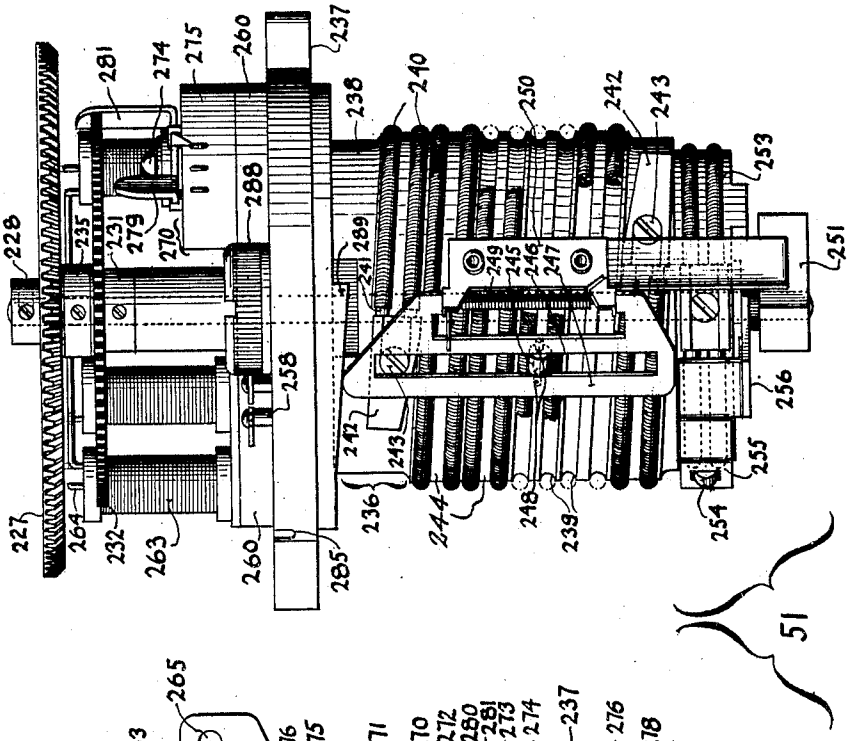
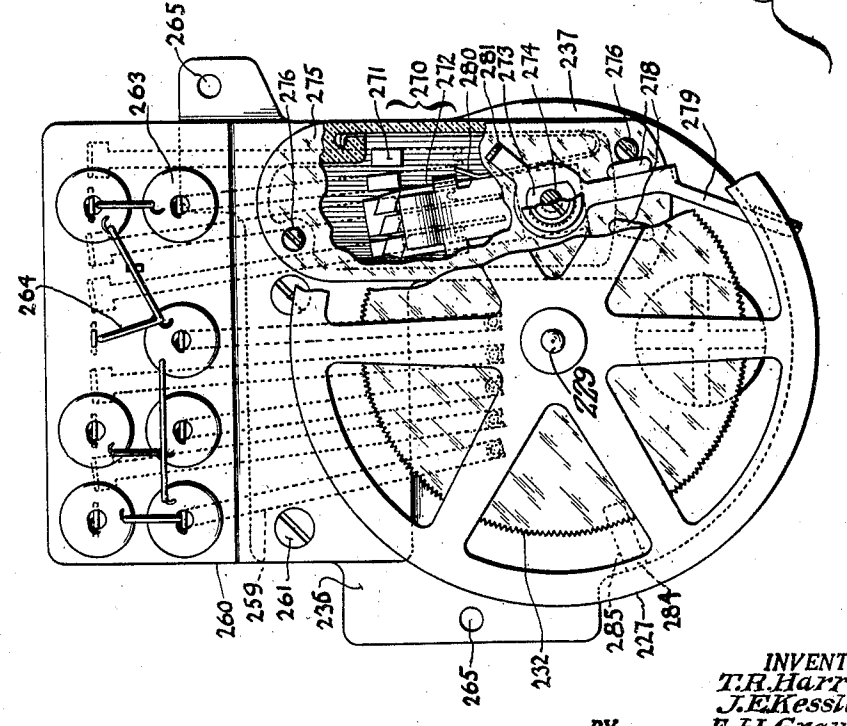


FIG XX



INVENTORS.
T.R.Harrison,
J.E.Kessler,
E.H.Grauel,
Louis J. McBaine
ATTORNEYS.

BY

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MEASURING, INDICATING, AND RECORDING INSTRUMENT

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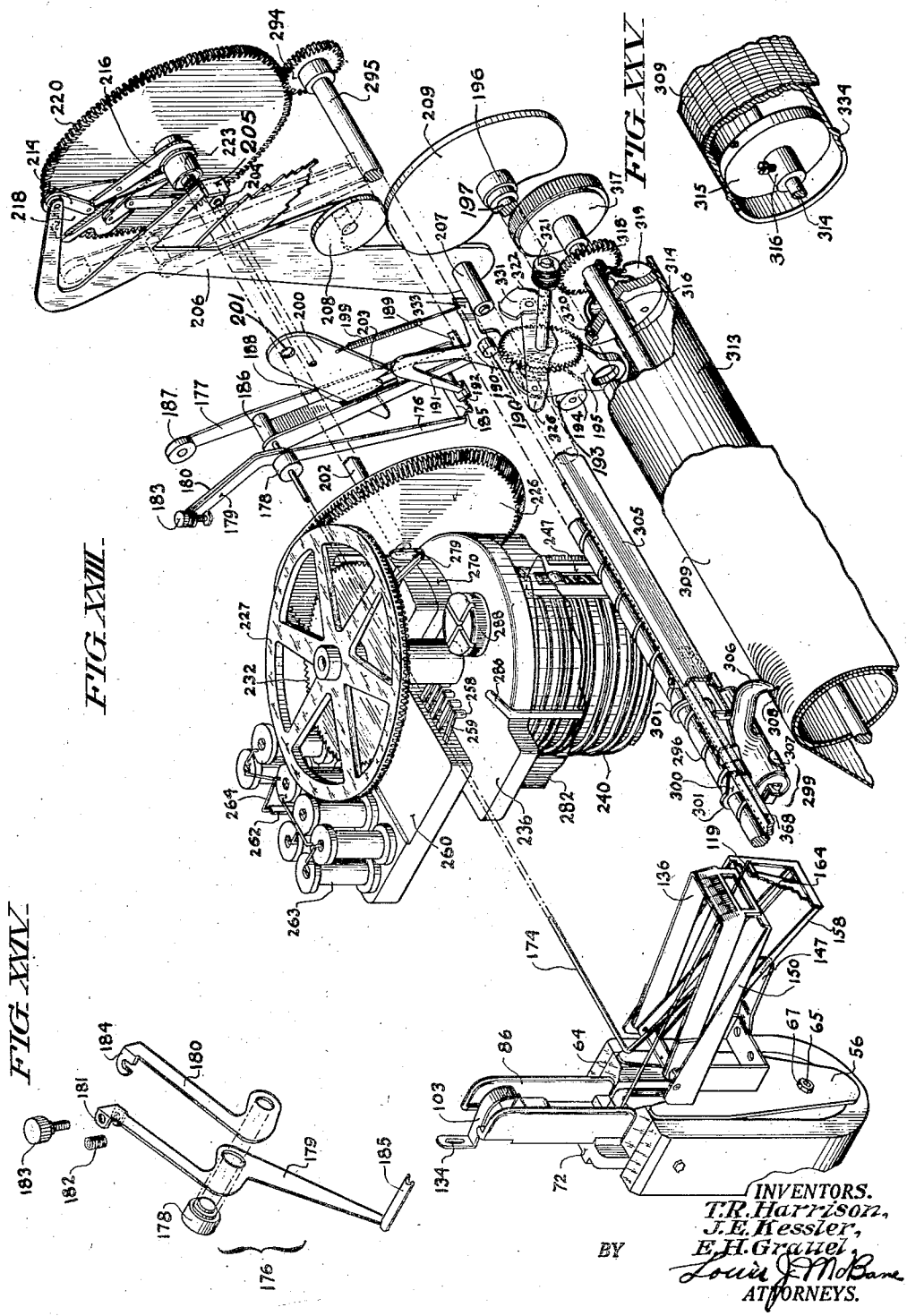


FIG. XXVI

FIG. XXVII

FIG. XXVIII

INVENTORS.
T. R. Harrison,
J. E. Kessler,
E. H. Grauel,
Louis J. McBane
ATTORNEYS.

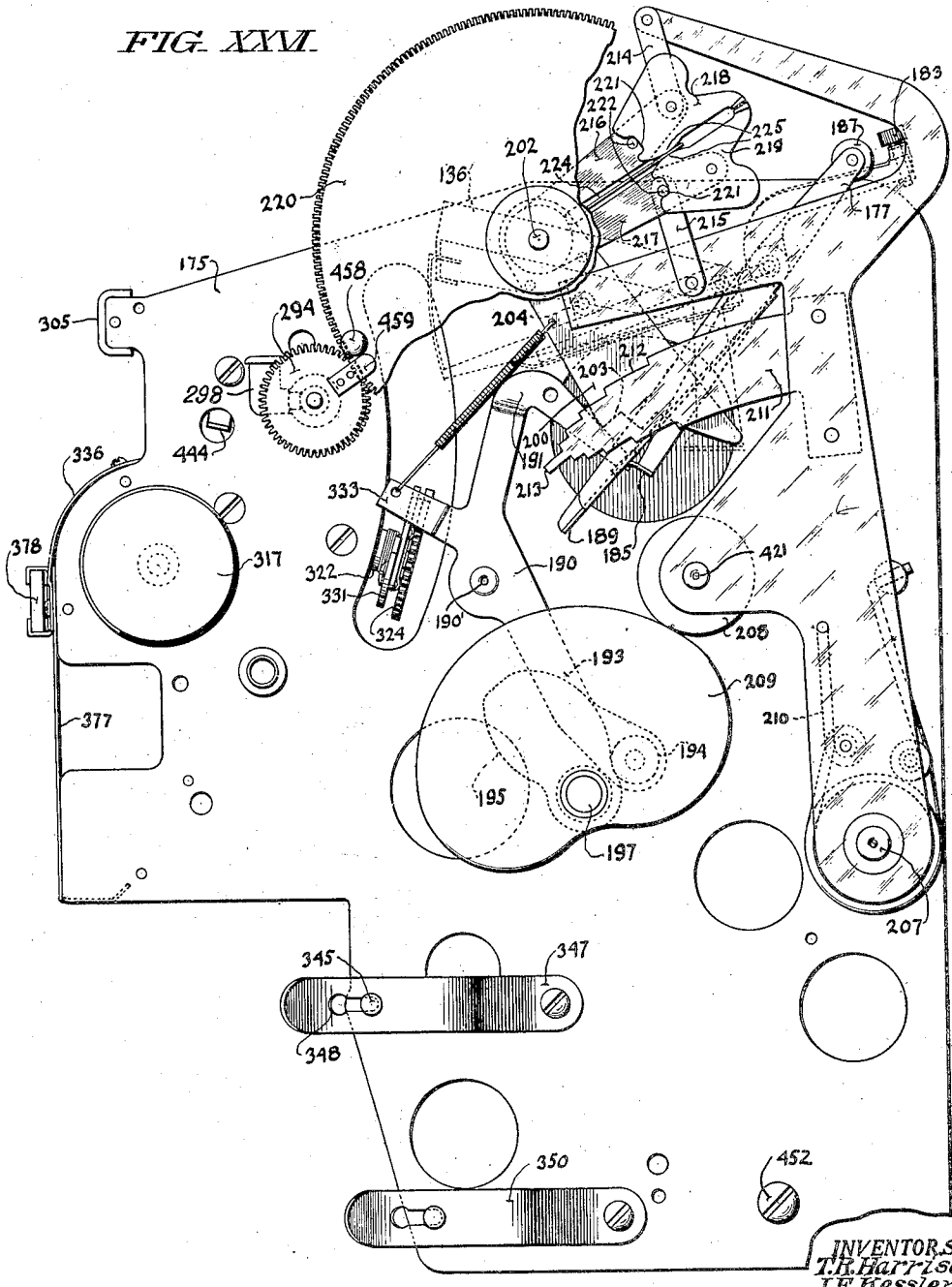
BY

March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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FIG. XXVI.



INVENTORS.
T.R.Harrison,
J.E.Kessler,
E.H.Grauel,
Louis J. McCann
ATTORNEYS.

BY

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MEASURING, INDICATING, AND RECORDING INSTRUMENT

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FIG. XXVII.

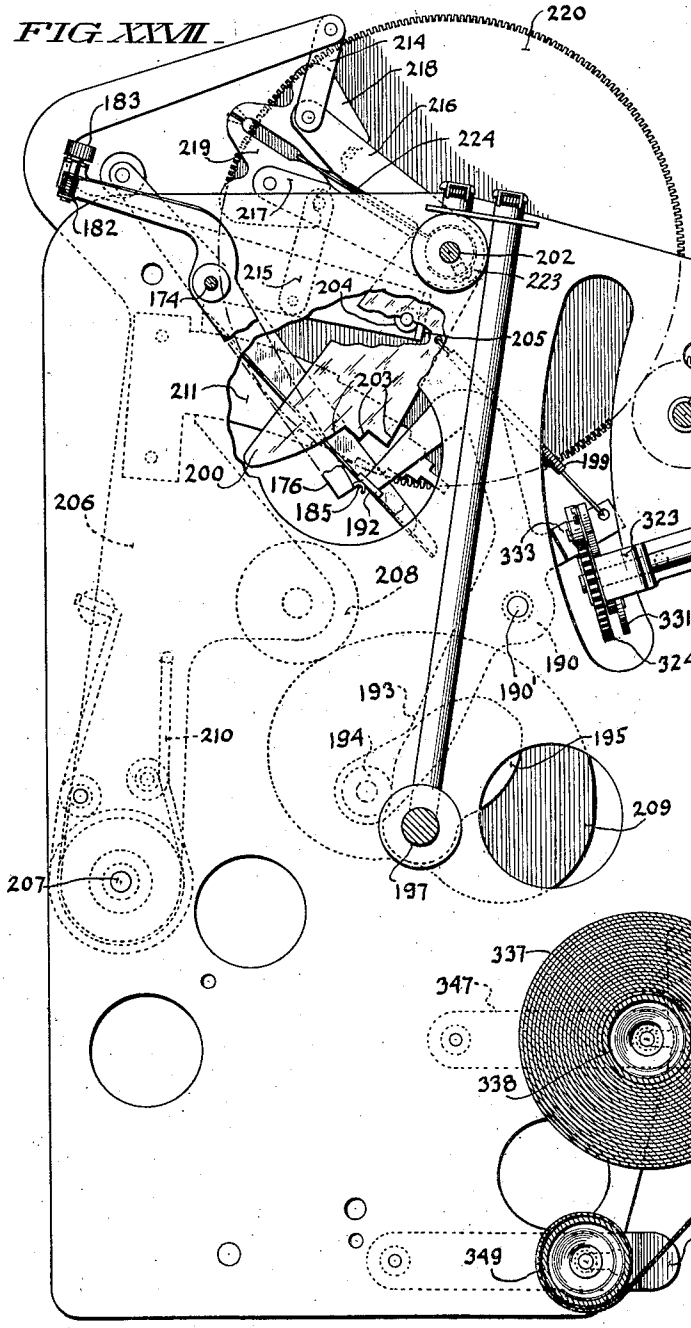
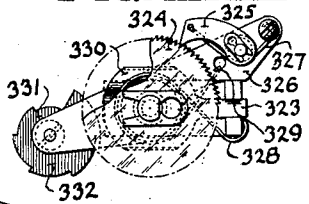


FIG. XXVIII.



INVENTORS.
T. R. Harrison,
J. E. Kessler,
E. H. Grauel,
Louis J. McBane
ATTORNEYS.

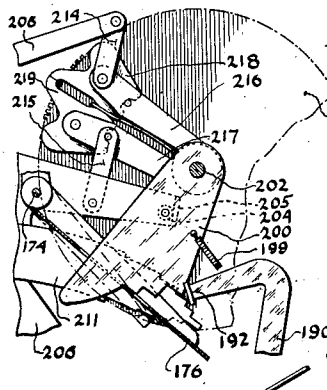
BY

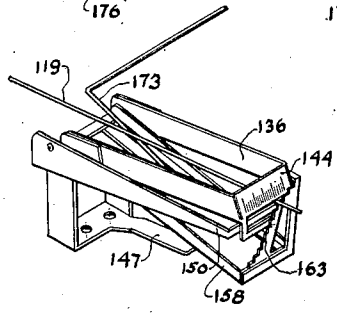
March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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FIG. XXX.





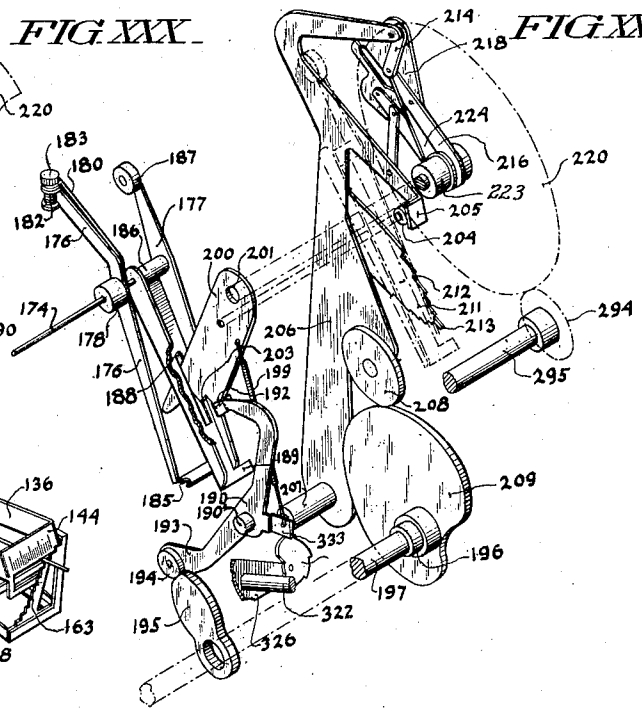
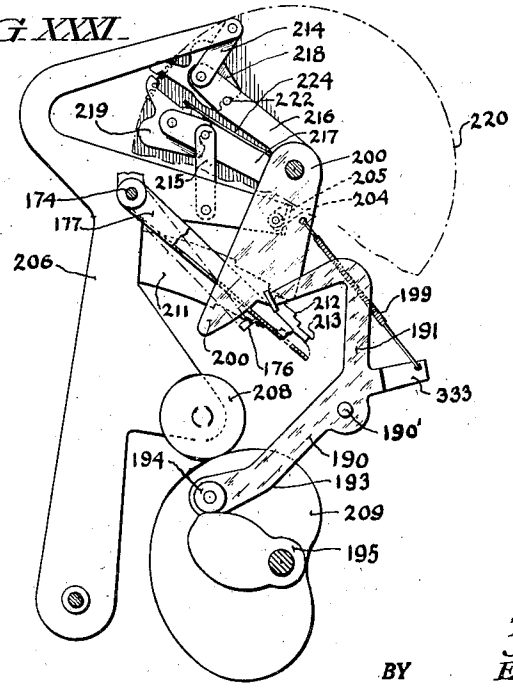


FIG. XXXI.



INVENTORS.
T.R. Harrison,
J.E. Kessler,
E.H. Grauel,
Louis McBane
ATTORNEYS.

BY

March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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FIG. XXII.

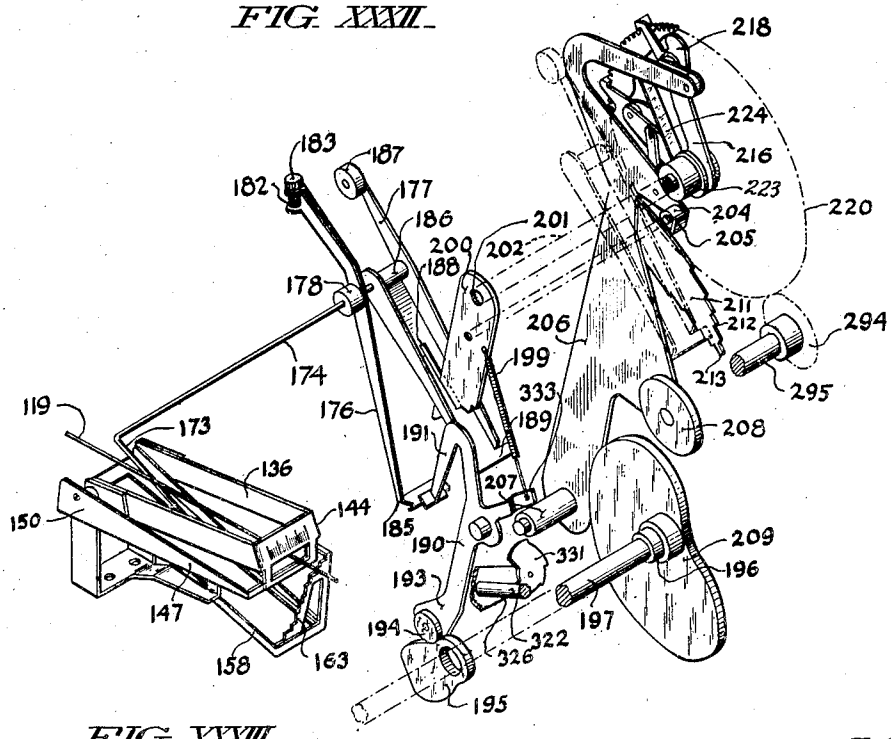
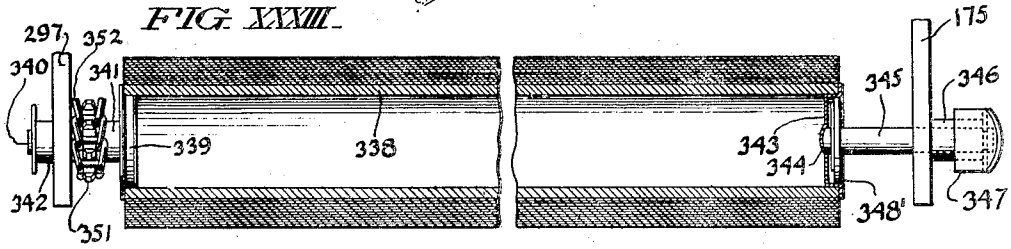


FIG. XXIII.



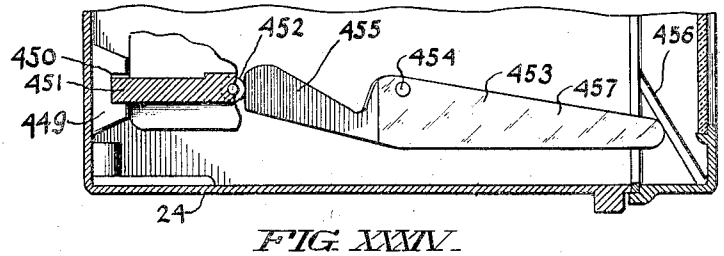


FIG. XXIV.

INVENTORS.
T.R.Harrison,
J.E.Kessler,
E.H.Grauel,
Louis J. McBane.
ATTORNEYS.

BY

March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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FIG. XXXV.

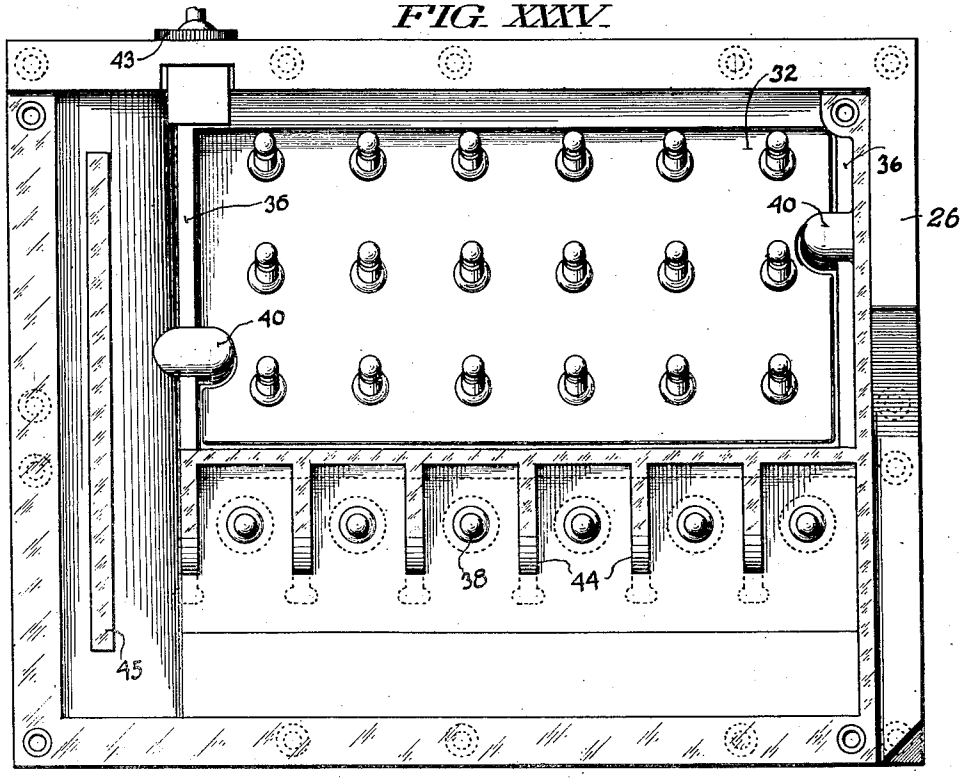
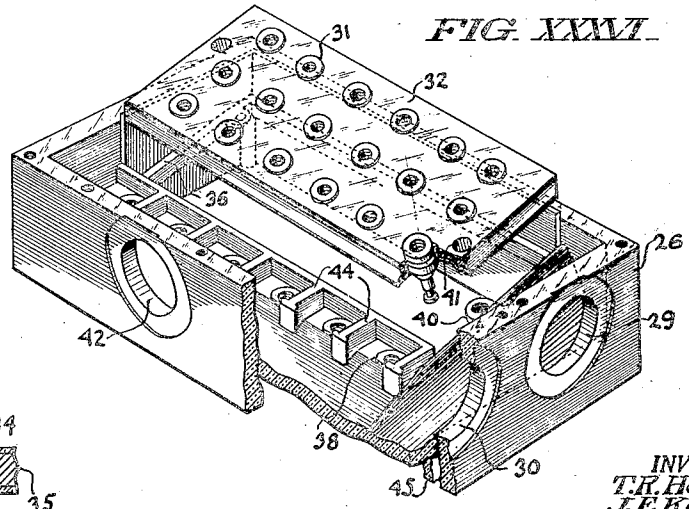


FIG. XXXVI.



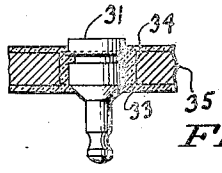


FIG. XXXVII.

INVENTORS.
T.R. Harrison,
J.E. Kessler,
F.H. Grauel.
BY
Louis McBerne
ATTORNEYS.

March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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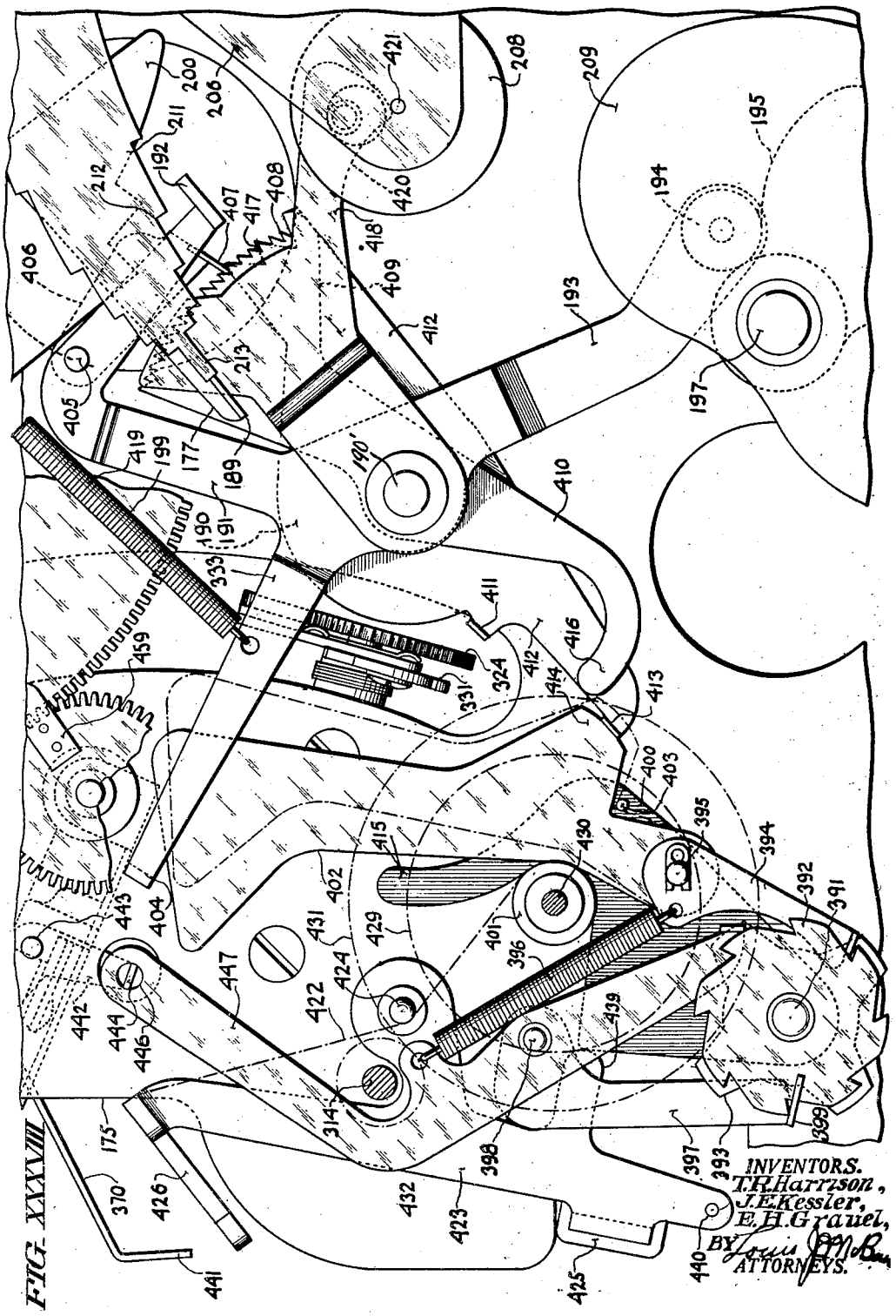


FIG. XXXVIII

INVENTORS.
T.R.Harrison,
J.E.Kessler,
E.H.Grauel,
BY Louis M. Ross
ATTORNEYS.

March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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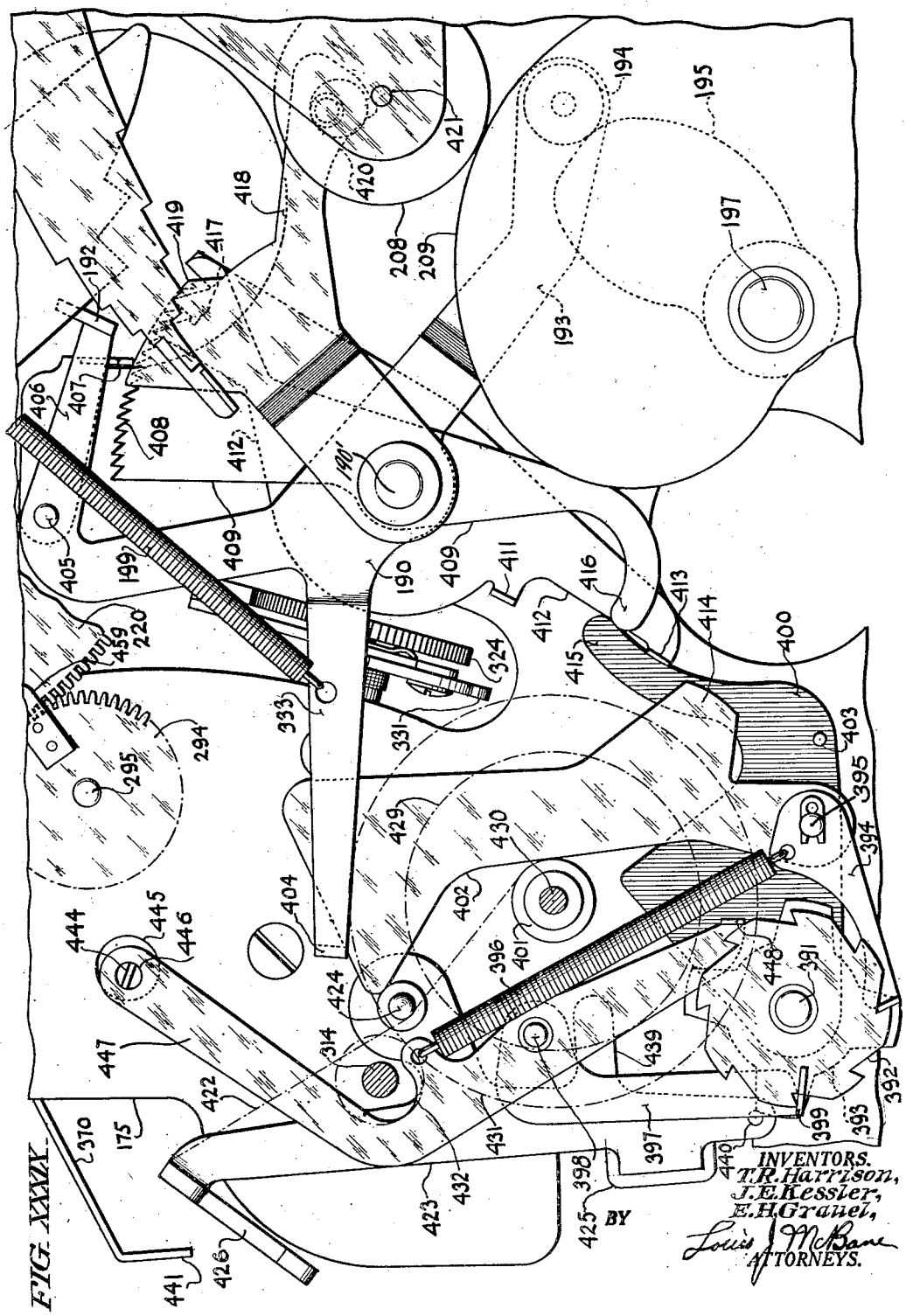


FIG. XXXIX.

INVENTORS.
T.R.Harrison,
J.E.Kessler,
E.H.Granet,
BY
Louis McBane
ATTORNEYS.

March 14, 1939. T. R. HARRISON ET AL. 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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FIG. XL.

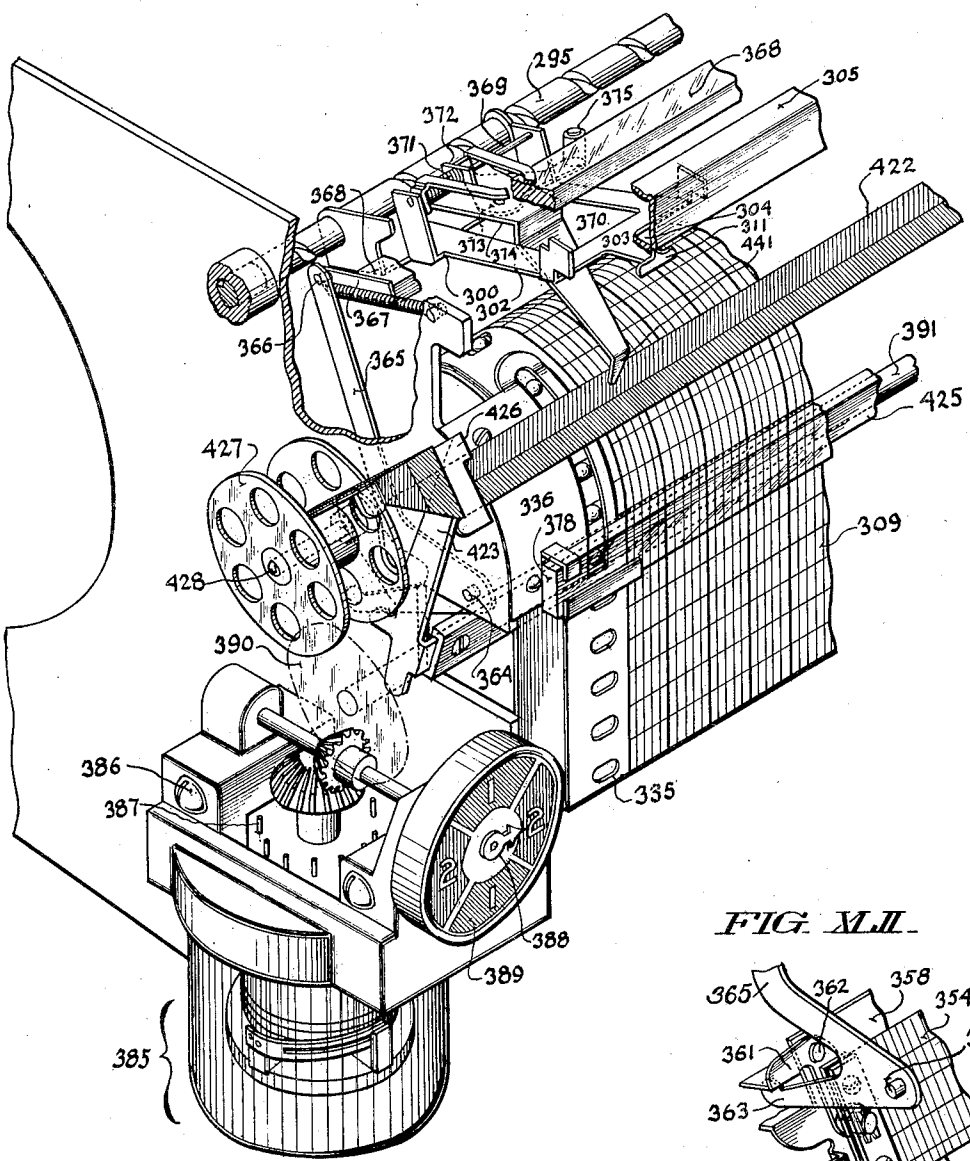


FIG. XLII.

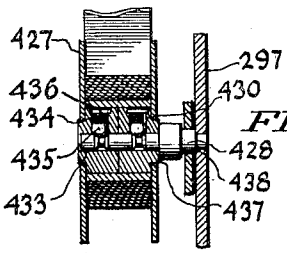


FIG. XLI.

INVENTORS.
T.R.Harrison,
J.E.Kessler,
E.H.Grauel,
BY Louis J. McBane
ATTORNEYS.

March 14, 1939. T. R. HARRISON ET AL 2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

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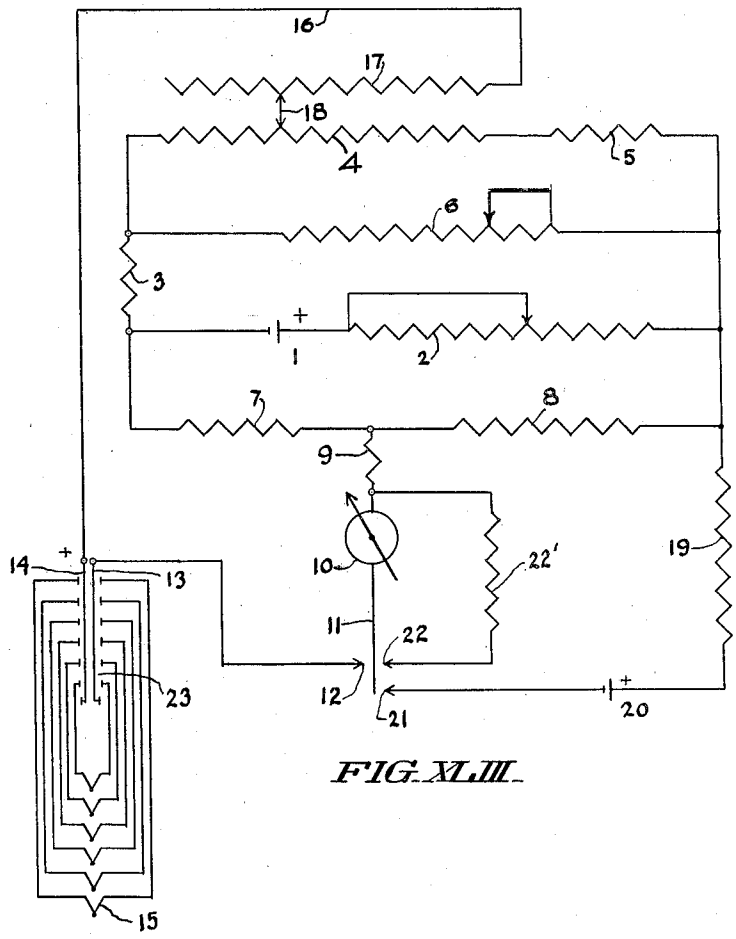


FIG. XLIII.

BY

INVENTORS.
T.R.Harrison,
J.E.Kessler,
E.H.Grauel.
Louis J. McBane
ATTORNEYS.

Patented Mar. 14, 1939 2,150,502

UNITED STATES PATENT OFFICE

2,150,502

MEASURING, INDICATING, AND RECORDING INSTRUMENT

Thomas R. Harrison, Wyncote, Ernest H. Grauel, Conshohocken, and John Ernest Kessler, Philadelphia, Pa., assignors to The Brown Instrument Company, Philadelphia, Pa., a corporation of Pennsylvania

Application June 23, 1931, Serial No. 546,290

20 Claims. (Cl. 234—5.5)

This invention relates to measuring instruments and more especially to improvements in potentiometric measuring and recording instruments.

Potentiometers of the automatic balancing type are well known and have been available in commercial form for many years. Such potentiometers, while affording a more or less satisfactory service and being of a design and construction adapted for a more or less satisfactory facility and cost of manufacture, fall short of the most desirable form and construction of potentiometer, both from the standpoint of operation and service, and facility and cost of construction and maintenance.

It is the object of this invention to provide a measuring instrument of the potentiometer type involving numerous improvements in the individual parts which collectively make up the potentiometer, and also in the relative arrangement and efficiency of cooperation of the parts. This invention comprises improvements in the galvanometer construction affording a simpler and less expensive mode of manufacture, providing a simpler galvanometer assembly having a maximum of accessibility for adjustment and service and a minimum of constructional features subject to failure in operation. This invention also includes the provision of an improved form of mechanism for automatically balancing the potentiometric circuit adapted to simplify practice in manufacture, to increase efficiency and smoothness of operation, and to provide greater independence of failure in operation. The invention also comprises the provision for indicating and/or recording the value of the quantity measured by the potentiometer system, which is a simplified construction and an improvement in efficiency of operation. The invention also includes improvements in case construction for containing the potentiometer mechanism, and improvements in standard cell construction and mounting. This invention provides such improved forms of construction of parts and assembly thereof, as permits the extensive use of sheet metal stamping and parts molded from heat plastic materials so that the formed parts may be combined into the complete potentiometer with a minimum of hand or machine operation. In addition, such parts as the galvanometer assembly, the galvanometer position gauging assembly, and the slide wire assembly, have been made as separate units complete in themselves for mounting in a frame, and so constructed that when assembled interfit in operative relation, thus facilitating greatly the manufacture, assembly, and service of such an instrument. Other objects and advantages of the invention appear in the detailed description which follows.

In the accompanying drawings,

Fig. 1 shows the front elevation of the potentiometer of this invention with parts broken away and in section.

Fig. 2 shows the top plan view of the instrument mechanism assembly with parts broken away and in section.

Fig. 3 shows a partial rear elevation with parts broken away and in section.

Fig. 4 shows, in perspective, the galvanometer assembly with the parts separated for clearness.

Figs. 5 and 6 show in front and rear elevation respectively, the galvanometer unit.

Fig. 7 shows, in perspective, the molding which forms an element in the galvanometer assembly.

Figs. 8 and 9 show details, in top plan and perspective respectively, of the galvanometer zero adjusting mechanism.

Figs. 10 and 11 show detail views in perspective and in section, respectively, showing the galvanometer pointer and coil construction.

Fig. 12 is a perspective view of the galvanometer position gauging assembly.

Fig. 13 is a perspective view similar to Fig. 12, taken from another angle.

Fig. 14 is a detail view in elevation of the galvanometer position gauging assembly.

Figs. 15, 16, and 17 are perspective views of the parts which collectively make up the galvanometer position gauging assembly.

Fig. 18 is a cross sectional view of the slide wire unit and associated parts showing the assembled relation of the unit to the frame and standard cell.

Fig. 19 is a top plan view, partly broken away and in section, of the slide wire unit.

Fig. 20 is a view, in front elevation, of the slide wire assembly.

Fig. 21 is a detail view of the slide wire assembly.

Fig. 22 is a view in perspective showing the electrical connections for the slide wire unit.

Fig. 23 is a view in perspective of the operating parts of the potentiometer with the parts relatively displaced to show more clearly their operation.

Fig. 24 is a detail view of the secondary pointer.

Fig. 25 is a detail view of the chart drive roll construction.

Fig. 26 is a view in end elevation of the po-

tentiometer showing the drive mechanism for automatically operating the potentiometer.

Fig. 27 is a view in elevation similar to Fig. 26, but taken in the opposite direction.

Fig. 28 is a detail view of the mechanism for operating the chart drive roll.

Figs. 29, 30, 31, and 32 are views in perspective and elevation, illustrating the operating parts of the potentiometer drive mechanism at different stages of operation.

Fig. 33 is a sectional detail view showing the construction of the chart re-roll.

Fig. 34 is a detail view, partly in elevation and partly in section, showing the latch construction for securing the instrument in proper position within its casing.

Fig. 35 is a bottom plan view of the terminal box.

Fig. 36 is a top view, in perspective, of the terminal box showing parts in displaced position.

Fig. 37 is a detail in section showing the terminal mounting construction.

Fig. 38 is a view in side elevation broken away and showing operating parts for multiple recording.

Fig. 39 is a view similar to Fig. 38 showing the parts in a different stage of operation.

Fig. 40 is a view, in perspective, showing parts of the multiple recording mechanism.

Fig. 41 is a detail view, in section, showing the mounting for the ribbon bobbin.

Fig. 42 is a detail in perspective showing features of the humidity compensator.

Fig. 43 is a diagrammatic view of a potentiometer circuit adapted for use with the potentiometer of this invention.

Potentiometer circuit

Referring to Fig. 43, 1 designates a substantially constant source of electromotive force such as an ordinary dry cell connected in series with an adjustable resistor 2, the adjustment of which is adapted to vary the current flow in the circuit containing the cell 1, a ballast resistor 3, a slide wire 4, another ballast resistor 5, a calibrating resistor 6, the value and manner of connection of which may be varied in order to vary the measuring range of the potentiometer circuit, completing the series of circuit. A shunt circuit containing resistors 7 and 8, is provided. The resistor 7 is included in the measuring circuit completed through resistor 9, galvanometer 10, switch 11, switch contact 12, conductors 13 and 14, across which are connected a source of potential such as a thermocouple 15, the value of which is to be measured, conductor 16, resistor 17 and sliding contact 18, to the slide wire 4. By making the resistor 7 of a suitable temperature coefficient of electrical resistance, the variation in temperature of a cold junction may be automatically compensated for, as is well known in the art. A resistor 8 is included in an auxiliary circuit extending from resistor 8 through resistor 19, standard cell 20, switch contact 21, switch 11, galvanometer 10, resistor 9, thus completing the circuit. A resistor 22' may be shunted about the galvanometer 10 in order to properly damp its movement when the switch 11 is thrown into engagement with the contact 21 and at the same time engages contact 22. In operation the source of electromotive force 1 supplies a steady current through slide wire resistor 4, thereby creating a definite potential drop across that resistor. The circuit including the thermocouple 15 applies an electromotive force on the slide wire 4 in a direction such as to oppose that created by the cell 1. By adjusting the sliding contact 18 along the resistor 4, a point on the resistor 4 is reached where the potential of the thermocouple applied to the resistor 4 is equal and opposite to the potential of the resistor 4 at that point. At such time the galvanometer 10, which is normally connected in circuit with the thermocouple 15 by virtue of a normally closed position of the switch 11, will have a zero deflection. Variations in the value of the electromotive force of the thermocouple cause deflection of the galvanometer 10 in a direction depending upon whether the variation is an increase or a decrease from that value for which the potentiometer system is previously balanced. The contact 18 may be adjusted again to bring the galvanometer into a position which corresponds to a balanced condition of the measuring system. When the potentiometer circuit is unbalanced a current, due to the thermocouple, flows through the circuit including the resistor 4, and corresponding changes in the position of the contact 18 to balance the circuit, thereby varies the amount of electrical resistance due to resistor 4 which is included in the thermocouple and galvanometer circuit tending to change the constant of the galvanometer circuit. The resistor 17 is connected in series in the thermocouple and galvanometer circuit in a manner such that additional resistance is added from resistor 17 when a like amount of resistance is eliminated from resistor 4 by movement of contact 18, thereby maintaining a constant electrical resistance in the thermocouple and galvanometer circuit so as to maintain an unvarying galvanometer constant throughout the measuring range of the potentiometer.

Inasmuch as the cell 1 tends to deteriorate slightly with age and use, it is necessary from time to time to adjust the resistor 2 in order to maintain a predetermined current flowing through the slide wire resistor 4. For standardizing the current flowing in the slide wire resistor, switch 11 is adjusted into engagement with contacts 21 and 22, thereby connecting the galvanometer 10 in a circuit which includes the standard cell 20 as a source of electromotive force arranged to oppose the potential drop across the resistor 8 due to the current flowing in the resistor 8 from the cell 1. Variations from the standard in the current flowing through resistor 8 from the cell 1, cause a deflection of the galvanometer 10 from the position of zero deflection. The resistor 2 is then adjusted to bring the galvanometer to a position of zero deflection which corresponds to a balance between the potential drop across resistor 8 and the potential of standard cell 20, thereby standardizing the current.

The potentiometer of this invention is constructed and arranged to perform the function of adjusting the potentiometer circuit to a state of balance automatically in response to variations of a measured electromotive force which may or may not be the ultimate quantity to be measured. The measured electromotive force may be responsive to and correspond with a variation in temperature, pressure, speed, humidity, color, etc. For purposes of illustration the invention is shown as applied to the use of thermocouples for measuring temperature variation. As shown in Fig. 43, a plurality of thermocouples 15 are illustrated, and a switch 23 diagrammatically illustrated by which any one of the thermo-

couples 15 may be selectively associated with the potentiometer circuit for measuring purposes. The measuring operation of the potentiometer circuit is the same for any of the thermocouples and accordingly will be so described first. The potentiometer mechanism for associating the thermocouples selectively and successively therewith, will be described later.

Terminal box

The potentiometer mechanism is housed in a suitable casing 24 which is provided with apertures 25, (Fig. 3), through which the electrical conductors from the thermocouples or other source of electromotive force being measured, are passed. Adjacent the apertures 25 and within the casing 24, is a terminal box 26 secured to the casing by screws or other suitable means. As shown in Figs. 1 and 3, the terminal box may conveniently, although not necessarily, be mounted at the top of the casing and an opening 27 provided in the casing wall through which access to the interior of the terminal box may be had, the terminal box being open in that direction. A plate 28 may be and preferably is secured to the casing wall over the opening 27 in order to provide protection for the terminals. The terminal box is illustrated in detail in Figs. 35, 36, and 37, as well as being shown in Figs. 1 and 3. The terminal box 26, as shown in Fig. 36, is provided with openings 29 and 30 which register with the openings 25 in the instrument casing when the terminal box is mounted therein. The opening 29 accommodates the passage of the conductors of the measuring circuit into the terminal box. The conductors associated with the measuring circuit lead to and are connected in any suitable manner as by screw threaded fittings into the terminals 31 carried in the block 32. As shown in Fig. 37, the terminals 31 are secured in the block 32 by being embedded in insulating material 33 extending through apertures 34 in a metallic plate 35. The insulating material 33 forms a sheath for the metallic plate so as to insulate all faces of it. Inasmuch as the instrument of this invention is adapted to measure very small changes in electromotive force, it is necessary that thermoelectric forces set up by differences in temperature at the terminals, be avoided. It is for this reason that the block 32 is made largely of metal having a high thermoconductivity so that the temperature of all of the electrical terminals supported in that plate be maintained at the same temperature. As shown in Fig. 36, the block 32 is arranged to rest upon ledges 36 formed in the body of the terminal box 26, the electrical connections extending from the instrument proper to the terminal block, passing through an opening 37 (see Fig. 3) in the base of the terminal box, and are secured to the small ends of the terminals 31 in a suitable manner as by soldering. The detachable form of connection of the instrument leads from without the casing by means of binding screws, the removable manner of securing the terminal block 32 within its mounting and its accessibility through the opening 27 of the instrument case, combine to an unusual degree convenience in installing and servicing the instrument and protection of the terminals from dust, dirt, water, fumes, and from unequal temperature conditions.

The power leads for operating the motor of the instrument are introduced into the terminal box through opening 30 and extend to terminals 38 embedded in the material of the terminal box. The power leads may be secured to the terminals 38 by screw fittings or otherwise, and the leads from the terminals 38 to the motor 39 may be soldered to the small ends of terminals 38 and extend through the opening 37 in a cover on the bottom of the terminal box to the motor.

The terminal box may be and preferably is formed as a molding of insulating material such as Bakelite, in which the terminals 38 are embedded during the process of molding, and in which the various openings, projections, contours, and threaded apertures are formed during the molding operation. In a similar manner block 32 may be and preferably is formed by molding the terminals 31 in place at the time that the molded insulation 33 is applied over the surface of the metallic block 35. Bosses 40, having screw threaded bushings embedded therein, provide means for securing the terminal block 32 to the box 26 by screws passing through apertures 41 in the terminal block 32.

In the terminal box construction and mounting, as shown in Fig. 3, provision is made for introducing the electrical conductors through the side of the instrument casing. Where, as is sometimes desirable, the electrical cables are introduced through the back wall of the casings, and apertures such as are shown at 42, are formed into the rear wall of the terminal box to accommodate the passage of the conductors. Electrical switch 43, of conventional construction, may be and preferably is molded into the body of the terminal blocks on the front thereof, where it will be conveniently accessible from the front of the instrument for switching on and off the power to the motor. Partitions 44 are provided to separate the terminals of the power conductors to insure against short circuiting, and a partition 45 is provided to separate the instrument conductors from the power conductors which extend from the instrument proper to the terminals. It is apparent that by this invention a terminal box construction adapted for facility and minimum of cost in manufacture, together with adequate electrical protection, with provision for maintaining the terminals of the conductors at the same temperature, with a maximum of accessibility and convenience of installation, have been provided.

The electrical conductors from the terminal block 32 extend, as shown at 46, along the frame 47 of the instrument, being supported thereon by clips 48, to the galvanometer 49, standard cell 50, and slide wire 51 (see Fig. 3). The frame 47 of the instrument is pivotally mounted upon projections 52, extending from the side wall of the casing 24, adjacent the front thereof, so that when the door 53 of the casing is open, the instrument frame may be swung out of the casing to make available the rear side of the frame and parts carried thereon, for inspection and service.

Galvanometer unit

The instrument frame is provided with a recess 54 in which the galvanometer unit is mounted by screw 55. The galvanometer unit is shown in detail in Figs. 4, 5, 6, and 7.

A plate 56 is provided with an aperture 57 through which the screw 55 extends to secure the plate 56 to the frame. Projections 58 are provided on that surface of the plate 56 adjacent the surface of the instrument frame and fit into recesses in the frame so as properly to align plate 56 when secured in place. Plate 56 is provided with pins 59 which extend into recesses (not

shown) in pole pieces 60 of the magnet, thereby properly positioning the pole pieces. The pole pieces 60 are provided with threaded recesses 61 into which bolts 62 are screwed, the bolts passing through apertures 63 in the horse shoe magnet 64 and securing the magnet 64 to the pole pieces 60. A hook 65 extending over and clamping the magnet 64, extends through aperture 66 in plate 56, and clamps the magnet 64 to the plate 56 by the nut 67 applied to the threaded end of the hook 65. Studs 68 extend through apertures 69 in plate 56 and are threaded into pole pieces 60 to secure the pole pieces to the plate 56. Pole pieces 60 are provided with apertures 70 through which the ends of studs 68 extend. The ends of studs 68 are arranged to pass through apertures 71 in a Bakelite molding 72. The studs 68 are provided with recesses 73, adapted to accommodate notches 74 in clamping bar 75. (See Figs. 4 and 6.) When the plate 56, pole pieces 60, magnet 64, and Bakelite molding 72 are in assembled relation, the bar 75, when turned into clamping position with respect to studs 68, secures the Bakelite molding to the magnet system. The bar 75 is mounted on the Bakelite molding 72 for rotation by bolt 76. The bolt 76 extends through passage 77 in core 78 adapted to fit within the galvanometer coil and provide a uniform electromagnetic field in which the galvanometer coil may move. The Bakelite molding is provided with a projection 79 having a face 80 shaped to receive and support the core 78 and the body of the molding 72 is provided with aperture 81 through which the bolt 76 passes. Suitable securing means, such as washer and nut 82, are threaded on the end of the bolt 76 to secure the core 78 in place. The bolt 76 is provided with a recessed projection 83 over which the aperture 84 of the bar 75 fits and which accommodates a cotter 85 to secure the bar 75 into position on the end of the bolt 76.

The molding 72 has extensions 86 provided with shoulders 87 and ways 88 adapted to receive and guidably support fitting 89 for motion longitudinally of the extensions 86. The fittings 89 are provided with offsets 90 which contact with and ride along the faces of shoulders 87. The face 91 of the body of the fitting 89, fits into the way 88 of the molding. The offset 90 cooperating with the shoulder 87, and the face 91 cooperating with the way 88, support the fittings 89 against lateral movement with respect to the extensions 86. Fitting 89 is provided with a lug 92 having a threaded aperture 93 into which is threaded a thumb screw 94. The shaft of the thumb screw 94 extends through aperture 95 in the Bakelite molding 72. The ends of the thumb screw 94 are provided with recesses into which fit cotters 96 for securing the thumb screw 94 against longitudinal movement with respect to the molding 72, and for limiting the movement of the fitting 89 along the screw thread of the thumb screw 94. Manipulation of the thumb screw 94 shifts the fitting 89 longitudinally of the extension 86. Fitting 89 is provided with a threaded aperture 97 to receive screw 98 passing through clip 99, having ears 100 which ride on the faces 101 of the extensions 86. The clips 99, when secured in place by the screws 98, afford additional support against lateral movement for the fittings 89. The clip 99 and screw 98 serve for the additional function of making electrical connection for the galvanometer coil suspension. As shown in Fig. 3, electrical connection is made to the screw 98 and clip 99 from the terminal box. As shown in Fig. 6, electrical connection is made between the clip 99 and the galvanometer suspension by conductor 102 secured to the clip 99 as by soldering or any other suitable means, and secured to the spring 103, to which the galvanometer suspension is connected, by a soldered or other suitable joint between the conductor 102 and lug 104, bent from the spring 103. The spring 103 is provided with aperture 105 which fits over projection 106 carried by arm 107 pivotally mounted as by means of pin 108 on the lug 109, integral with fitting 89. The spring 103 is secured in place upon the arm 107 by turning over the projection 106, or in any other suitable manner. The pivotal mounting of the arm 107 on lug 109, provides for adjustment of the galvanometer suspension about its axis in order to properly position the galvanometer suspension with respect to the zero point as determined by the other parts of the instrument with which the galvanometer suspension is associated. In order that movement of the arm 107 about pivot 108 may provide only rotational adjustment of the galvanometer suspension, the spring 103 is formed with extension 110 to which bushing 111 is secured in such position as to be in axial alignment with pivot 108 when the spring 103 is secured to arm 107 by projection 106. The bushing 111 may be secured to the spring 103 by welding or any other suitable manner. The bushings 111 receive ferrules 112 which are secured thereto by means of screws passing through the bushings or in any suitable manner. Suspension wire or strip 113 is secured to the ferrules as by soldering. Ferrules at the other end of the suspension wires 113 are secured to bosses 114. Bosses are fastened as by welding to sheet metal clips 115 which are bent around the top and bottom portions of the galvanometer coil to rigidly secure the galvanometer coil thereto. One of said clips 115 is provided with an integral projection having at its end an edge 116. The same clip 115 is provided with a projection 117 extending in the opposite direction from the first mentioned projection, to which is secured, as by welding, a leaf spring 118 forming an extension of the pointer 119 of the galvanometer. The spring 118 is provided with aperture 120 through which boss 114 extends. The spring 118 is provided with a ridge or like edge forming surface 121 adapted to cross and rest upon the edge 116. The point of contact between edge 116 and ridge 121 affords a single point of bearing about which the pointer 119 may be moved slightly during the operation of the mechanism for gauging the position of the galvanometer, thus providing a single point of support between the galvanometer pointer and edge 116, whereby wabbling of the pointer and distortion of the suspension system due to force acting on the pointer, is prevented. As will be described later, the operation of mechanically gauging the point, at the time of releasing the pointer, tends to set the pointer into vibration. The contact between edges 116 and 121 damps the pointer oscillations and quickly brings the pointer to rest. The clip 115 to which the pointer 119 is secured, is provided with a threaded rod 121′ projecting laterally of the coil in line with the pointer which carries the nut 122 threaded thereon for adjustment to balance the weight of the pointer 119.

As will be observed in Figs. 5 and 6, the parts shown in displaced relation in Fig. 4, when assembled, are so arranged that the galvanometer

coil extends about the core 78 and is situated between the poles 60 of the magnet, the whole system comprising the galvanometer suspension, core, magnet, and poles being clamped together by bolts 68 and cooperating parts. Molding 72, as shown in Fig. 7, is provided with troughlike depressions 123 so positioned that when the movable system of the galvanometer is being assembled, bosses 114 on the galvanometer coil supporting clips rest in a pair of the recesses 123 and the ferrules 112 distant from the galvanometer coil rest in the other of the pair of recesses 123. Recesses 123 provide convenient supports for the parts mentioned to facilitate the assembling operation.

It is apparent from the foregoing description, by this invention there has been provided a markedly simplified form of galvanometer construction employing molded and stamped parts, which in molded and stamped form interfit to provide a complete assembly affording a maximum of adjustability together with marked simplicity of construction, affording facility of manufacture and assembly at a minimum cost. The galvanometer unit is so constructed that it can be assembled as an independent unit comprising those parts illustrated in Fig. 4, the single unit being shown in Figs. 5 and 6, which may be secured on the instrument frame in proper relation with the other parts of the instrument by a single screw 55 passing through the aperture 57 in plate 56. The unit is arranged for facility in inspection, dismantling, service and repair.

Galvanometer mounting

The recess 54 in the instrument frame unit on which the galvanometer unit is mounted, is provided with a rear cover 124 (see Figs. 2 and 3), which is adapted to fit onto the walls of the recessed portion of the frame by spring action and can be removed manually when the instrument frame is swung out of the casing, making the back of the frame available. The recess 54 extends forwardly as indicated at 125 (see Fig. 2) and is open at the top, the top wall of the recess terminating at 126, as shown in Fig. 3. A cap 127 (Figs. 1, 2, and 3) closes the top of the recess and rests upon the top edge 126 of the recess. A front cover 128 closes the front of the cap 127 and is provided with a window through which the galvanometer pointer and the pointer gauging mechanism may be viewed. (See Fig. 1.) As shown in Fig. 8, the cap 127 rotatably carries in apertures formed therein, a shaft 129 which extends through the front of the cover 128, as shown at 130 in Fig 1, the exposed end being provided with a kerf. Shaft 129 carries on its other end a gear 131 meshing with gear 132, the axle of which is journaled in the bushing 133 molded into the material of the cap. When the galvanometer unit is mounted in position upon the instrument frame, and when the cap and associated parts are mounted in position, the axle of gear 132 is in axial alignment with pivot 108 and the galvanometer suspension. (See Fig. 4.) The spring 103 carried upon the fitting 89 by arm 107 rotatable about pivot 108, is provided with an upward extension 134 having a ridge 135 formed therein, which, as shown in Figs. 8 and 9, extends between teeth of the gear 132 so that rotation of gear 132 by manipulation of shaft 129 will transmit angular motion to the spring 103 and galvanometer suspension connected thereto, about the axis of the suspension. The adjustment of the galvanometer suspension about its axis is provided to set the pointer to the zero position relative to the other parts of the instrument when no current is flowing through the galvanometer. The construction of the zero adjusting means of the galvanometer is simple, trouble free, easy to make, conveniently arranged for operation on the instrument, and readily assembled and available for servicing. The recesses 54 and 125, and the covers 124, 127 and 128 form a closed housing for the galvanometer unit and the gauging unit affording ready and complete access to those units together with protection from external influence.

Galvanometer pointer position gauging assembly

As pointed out in connection with the description of the potentiometer circuit, diagrammatically illustrated in Fig. 43, deflection of the galvanometer as to extent and direction is a measure of the direction and degree of unbalance in the potentiometer measuring circuit. In order to adjust the slide wire resistance in the proper direction and to the proper extent so as to rebalance the potentiometer measuring circuit, it is necessary to gauge the extent and direction of the galvanometer deflection and to adjust the slide wire contact accordingly.

Mechanism for gauging the position of the galvanometer pointer and thereby the position of the galvanometer suspension system, is illustrated in detail in Figs. 12 to 17, and is shown in assembled relation with other parts of the instrument in Fig. 2. The pointer gauging mechanism is constructed as a separate unit adapted to be mounted upon the frame of the instrument in proper operating relation with respect to the other parts of the instrument. As shown in Fig. 2, the pointer gauging mechanism is mounted within the extension 125 of the recess 54 in which the galvanometer unit is mounted. A frame 136 (see Figs. 12 and 16) is provided with a foot 137 having apertures 138, through which screws 139 (Fig. 2) pass and are threaded into the frame of the instrument to secure the frame 136 in place in the recess 125. Frame 136 has upstanding legs 139 to which are rigidly secured as by rivets 140 and pins 141, forwardly extending arms 142 carrying integral therewith, a slotted plate 143. The plate 143 has slot 144 and integral lug 145. Pins 141 carry rigidly spacer blocks 146. Strip 147 projects forwardly from foot 137 and has integral therewith lug 148 provided with apertures 149. The frame 136 is essentially made up of two sheet metal stampings. The slot 144, when the frame 136 is mounted in the frame of the instrument, admits passage of the galvanometer pointer 119 therethrough.

A pointer clamping member 150 (see Figs. 12, 13 and 17), has side arms 151 provided with apertures 152 which may be in the form of eyelets pressed into apertures of the metal of the arms 151. A bar 153 connects the side arms 151 for rigidity. Extending between and connected to the other extremities of the side arms 151 is a plate 154 having an aperture 155 and a lug 156. Riveted to one of the side arms 151 is a notched finger 157. The element 150 may be assembled on the frame 136 by springing the apertures 152 over the outer ends of pins 141 rigidly carried by the frame 136, as shown in Fig. 12. A downward movement of the element 150 is limited by a portion of the bottom edge of plate 154 striking the lug 145 of the frame 136. When the element 150 is mounted upon frame 136, a spring 158 is connected between the notched bar 157 and one of the apertures 149 in the frame

136. The spring 158 tends to move the plate 154 upwardly as viewed in Fig. 12, with respect to the plate 143. The pointer 119 of the galvanometer is arranged, when the parts are in assembled relation in the frame of the instrument, to extend through slot 155 as well as slot 144. The upward movement of the plate 154 brings the lower edge of slot 155 into engagement with the galvanometer pointer and clamps the galvanometer pointer between that edge and the upper edge of the slot 144 in plate 143 of frame 136, thereby securely holding the galvanometer pointer 119 in a clamped position so that the pointer position gauging operation may proceed unhindered without movements of the galvanometer pointer.

A pointer position gauging element 159 is shown in Figs. 12, 13, and 15. Element 159 has arms 159A and cross piece 160 joining the side arms to provide rigidity. The arms 159A are provided with apertures 161 which may be reinforced by eyelets if desired. At the ends of arms 159A, distant from the apertures 161, is a plate 162 connecting the arms and having in a plane transverse to the lengthwise direction of arms 159A, an upstanding finger 163 provided with a series of offset steps 164 arranged in a series of steps, the successive ones of which are at successively greater heights above the bottom step and are at successively greater distances horizontally from the bottom steps so as to provide in contour a sloping edge serrated so that the pointer may be engaged by one or another of the serrations. The finger 163 has a forwardly projecting lug 165 (see Fig. 14), onto which is sprung the bottom edge of finger 166 integral with plate 167, having a bottom portion 168 adapted to be sprung over the bottom of plate 162. Member 167 is provided with a lug 169. Plates 167 and 162 may, if desired, be unitary. The finger 166 is provided with a further series of steps forming a continuation of the series of steps 164. Element 159 is mounted on frame 136 by springing the arms 159A so as to fit the apertures 161 over the inwardly extending ends of pins 141. (See Figs. 12 and 13.) The bar 160 of element 159 is provided with a notch 170 to which is secured one end of spring 171, the other end of which is connected to one of the apertures 149 in the frame 136. Spring 171 tends to move the element 159 upwardly with respect to frame 136 into engagement with the pointer 119. A blade spring 172 is riveted to element 159, as shown in Fig. 15. A rod 173, (Figs. 12 and 13), is arranged to be rotated about the axis of its extension 174 and cooperate with the blade spring 172 to force the element 158 downwardly with respect to frame 136, as shown in Figs. 12 and 13. The lug 169 carried by element 159, is arranged, when the parts are assembled, as shown in Figs. 12 and 13, to engage lug 156 of member 150 and carry member 150 downwardly with element 159. The extent of downward movement of the element 159 is limited by the engagement of lug 169 with the top edge of lug 145, as shown in Fig. 12. When the rod 173 is rotated in an upward direction, as shown in Fig. 13, springs 158 and 171 urge elements 150 and 159, respectively, upwardly, as viewed in Fig. 13. The movement of element 150 continues until it engages and clamps the pointer 119, the parts being so proportioned that the pointer 119 is clamped by member 150 before any of the steps 164 of the element or step table 159, have moved far enough to engage the pointer 119. The movement of the step table 159 continues until arrested by engagement of one of the steps thereof, with the pointer 119. Inasmuch as the steps are offset successively in the same direction and are correspondingly arranged in successive heights, the angular position occupied by the step table 158 when arrested by engagement with the pointer, corresponds with the direction and extent of deflection of the galvanometer pointer relative to a predetermined neutral position. The neutral or zero position of the galvanometer pointer is determined by the center step or any other selected step of the step table, the location of which may be marked for convenience, on the face of plate 143, as shown in Fig. 12. As will be observed by inspection of Fig. 1 of the drawings, the pointer position relative to the scale on face plate 144 may be seen from the front of the instrument, and the zero adjusting screw 130 may be manipulated from the same position, so that in practice the screw 130 is adjusted until the pointer 119 is in alignment with the zero on plate 144 when no current is flowing through the galvanometer suspension.

The slot 155 in plate 154 is of such size that when the clamper member 150 is moved downwardly the upper edge of slot 155 passes below the upper edge of slot 144, thereby stripping the point from that edge in case sticking should occur. Also, the lower edge of slot 155 passes below the lower edge of slot 144 providing a stripping action for the pointer in case the pointer should stick to the lower edge of slot 155. Thus a stripping action is provided for all edges which clamp the pointer.

The construction of parts making up the pointer gauging mechanism, as illustrated in Figs. 12 and 13, is, by virtue of the type of step table employed and its manner of operation into engagement with the pointer, such that a large range of different angular positions for the step table are provided to correspond with the various positions of deflection of the galvanometer pointer, thus a given extent of galvanometer pointer deflection results in a change in angular position of the step table which corresponds in degree to the degree of point of deflection, so that no loss of sensitivity is suffered by virtue of the transfer of galvanometer deflection to step table position. In addition, the nature of the step table construction and its arrangement with respect to the other parts of the gauging mechanism is such that the arrangement of steps as to number and slope, may be varied widely, thereby permitting a selection of any of a wide range of operating characteristics for the instrument as determined by the arrangement of the steps of the step table. The manner of mounting the step table on the instrument frame, and the arrangement of a cap 127 thereover, makes it easily possible to gain access to the pointer gauging mechanism for inspection and servicing, and to remove the pointer gauging mechanism from the instrument for repair or replacement, or to insert a different step table in order to modify the operating characteristics of the instrument. The arrangement of the steps of the step table, as illustrated in the drawings, is such that at and adjacent the neutral step, the slope of the steps is steep, so that for a slight deflection of the galvanometer pointer from neutral or balanced position, a considerable change in angular position of the step table is effected. This provides great sensitivity at the most critical position of the galvanometer pointer, namely the balanced position. At distances of galvanometer

pointer deflection further removed from the balanced position, great sensitivity is not so essential and accordingly the slope of the steps may be and preferably is of decreasing order as the extent of pointer deflection from balanced position increases. For example, at and adjacent to the neutral step of the step table, the ratio between the pointer deflection and the corresponding movement of the step table may be as 1 to 10, while at the extreme positions of deflection of the galvanometer pointer from balanced position, the ratio of movement of the galvanometer pointer to the corresponding movement of the step table, may be 1 to 1.

The rod 173 is under control of the drive mechanism of the instrument and in performing the pointer gauging operation is merely released for movement, the spring 171 providing the necessary force for operating the step table and simultaneously moving the bar 173 in correspondence therewith. Accordingly the shaft 174, of which rod 173 is an extension, is caused to take up an angular position which corresponds to the angular position of the step table 159 when in engagement with the pointer, thereby transmitting to the driving mechanism of the instrument either in multiplied or reduced degree, the galvanometer deflection relative to neutral or balanced position. Thus by this invention, a novel type of pointer gauging mechanism is provided, which, by virtue of the simplicity of construction and design, is inexpensive to manufacture, may be manufactured as standard parts with facility, is easy to assemble, is trouble free in operation, and yet provides the necessary accuracy and dependability of operation. The construction of the pointer gauging mechanism and the manner of mounting it in operative association with the other parts of the instrument, makes it readily possible to install, inspect and service the mechanism.

Mechanical relay system

As shown in Fig. 2, the shaft 174 extends to the right from the galvanometer gauging mechanism and is rotatably supported in the end plate 175, and carries adjacent the end plate 175 an arm 176. The shaft 174 extends beyond plate 175 and is supported for rotation in a stud carried by the end plate, on which stud the secondary pointer 177 is rotatably mounted. The parts referred to are shown more clearly in Figs. 23, 24, 26, 27 to 32. The arm 176, as shown in detail in Fig. 24, comprises the lever 179 and radius arm 180. The radius arm 180 is rigidly secured to the shaft 174 by a collar 178, the latter being attached to the shaft 174, and the arm 180 being secured to the collar 178 by a drive fit or otherwise. The lever 179 is journaled upon the collar 178. Lever 179 is provided with ears 181 having apertures and projecting laterally from the arm so as to accommodate a spiral spring 182 between ears in line with the apertures. A screw 183 threads into the spiral spring 182, the spring providing both receiving threads for the screw 183 and sufficient tension to frictionally hold the screw in adjusted position. The radius arm 180 is provided with slotted ear 184 which fits into a collar on the screw 183 above the upper ear 181, as shown in Fig. 24. Rotation of screw 183 angularly adjusts the lever 179 relative to the crank arm 180, thereby providing for a micrometer adjustment of arm 176 relative to the shaft 174. Angular movements of the shaft 174 are reproduced by projection 185 at the extremity of the arm 176 so that the position of the projection 185 corresponds to the position of the step table when in engagement with the galvanometer pointer, and according to the extent and direction of deviation of the galvanometer pointer from its balanced position.

The secondary pointer 177 is a sheet metal stamping of the shape shown in Fig. 23, and is provided with a collar 186 in register with apertures formed in the sides of the secondary pointer to accommodate the stud on which the secondary pointer is mounted for oscillation. A weight 187 is provided for counterbalancing the secondary pointer. The secondary pointer is provided in the body thereof, with a slot 188, and at the extremity thereof with a lateral projection 189. The secondary pointer 177 is so balanced as to tend to fall into contact with the projection 185 of arm 176, and accordingly when the secondary pointer is free to do so, it takes up a position corresponding to the position of the arm 176, and therefore corresponding to the direction and extent of galvanometer pointer deflection from balanced position.

It will be observed that the construction and operation of mechanism for positioning the secondary pointer 177 in correspondence with the position of the galvanometer pointer when its position is gauged, is such that its function is only one of positioning the secondary pointer 177 in correspondence with the position of the galvanometer pointer, and is not a function of driving any of the instrument parts such as the slide wire contactor or the recording and indicating mechanism. None of the driving force for operating the slide wire contact, and the recording and indicating mechanism, passes through the mechanism for positioning the secondary pointer from the position of the galvanometer pointer. By thus limiting the forces involved in the operation of positioning the secondary pointer, to only those necessary to manipulate the parts involved, it is possible to obtain a large motion multiplying ratio by virtue of the simplicity and the light weight of the parts involved, without affecting sensitivity, thereby permitting the use of a highly sensitive galvanometer. In order that the parts of the instrument, such as the recording and indicating mechanism, and the slide wire, may be operated positively, and be of sturdy construction, it is desirable that the driving force for operating those mechanisms be a considerable one, such that if applied to the galvanometer pointer it would make it necessary to construct a galvanometer pointer of much greater mechanical strength in order to withstand the load applied thereon, which would necessarily reduce the sensitiveness of the galvanometer. In order that adequate driving force may be employed for the efficient and unfailing operation of the parts driven thereby, the secondary pointer 177 is provided to stand in the place of the galvanometer pointer in that it takes up a position corresponding to that of the galvanometer pointer and is made of sufficiently sturdy construction as to withstand the load imposed thereon by the driving mechanism.

Inasmuch as it is desirable that the galvanometer be unrestrained for as large a proportion of time as possible, in order that it may follow more accurately and quickly the changes in the measuring force, the lost motion connection between the arm 176 and the secondary pointer 177 has been provided. By providing such a lost motion connection, the pointer gauging

mechanism may be maintained in contact with the galvanometer pointer only for so long a time as is necessary to position the secondary pointer 177 through the arm 176, and to clamp the secondary pointer in that position. Once the secondary pointer has been so clamped in adjusted position, the galvanometer pointer gauging mechanism may be and preferably is released, thus freeing the galvanometer pointer while the secondary pointer is maintained in clamped position and the driving operations proceed under the control of the secondary pointer.

As before explained, the rod 173 and shaft 174 are moved under the influence of the spring which lifts the step table into engagement with the galvanometer pointer. At other times the rod 173 is held downwardly thereby holding the step table and clamping table in disengaged position relative to the galvanometer pointer. In order periodically to hold the rod 173 in lowermost position and to free the rod 173 and shaft 174 to be operated by the step table, there is provided a crank 190 pivotally mounted on stud 190', fixed in the frame plate 175. Crank 190 has arm 191 carrying shoe 192 at its extremity to thrust against the projection 185 on the arm 176. (See Figs. 23, 26 and 27.) Another arm 193 of crank 190 carries roller 194 arranged to ride upon cam 195 fixed upon hub 196, rigidly carried by shaft 197, which, as shown in Fig. 2, is driven from motor 39 through a gear reduction 198. Motor 39 operates continuously to rotate the shaft 197 and cam 195. The position of the parts controlled by cam 195, as shown in Figs. 23, 26, and 27, may be considered as the initial position of the parts. With the cam 195 in the position shown in Figs. 23, 26, and 27, the crank 190, under the influence of spring 199 connected thereto, is urged in a direction to depress the arm 176 by virtue of the contact between shoe 192 of the crank 190 and projection 185 of the arm 176, thereby depressing the rod 173 which acts to maintain the step table and the pointer clamping table disengaged from the galvanometer pointer. As the cam 195 is rotated in a clockwise direction, as viewed in Fig. 26, the crank 190 is rotated about its pivot 190' rapidly so as quickly to release the arm 176, thereby permitting springs 158 and 171 of the pointer gauging mechanism to operate the pointer clamping table and the step table into engagement with the galvanometer pointer, thus angularly positioning the arm 176 and the secondary pointer 177 which is free for operation by the arm 176 into a position corresponding with the position of the galvanometer pointer when engaged by the step table. The rotation of the cam 195 lifts the shoe 192 free of the projection 185 to an extent shown in Fig. 29, where the roller 194 is shown as riding upon the high part of cam 195, thus providing sufficient clearance for the maximum upward adjustment of the arm 176 and the secondary pointer 177 corresponding to the lowest step on the step table of the galvanometer pointer gauging mechanism.

As pointed out before, it is desirable to clamp the secondary pointer 177 in adjusted position so that the arm 176 may be retracted and the galvanometer pointer freed for operation in accordance with variations in the measuring force. In order to clamp the secondary pointer in its adjusted position, there is provided a clamping arm 200 apertured at 201 to fit shaft 202 for pivotal support thereon. Spring 199 is connected to clamping arm 200 tending to urge it in a direction to clamp the secondary pointer 177. The clamping arm 200 is provided with two or more surfaces 203 generally transverse to the body of the secondary pointer. The clamping member 200 extends through slot 188 and when free to do so, one of the faces 203 is brought into engagement with the lower edge of the slot 188, thereby clamping the secondary pointer against movement. As the clamping arm 200 is shown in the drawings, a plurality of faces 203 are provided; however, for the purposes of the invention as disclosed in this application, it would be sufficient if two clamping faces 203 were provided for engagement with the lower edge of the slot 188. However, the part 203 performs its function equally well so far as the invention as disclosed in this case, is concerned, where a plurality of steps 203 are provided, the plurality of steps being for the purpose of effecting a control action where the instrument in this case is employed as a control instrument and the same part 200 being used for standardization in manufacture.

The clamping arm 200 carries a stud 204 projecting laterally from one face thereof. The stud 204 is arranged for engagement by ear 205 carried on or integral with lever 206 pivotally supported on stud 207 fixed in the frame plate 175 of the instrument. The lever 206 carries roller 208 arranged to ride upon cam 209 fixed upon hub 196 carried rigidly by shaft 197 continuously driven by motor 39. In the assembled instrument the cams 195 and 209 are fixed in relative angular position, the parts being formed as stampings with the necessary apertures to accommodate studs to fix the angular relation of the cams upon the shaft 197, the hub 196 being fixed upon shaft 197 by a force fit or in any other suitable manner. In the initial position of the drive parts, as shown in Figs. 23, 26, and 27, the lever 206 is supported by the cam 209 against the force of coil spring 210 tending to urge the lever 206 downwardly from the uppermost position in the range of positions occupied by the lever 206. In such position of the lever 206 the ear 205 acts through stud 204 to hold the clamping arm 200 out of clamping engagement with the secondary pointer 177. As the cams 195 and 209 proceed in their rotation, the cam 195 releasing the arm 176 so that the secondary pointer 177 may be positioned in accordance with the position of the galvanometer pointer, the lever 206 is allowed by rotation of cam 209 to move forwardly and downward so that the ear 205 permits the clamping arm 200 to move into clamping engagement with the secondary pointer 176 under influence of spring 199. The cams 195 and 209 are so relatively arranged in proportion, that the clamping arm 200 is allowed to move into engagement with the secondary pointer 177 while the shoe 192 is raised from engagement with the projection 185 on arm 176. Fig. 29 shows the arrangement of the drive mechanism at the point in the cycle at which the step table is in engagement with the galvanometer pointer and the secondary pointer 177 is held in position by arm 176. As rotation of cam 209 proceeds slightly further from the position shown in Fig. 29, the clamping arm 200 moves into engagement with the secondary pointer 176 and further movement of the cams 195 causes crank 190 to depress the arm 176 and the step table. The position of the parts, as shown in Fig. 29, is shown partially in elevation in Fig. 30. The clamping action on the secondary pointer is illustrated in Fig. 31, where the secondary pointer

177 is being clamped in the position corresponding with the last gauged position of the galvanometer pointer available for controlling the operation of the drive mechanism. The projection 189 on the secondary pointer 177 is arranged for cooperation with a finger 211 carried by the lever 206, in any suitable manner as by being riveted thereto, or integral therewith. The finger 211 is provided with a series of steps 212 arranged with the faces thereof adapted for engagement with the rear edge of the projection 189 on the secondary pointer 177. In Figs. 23, 29, and 32 the secondary pointer is shown in dot and dash line, in transposed position, in which it is in operative relation with the step finger 211. The finger 211 has the steps 212 arranged thereon in two series diverging from a foremost step 213 which corresponds with the neutral step of the step table of the galvanometer gauging mechanism, that is, when the galvanometer pointer is in balanced position so that the neutral step of the step table engages the pointer during the gauging operation, the secondary pointer 177 is so positioned that upon operation of the lever 206, the foremost step 213 of the finger 211 engages the projection 189 of the secondary pointer 177. Deviations of the galvanometer pointer from the balanced position in either direction set the secondary pointer 177 in such a position as to engage a corresponding one of the corresponding series of steps on the finger 211. When the step table engages the galvanometer pointer on a high step, the finger 211 engages the projection 189 on the secondary pointer on one of the lower steps, as viewed in Fig. 26. Likewise, when the step table engages the galvanometer pointer on one of its lower steps, the secondary pointer is so positioned that the finger 211 engages the projection 189 on one of its upper steps, treating the step 213 as the center step. Inasmuch as the steps 212 are arranged in series receding from the center step 213, the position of the secondary pointer 177 which determines which of the steps 212 is engaged, determines the extent of stroke of the lever 206, the stroke being a minimum when step 213 is engaged, and being successively greater as steps 212 successively further removed from step 213 are engaged, corresponding to steps on the step table of the galvanometer gauging mechanism successively further removed from the neutral step; that is, the extent of stroke of the lever 206 corresponds to the extent of deflection of the galvanometer pointer from the balanced position.

The motion of the step lever 206 is transmitted by links 214 and 215, pivotally mounted by pins upon arms of the lever 206. Links 214 and 215 are pivotally connected by pins to radius arms 216 and 217, which are pivoted for oscillatory movement about the shaft 202. Pawls 218 and 219 are pivotally carried on the extremities of radius arms 216 and 217, and are arranged to engage the teeth of wheel 220 rigidly connected to a driving shaft 202. Pawls 218 and 219 are provided with recesses 221 at the opposite side of the pivot pins from the teeth thereof. Pins 222 are carried by radius arms 216 and 217 over which the recesses 221 ride. It will be observed by inspection of Figs. 26 and 27, that when the lever 206 is in its initial position, the lines connecting the pivot pins for the links 214 and 215 each pass substantially through the center 207, about which lever 206 is pivoted for oscillation. The lines passing through the pivots of links 214 and 215, may pass slightly to the left of the pivot, as viewed in Fig. 26; and it will be observed that upon forward motion of the lever 206, as viewed in Fig. 26, the links 214 and 215 will be moved so that the lines connecting the pivot pins of said links will pass through the pivot pin 207; thus the links 214 and 215 are arranged to pass over a dead center at the beginning of the oscillatory motion of the lever 206, so that the initial movement of the lever 206, while imparting corresponding movement to those ends of the links 214 and 215 which are connected to the lever 206, does not impart any appreciable movement to the radius arms 216 and 217 by virtue of the fact that the links 214 and 215 pass over the dead center. Thus a motion of the lever 206 is provided, which is substantially independent of the motion of the radius arms 216 and 217, and pawls associated therewith, which motion may be used to effect adjustments in the drive mechanism which necessarily are preliminary to the driving action.

The lever 206 and the clamping arm 200 are so relatively constructed and arranged that the initial movement of the lever 206 effects the clamping operation of the arm 200 during the time that the links 214 and 215 are passing over the dead center. The arm 200 has fixed rigidly thereto, a collar 223 rotatable about the shaft 202. A leaf spring 224 is secured to the collar 223 as by a screw or in any other suitable manner. The leaf spring 224 extends between cheeks 225 of the pawls 218 and 219. When the drive parts are in their initial position, as shown in Figs. 23, 26, and 27, the end of the leaf spring 224 is clamped between the cheeks 225 of the pawls 218 and 219, the teeth of the pawls 218 and 219 being juxtaposed and the pawls being rotated about their pivotal support on arms 216 and 217 until stopped by coaction with pins 222. As the lever 206 moves forwardly from its initial position, allowing the clamping arm 200 to move into engagement with the secondary pointer 177, the movement of the arm 200 flexes spring 224 according to the step 203 which engages the secondary pointer 177; that is, if the secondary pointer be in a raised position with respect to its neutral, one of the foremost steps 203 will engage the secondary pointer, thereby arresting the movement of the arm 200 at an early stage of its movement and flexing the spring 224 in a direction tending to exert a force upon the cheek of pawl 218 (Fig. 27). On the other hand, if the secondary pointer be in a position beneath the neutral position, as viewed in Fig. 27, the clamping arm 200 will be moved a maximum distance in order to engage and clamp the secondary pointer, thereby flexing the spring 224 in a direction such as to apply a force to the cheek of pawl 219. If the secondary pointer be adjusted to the neutral position, the intermediate step of the clamping member 200 will engage it thereby affording clamping movement of the arm 200 such as to leave the spring 224 substantially unflexed. For reasons which will later appear, the neutral step on the clamping member 200 could be omitted for the purposes of this invention. It is convenient to provide the neutral step on arm 200 as a standard, however, inasmuch as it performs a control function when the instrument of this invention is used as a control instrument.

Inasmuch as the clamping arm 200 is moved into engagement with the secondary pointer at the time when links 214 and 215 are passing over dead center, the selecting force acting upon pawls

218 and 219 through spring 224, is effective at that time, so that the particular pawl selected for engagement with the wheel 220 is determined before any driving movement of the pawls is effected. That action is illustrated in Fig. 31, where the pawl 219 has been selected by virtue of the fact that the secondary pointer is below its neutral position, thereby permitting a maximum rotation of the clamping arm 200, and a flexing of the spring 224 in such a direction as to apply a selecting force to the cheek of the pawl 219. As the links 214 and 215 pass over dead center with the forward motion of the lever 206, the pawl 219 moves radially of the wheel 220 into engagement with the teeth thereof, thus the motion of the lever 206 is made to effect the selecting action on the pawls 218 and 219 independently of the driving action. The continued forward movement of the lever 206, under the influence of cam 209 and spring 210, operates through link 215, radius arm 217, and pawl 219, to drive the wheel 220 in a counterclockwise direction, as viewed in Figs. 27 and 31. The position of the drive parts at the completion of the driving operation, is illustrated in Fig. 32. The engagement of one of the steps 212 of the finger 211 with the projection 189 on the secondary pointer 177, limits the extent of stroke of the lever 206, and thereby determines the extent of operation of wheel 220. The wheel 220 is operated to an extent which corresponds to the extent of deflection of the galvanometer pointer from balanced position. The operation of the pawl selecting mechanism, as before described in accordance with the direction of deflection of the secondary pointer relative to its neutral position, causes the wheel 220 to be driven in a direction corresponding to the direction of deflection of the galvanometer pointer from balanced position; thus a movement of the wheel 220 is effected which corresponds both in direction and extent to the direction and extent of deflection of the galvanometer pointer from balanced position.

The pawls 218 and 219 are supported pivotally at a point within the edge of wheel 220 that is engaged by the pawl teeth, and the pawl teeth, when in engagement with the periphery of wheel 220, lag behind the pivot points for the pawls in the driving movement of the pawls. By virtue of the mounting of the pawls relative to the periphery of the wheel 220, the driving force exerted on the pawl through the pivot thereto, sets up a component of force on the pawl tooth directed inwardly and radially of the wheel 220, which maintains the pawl tooth in engagement with the periphery of the wheel. When the limit of stroke of the lever 206 has been reached, as shown in Fig. 32, further rotation of cam 209 eventually returns the lever 206 to its initial position, the cam 195 effecting no motion of the crank 190 during the return movement of the lever 206 to initial position. As the lever 206 starts back toward initial position, the driving force acting through the pivot on pawl 219, sets up a component of force radially and outwardly with respect to wheel 220, which moves the pawl tooth free from the periphery of wheel 220. The balance of the pawls 218 and 219 is such that when free from engagement with the periphery of wheel 220, they tip into a position such as that shown for pawl 218 in Fig. 31 where the pawl tooth is free from the periphery of the wheel and the pawl rests against pin 222. The return movement of the lever 206 is completed with both pawls free of the periphery of the wheel 220. In the forward movement or driving stroke of the lever 206, the unengaged pawl 218 remains disengaged by virtue of its balance.

It is evident from an understanding of the construction and operation of the drive mechanism so far described, that this invention provides for the utilizing of parts made largely of sheet metal stampings, which in stamped form may be assembled in relative relation, thus providing a construction inexpensive to make and easy to assemble. The drive of this invention is so constructed, that so far as possible the several elements thereof are made to perform a plurality of functions both by virtue of a construction of the individual elements, and by virtue of the manner of operation of the assembly, thereby making for simplicity in construction and operation which affords a maximum of dependability and accessibility for inspection service and repair.

Slide-wire assembly, operation, and calibration

As pointed out hereinbefore, a condition of unbalance of the potentiometer measuring circuit is compensated for by adjustment of the slide wire resistance, and it is a function of the driving mechanism of the potentiometer operating in accordance with the extent and direction of galvanometer deflection from the balanced position, to adjust the slide wire resistance automatically so as to bring the potentiometer circuit into electrical balance. Accordingly a motion of the wheel 220 in accordance with the extent and direction of galvanometer deflection from balanced position, is transmitted through shaft 202 to gear 226, which is arranged to mesh with gear 227 of the slide wire unit. The slide wire unit is illustrated in assembled relation with other parts of the instrument, in Figs. 1, 2, 3, and 23, and is illustrated as a unit in Figs. 18 to 22. The gear 227 driven from wheel 220, has collar 228 carrying set screws for rigidly securing the gear 227 onto shaft 229. Shaft 229 is journaled in hollow shaft 230 to which is secured by a set screw, or in any other suitable manner, a hub 231 of serrated wheel 232. Hollow shaft 230 is journalled in collars 233 in the stationary tube 234. A collar 235 is secured to the shaft 229 by a set screw and is interposed between gear 227 and wheel 232 so as to maintain shaft 229 in place when gear 227 is removed. The tube 234 is secured as by molding or in any other suitable manner into the molded support 236. Molding 236 has top portion 237 adapted to form a cap for the slide wire unit and a cylindrical body portion 238 depending from the top portion 237. The cylindrical portion 238 is hollow and the members 229, 230, and 234 extend axially therethrough. The cylindrical portion 238 is formed, by molding, with a pair of helical grooves 239, which extend from top to bottom of the cylindrical portion, and which are adapted to receive a pair of coiled electrical resistors 240. The electrical resistors 240 are wound upon a body member of wire 241, the ends of which are clamped beneath plates 242 by pressure exerted, the screws 243 securing the plates 242 to the molding, screws being threaded into the molding. The coiled resistors 240, when tightly arranged in the helical grooves 239, and the ends thereof secured by clamps 242, are adequately supported by the cylindrical body 238 of the molding. The resistors 240 are evenly spaced throughout their length to provide a track 244 in which the slide wire contact 245 may ride. The contact 245 is a small cylindrical body of

electrical conducting material of a size to span the track 244 formed between the resistors 240 and complete an electrical circuit therebetween, the resistors being bare along the points of contact. Roller 245 is arranged to ride in slot 246 in the frame 247, the roller being provided with reduced projections or pins 248, which engage the inner faces of the plate 247 adjacent the slot 246 and prevent the roller or contact 245 from passing through the slot 246. Slot 246 extends transversely with respect to the track 244, and the plate 247 is urged by spring 249 disposed about the axle for the plate and cooperating with the supporting frame 250 and the plate 247, so that the contact 245 is maintained in position between the slot 246 and the track 244 as the contact moves over the resistors. The track 244 provides a guide for moving the contact throughout the length of the resistors. Supporting frame 250 is molded into and supported by the arm 251 having a bushing 252 molded thereinto, in which the end of shaft 229 is secured by a force fit, or in any other suitable manner. Movement of the shaft 229 by gear 227, in response to movements of the wheel 220, sweeps the supporting frame 250 over the surface of the helically arranged resistors 240, carrying the contact 245 along the track formed between the resistors, thereby adjusting the amount of electrical resistance in the measuring circuit of the potentiometer, resistors 240 corresponding to resistors 4 and 17, illustrated diagrammatically in Fig. 43, and the contact 245 corresponding to the contact 18, as illustrated diagrammatically in Fig. 43. At the bottom of the cylindrical body of the molding 238 is formed a pair of grooves adapted to accommodate a resistor 253 of the same type and mounted in the same manner as resistors 240. The resistor 253 is formed in two parallel portions providing a track therebetween in which the contact 254, similar to contact 245, rides, being supported thereagainst by the plate 255, having a slot therein to accommodate the contact 254. Plate 255 is carried upon arm 256 rigidly connected to the hollow shaft 230. Manipulation of the serrated wheel 232 sweeps the plate 255 over the resistors 253, carrying the contact 254 along the track therebetween to adjust the electric resistance thereof. The resistor 253 and contact 254 correspond with the resistor 2 and its adjustable contact, as illustrated diagrammatically in Fig. 43. Adjustment of the contact 254 is effected by the manual manipulation of wheel 232 in order to standardize the current flowing through the potentiometer measuring circuit.

The electrical connections for the resistors 240 and 253 are made by conductors 257 passing through apertures formed in the wall of the cylindrical molding 238 and united to the resistors by soldering or in any other suitable manner. As shown diagrammatically in Fig. 22, the conductors 257 are joined to the lower extremities of conducting rods 258, which extend into the molded cylinder 238. The conducting rods 258 are molded into the material of the cap 237 of the molding 236 and project above the surface thereof, as shown in Fig. 21. A plurality of horizontally arranged conducting rods 259 are embedded in the body of a molding 260 adapted to be secured to molding 236 by screws 261, or in any other suitable manner. When the molding 260 is secured upon molding 236, the conductors 259 make connection with the terminals of conductors 258, the two being united by screws or soldering, or in any other suitable manner. As shown more clearly in Fig. 22, some of the rods 259 are upturned at their other extremities, as indicated at 262, to form supports and electrical connections for spools 263 of electrical resistance wires which are connected into the potentiometer circuit in any suitable manner and may constitute resistances such as 3, 5, 6, 7, and 8, shown diagrammatically in Fig. 43 of the drawings. Suitable electrical conductors 264A are provided for joining the resistance spools electrically. Other of the conducting rods 259 extend downwardly and are provided with connecting clips 264, as shown in Figs. 18 and 22. The molding 236 is provided with apertures 265 to accommodate bolts 266 passing therethrough into threaded engagement with the frame 47 of the instrument, thereby mounting the slide wire unit upon the frame. Separately attached to the frame 47 is a molding 267 in which are embedded conductors 268, so arranged that when the molding 260 is secured in place upon the molding 236 and attached to the frame 47, the projections 264 of conducting rods 259 are juxtaposed to the conductors 268, as shown in Figs. 3 and 18, where the conductors 264 and 268 may be united electrically by means of screws or in any other manner. The molding 267 provides a passage 269 between itself and a portion of the instrument frame 47, which accommodates the cable of conductors extending from the terminal block 32 for the measuring leads. The conductors are connected to the conducting bars 268 to place the slide wire resistance, resistors 240, and the calibrating resistance 253 in the electrical measuring circuit.

As before described, in normal operation of the circuit, the switch 11 is in engagement with contact 12 (referring to Fig. 43). When it is desired to standardize the current flowing in the potentiometer circuit, switch 11 is moved into engagement with contacts 21 and 22. The switch for performing the last mentioned functions may be and preferably is arranged in association with the slide wire and the standardizing resistance. Such a switch is indicated generally at 270, in Figs. 18 and 19. The contacts 271 for the switch 270 are formed as illustrated most clearly in Fig. 22, by bending up a portion of certain of conductors 259 so that the bent up portions are exposed at the surface of the molding 260. Switch blade 272 is of the spring type adapted to press against the contacts 271 and is carried by shaft 273 having a flat thereon adapted to prevent rotation of parts mounted thereon relative thereto. The switch blade or brushes 272 fit over the shaft 273 and are secured thereto by bolt and nut 274. The shaft 273 is carried in the top wall of a molded cap 275, being secured thereto by the bolt 274. Cap 275 is arranged to cover the switch contacts 271 when secured in position upon the molding 260 by screws 276. A rider 277 fits over the switch blade or brushes 272 and presses against the bottom surface of the top wall of the molding 275 to wipe the brushes against the contacts 271. Stops 278 are formed in the material of the cover 275 to limit the stroke of the switch, the stops cooperating with a handle 279 of the switch.

Inasmuch as the calibrating resistor should not be adjusted at any time other than when the switch is in such position as to connect the calibrating resistor and standard cell in series with the galvanometer, it is desirable to lock the wheel 232 against movement when switch 270 is in the position placing the galvanometer in the measuring circuit. A spring 280, arranged along the wall of the molded cap 275, thrusts the switch blade 272 to the left, as shown in Fig. 19, in which position

the galvanometer is placed in the measuring circuit. The operating handle 279 of the switch is provided with a projection 281 arranged to engage with the serrated periphery of the wheel 232 when the switch is in the position illustrated in Fig. 19. When it is desired to standardize the current in the potentiometer circuit, the operating handle 279 is manipulated manually to move the switch blade in a clockwise direction, as viewed in Fig. 19, thereby placing the galvanometer in series with the calibrating resistor and standard cell, and at the same time moving the projection 281 out of engagement with the wheel 232 so that adjustment of the calibrating resistor 253 may be effected manually. When the current has been calibrated, the switch handle 279 is released and the spring 280 moves the switch blade to that position placing the galvanometer in the measuring circuit and moving the projection 281 into locking engagement with the wheel 232.

Inasmuch as the resistance of the slide wire resistor, which is placed in circuit at the time that the potentiometer circuit is in balance, constitutes the measure of the electromotive force under measurement, it is highly desirable to protect the slide wire resistor, and for similar reasons to protect the calibrating resistor from mechanical injury and accumulation of foreign material which would tend to change the resistance thereof, or to cause deterioration thereof. It is also desirable, in order to attain great sensitivity, to provide a slide wire resistor of great length, and accordingly, by arranging the slide wire resistor as a helix upon a cylinder, as illustrated in Figs. 18 and 20, it becomes possible to employ a slide wire of great length arranged in such a compact manner as to afford opportunity for enclosing the slide wire resistor and immersing it in a bath of insulating oil to protect the same. The arrangement of the cylindrical molding 238 in a vertical position, when the slide wire unit is arranged in the frame of the instrument, allows the use of a cup-like vessel 282 arranged to fit a rim 283 formed in the material of the molded cap 237, from which the cylindrical molding 238 depends. Recesses 284 (see Figs. 18 and 19), are formed in the molded cap 237 to accommodate the turned-in ends 285 of a wire bail 286, which extends beneath the vessel 282. A snap acting clamp 287 is arranged on the bail 286 to engage the bottom of the vessel 282 and force the same into sealing engagement with the rim 283 on the top of the molding 237, as shown in Fig. 18. By manipulation of the clamp 287, the bail 286 may be freed so that it may be swung out of the way and the vessel 282 removed. The vessel 282 may and preferably does contain oil rising to a height sufficient to immerse the resistors on the cylindrical projection 238. A plug 288 is threaded into the cap 237 and may be removed to add oil to the vessel 282.

The molded cap 237 is provided with a projection 289 (see Figs. 18 and 20) arranged to form a guide for the upper end of the plate 247, so that when the contact 245 approaches either end of the track formed by the resistors 240 and might tend to ride up over the clamps 242, the projection 289 supports the plate 247 against such an outward thrust, thereby preventing the contact 245 from riding free of the track 240 at the ends thereof. The molding 236 is provided with a lug 290 (see Fig. 18), which, in cooperation with frame 47 of the instrument, provides a bearing for the shaft 174.

That portion of the frame 49, on which the slide wire unit is mounted, is provided with a recess 291 into which the standard cell 50 fits. The projection 267 on the molding 236, carries a clip 293 arranged to press against the standard cell and hold it in place.

The slide wire unit described hereinabove, embodying the features of this invention, is formed largely from molded parts which may be constructed with a minimum of labor and material, and when formed, requires no further fabricating operations thereon, and wherever possible, the other parts have been supported in said moldings by being embedded therein. By employing such moldings the number of parts has been reduced to a minimum thereby simplifying the operation of the assembled parts of the unit, and by arranging the support for the resistors as a vertical cylinder the use of an immersed slide wire of great length is made possible, the electrical and mechanical parts which are operatively associated in the potentiometer circuit are assembled for convenience of operation in the unit, providing an exceedingly compact construction, reliable in operation, readily accessible for inspection and repair, and convenient for mounting in operative association with the other parts of the potentiometer instrument. Many novel details of construction of the parts of the unit, and their manner of assembly, afford greater efficiency and accuracy, and convenience of operation of the unit. As shown in Figs. 1 and 2 of the drawings, the slide wire unit is assembled on the instrument frame in a position where its condition and operation may readily be observed, where the switch 270 is conveniently available for operation from the front of the instrument, and where the standardizing resistor may be conveniently manipulated from the front of the instrument. The electrical parts of the instrument, namely the galvanometer, the slide wire unit, the resistors associated therewith, and the standard cell, are arranged in a convenient, compact group readily accessible for making the electrical connections, and conveniently arranged for servicing, being available in every particular from either the front or back of the instrument and being demountable from the frame as suitable units, thereby facilitating replacement of parts.

The resistance of the slide wire resistor is varied by an adjustment of the contact 245, through operation of gear 227 from gear 226 on the shaft 202, which is turned by wheel 220, thus the contact 245 is adjusted to vary the proportion of the potentiometer slide wire resistance in the galvanometer circuit in accordance with the direction and extent of the deflection of the galvanometer pointer from the balanced position so that with each cycle of operation of the potentiometer drive mechanism an adjustment in the slide wire resistance is made, which to a high degree of approximation brings the potentiometer circuit back into a state of balance. Due to the construction of the step table for engaging the galvanometer pointer, whereby the maximum of sensitivity is attained when the galvanometer pointer is closely adjacent to balanced position, the instrument operates to make a rough adjustment of the slide wire resistance tending to balance the potentiometer circuit when the deviation from balance is large, and when a condition of balance in the potentiometer circuit is approached the operation of the drive in response to condition of unbalance becomes highly sensitive and produces an accurate adjustment of the

slide wire resistance to bring the potentiometer circuit into balance.

Pen carriage

Inasmuch as the resistance of the slide wire is varied until a state of balance is attained, the position of the slide wire contactor, when the potentiometer circuit is in balance, produces a measure of the value of the measured electromotive force, and by positioning an indicating, recording, or other exhibiting element, relative to a scale or chart, in accordance with the position of the slide wire contact, the value of the electromotive force being measured may be exhibited.

Heretofore it has been a common practice in the potentiometer art to operate such an exhibiting element directly from the mechanism determining the position of the slide wire contact, thus in the type of potentiometer instrument illustrated in Fig. 23, if the old practice were followed, the pointer or pen carriage could be adjusted from the shaft which proximately is connected to and adjacent the slide wire contact, or to some other part proximately connected with the slide wire contact. By so operating the exhibiting element, there is an accumulation of lost motion throughout the drive system for operating the slide wire contact and from that point on to the mechanism for driving the exhibiting element, which additively combines the errors due to lost motion in the system. In order to avoid such an accumulation of errors due to lost motion, the potentiometer of this invention has been designed so that the drive for the exhibiting element is taken from the first part of the mechanism which is adjusted in accordance with the extent of unbalance in the potentiometer circuit from the galvanometer, namely, the wheel 220. Inasmuch as wheel 220 is the first in a series of elements leading to the slide wire unit, which is operated into positions corresponding to potentiometer balance or unbalance, no chance for lost motion in that part has occurred. Accordingly, gear 294 (see Fig. 23) is arranged to mesh with wheel 220 and be driven thereby. Gear 294 is fixed upon shaft 295 provided with a spiral groove 296, the shaft 295 extending between end plates 175 and 297 of the instrument across the front thereof. The shaft 295 is journalled in suitable bearings 298 secured to the end plates of the instrument. The exhibiting means 299 is adjustable lengthwise of the shaft 295 and comprises a carriage 300 having ears 301 apertured to receive the shaft 295 therethrough, and having forwardly projecting arms 302 carrying lugs 303 adapted to rest upon the surface 304 of bar 305 extending between the end plates of the instrument parallel with the shaft 295. The bar 305 and the shaft 295 support the carriage for longitudinal movement thereof. (See Figs. 1, 2, 23, and 40.) Since the drives from wheel 220 to the slide wire contactor and to the pen carriage are parallel, the lost motion occurring in the two parallel transmission systems tends to balance out.

The form of carriage for the exhibiting element shown in Fig. 40, is like that shown in Figs. 2 and 23. The type of marking element illustrated in Figs. 1, 2, and 3 consists of a fountain pen 306 hung from the carriage by a clip 307 with the needle 308 of the pen resting upon the surface of a recording chart 309 arranged to pass continuously under the point 308.

The bar 305 affords a convenient support for an indicating scale 310, with which the pointer 311 associated with the pen 306, cooperates to indicate the value of the quantity being ultimately measured, such as temperature. It is apparent from the description of the potentiometer slide wire unit, that the variation of the electrical resistance of the unit is in direct proportion to the position of the contact relative to the resistor. Accordingly, where the law of variation of the quantity ultimately measured, such as temperature, is not a linear one with respect to the electromotive force created as the measuring force, correction for the non-linear relation between the temperature and the generated electromotive force, may be allowed for in the scale and chart markings. Scale 310 is secured upon the bar 305 by screws 312 passing through slots in the scale and threaded in the bar 305. Where the instrument is used as a recorder for making a single record, the type of record making pen illustrated in 306 in Fig. 23, is used. Where the instrument is used as a multiple recorder for making a plurality of records the type of record making element as illustrated in Fig. 40, is employed.

Chart feed roller drive

The chart 309 is advanced by roller 313, carried upon shaft 314, the roller being rigidly secured to the shaft 314 by end plates 315, having collars 316 accommodating set screws for engagement with the shaft 314. Shaft 314 is journalled in the end plates 175 and 297 of the instrument, suitable bearings being supported by the end plates for that purpose. One end of the shaft 314 has a knob 317 secured thereto by a set screw, or in any other suitable manner, so that the roller 313 may be rotated by manipulation of knob 317 in order to properly position the chart 309 with respect to the marking element 306, the charts usually being graduated lengthwise in terms of time.

In order to drive the chart 309 at a regular time rate, a gear 318 is journalled upon the shaft 314, and a friction clutch 319 of the spring plate type, is pinned, as indicated at 320, to a head 315 of the roller 313. The spring rides in and thrusts against a collar carried by the gear 318. The friction between the clutch 319 and said collar is such that the driving force transmitted from the gear 318 normally drives the roller 313 and chart advanced thereby. The clutch 319 is provided in order to allow for manual adjustment of the roller 313 relative to its drive mechanism. The gear or worm wheel 318 is driven from a worm 321 carried rigidly upon shaft 322, journalled in a bracket 323 secured to the end plate 175 of the instrument (see Figs. 23, 27, and 29). The worm drive for the worm wheel 318 prevents the movement of wheel 318 during manual rotation of the roller 313, so the clutch is provided in order to permit manual adjustment of the chart position. Shaft 322 has rigidly fixed thereto a ratchet wheel 324. A pawl 325 is arranged to engage with and operate the ratchet wheel 324 in one direction, the pawl being pivotally supported on a rocker arm 326 and urged toward the ratchet wheel by spring 327 fixed upon the rocker arm 326 and connected to the pawl 325. The rocker arm 326 is provided with an aperture through which the shaft 322 extends, affording a journal for the rocker arm upon that shaft. A spring 328 connected to bracket 323 is looped about the shaft 322 and connected as at 329 to the rocker arm 326. Spring 328 urges the rocker arm 326

in clockwise direction, as viewed in Fig. 28, the movement of the rocker arm 326 being limited by engagement with the bracket 323 which serves as a stop. The spring plate clutch 330 is spaced between one arm of the bracket 323 and the ratchet wheel 324 in order to frictionally hold the ratchet wheel 324 and the shaft 322 against rotation when the pawl 325 is moved in a clockwise direction. Rocker arm 326 carries a wheel 331 mounted for pivotal adjustment thereon and adapted to remain in adjusted position by frictional engagement with the surface of the arm. The wheel 331 is provided with a plurality of faces 332 along its periphery at various radial distances from its axis of rotation. The crank 190, oscillated periodically by the cam 195, is provided with an arm 333 adapted, during the stroke of the lever 190, to strike with one of the faces 332 of the wheel 331 positioned thereunder. The movement of wheel 331, under the driving action of the wheel 333, rocks the rocker arm 326 in a counterclockwise direction, as viewed in Fig. 28, and acts through pawl 325 to advance the ratchet wheel 324, thus driving shaft 322, and through worm 321 and worm wheel 318 drives the chart roller 313.

The movement of the lever 190 under the influence of cam 195, is made at regular time intervals, inasmuch as the shaft, upon which cam 195 is carried, is driven from the constant speed motor 39. The operation of lever 190 in a regular time cycle, drives the chart roller 313 at a definite speed. Inasmuch as the arm 333 of lever 190 engages the wheel 331 intermediate the limits of its oscillatory movement, and since the wheel 331 is carried with the arm 332 to the lower limit of the movement of the arm 333, it is possible to adjust the proportion of the stroke of the arm 333 during which the wheel 331 is driven by turning the wheel 331 about its pivot to present a different one of the faces 332. Since the faces 332 are at different radial distances from the pivot of the wheel 331, the arm 333 will engage the wheel 331 at an earlier or later point on its downward stroke, according to which of the faces 332 is presented by the engagement of the arm 333. By thus varying the stroke of the wheel 333, the stroke of the pawl 325 is varied, and the extent of driving movement imparted to the chart roller 313 for each oscillation of the lever 190 is varied, thus varying the rate of chart feed.

Chart feed

The chart drive roller 313 is provided at its margin with projections 334, which project through apertures 335 in the margins of the chart and afford a driving engagement between the chart drive roller 313 and the chart 309. Guards 336, mounted upon the end plates of the instrument, press the margins of the chart paper against the surface of the roller 313 adjacent the projections 334 and prevent disengagement of the chart paper from the roller 313 and slipping relative thereto. The chart 309 is drawn from a supply roll 337 (see Fig. 27), which is carried upon a core drum 338 supplied as a part of the chart roll. The construction of roll mounting, shown in Fig. 33, is that for the re-roll but except for the sprocket and chain drive, the construction of the chart supply roll mounting is the same as that illustrated in Fig. 33, and reference is made to Fig. 33 for an understanding of the mounting for the supply roll 337. As shown in Fig. 33, the head 339 fits into the end of the core drum 338. The head 339 is carried upon a shaft 340 and a collar 341 is provided which thrusts against the face of end plate 297 of the instrument, spacing the head 339 from the end plate. Bearing 342 is provided in the end plate 297, to which the shaft 340 is journalled. At the other end of the core drum 338 is a disc 343 fitting into the end of the drum. The disc 343 is provided with a depression 344 adapted to receive the end of shaft 345, which extends through and is journalled in the bearing 346, carried by the end plate 175 of the instrument. A blade spring 347, (see Figs. 33 and 26) is provided with a slot 348 having an eye through which the end of the shaft 345 may be inserted, the end of the shaft 345 being provided with a groove adapted to fit into the slot 348. The spring 347 presses the shaft 345 against disc 343, thereby holding the disc 343 in position at the end of the core drum 338 and forcing the other end of the core drum 338 into supporting relation with the head 339. A disc 348' fixed on the shaft 345 fits snugly into the cup-like depression of the disc 343 in order to guide the shaft 345 with respect to the disc 343. The mounting for the core drum 338 not only produces a rotatable support therefor, but provides a frictional drag between the hub 341 and the end plate 297 of the instrument, or between head 339 and drum 338, so that as the chart 309 is drawn from the roll 337 the friction in the mounting for the roll 337 prevents the paper from becoming slack.

As shown in Fig. 27, the re-roll 349 is mounted in the end plates 175 and 297 and supported by a spring 350 similar to spring 348. In the case of the re-roll, the hub 341 is provided with a sprocket 351 and a chain 352 is trained over the sprocket 351 and another sprocket 353, (see Fig. 1 of the drawings). The sprocket 353 is rigidly carried upon the shaft 314 of the chart drive roller 313. The sprockets 351 and 353 are so proportioned that the re-roll 349 is driven at a rate sufficient to take up the chart paper 309 as rapidly as it is fed thereto, when the first few layers of chart only are drawn upon the re-roll 349. As the chart passes from the feed roll 337 to the re-roll 349, increasing the effective diameter of the re-roll, the excess of periphery speed of the re-roll over the rate at which the chart is fed by the chart drive roll 313, is allowed for by slippage between the head 339 and the core drum 338, sufficient friction existing between the head 339 and the core drum 338 to always keep the paper taut.

The chart drive construction and the mounting for the take-off roll, and the re-roll, are such as to afford facility and economy of manufacture, reliability of operation, and simplicity of construction affording ready accessibility for inspection, replacements and repair of the parts. As it is apparent from an understanding of the drive construction and the take-off roll, and the re-roll construction, wherever possible the individual parts are designed and associated so as to perform a multiplicity of functions, thereby rendering the design one of mechanical simplicity.

Compensation for paper expansion

The usual material for recording charts being paper, the charts are subject to dimensional change with changes in ambient conditions, such as humidity. The apertures 335 in the left margin of the chart are elongated to allow for the expansion of the chart paper relative to the roller 313. The apertures 335 at the right end

of the roller 313, as viewed in Fig. 1, fit the projections 334 so as to fix the right margin of the chart paper against lateral movement with respect to the roller 313. Expansion of the material of the chart shifts the chart lines relative to the record being made by the record member and so introduces an error in the record. In order to accommodate for that error it is desirable to move the pen to an extent and in a direction corresponding with the extent and direction of dimensional change in the chart at the point where the record is being made.

In order to provide a compensating force operating in accordance with the changes in ambient conditions, which dimensionally affect the chart, a sample of the chart paper 354 is mounted upon the instrument adjacent to the chart paper where it is subjected to the same ambient conditions as the chart paper. One end of the strip 354 is fastened in clip 355 pivotally supported at 356 on arm 357 pivoted to plate 358 (see Figs. 1 and 27), supported in the end plates of the instrument. The other end of the arm 357 is adjustably secured in position by eccentric screw 359 cooperating with a slot in the lever 357, and mounted for rotation in the plate 358. The other end of the strip 354 is connected to a clip 360 (see Fig. 42) pivotally mounted on a bell crank 361 pivoted at 362 upon plate 358. The arm of the bell crank 361 distant from the clip 360, engages arm 363 of a bell crank which is pivoted on end plate 297 as indicated at 364, and the other arm 365 of which (see Fig. 40) is pivotally connected at 366 to projection 367 carried upon the bar 368 extending transversely of the instrument, parallel and adjacent to the spiral shaft 295. As shown in Fig. 40, the carriage 300 for the exhibiting and recording elements, is adjustable longitudinally of the shaft 295 by rotation thereof, there being a follower mounted on the carriage 300 and fitting into the spiral groove of the shaft 295. The carriage 300 supports a shaft 369 arranged parallel to the spirally grooved shaft 295. The marking element 370 is carried upon the shaft 369 for movement longitudinally of the shaft 369. The spiral spring 371 about the shaft 369 presses at one end against a portion of carriage 300, and at the other end against a lug 372 on the marking element 370, thereby urging the marking element 370 in a right hand direction, as viewed in Fig. 40. A bell crank 373 is pivoted at 374 upon the carriage 300 and is provided on one arm with a roller 375 riding upon the face of bar 368. The other arm of the bell crank 373 thrusts against the lug 372, spiral spring 371 applying a force through lug 372 onto the bell crank 373, urging the roller 375 against the bar 368.

Expansion and contraction of the sample of chart paper 354 moves the arm 365 of the bell crank 364, thereby moving the left end of the bar 368, as viewed in Fig. 40, toward or away from the spirally grooved shaft 295. Movement of bar 368 in response to changes in humidity, acts through the bell crank 373 to adjust the marking element 370 relative to its carriage 300, in a direction and to an extent such as to compensate for the movement of the chart due to expansion or contraction at the point at which the record is made. Inasmuch as the movement of the bar 368 is effected at the left end only, the right end being mounted for pivotal movement only, the extent of the compensating adjustment of the marking element 370, with respect to its carriage 300, is proportional to the distance of the carriage 300 from the right hand side of the chart 309. Since the movement of the chart, due to its expansion and contraction, increases progressively from the right margin of the chart, as viewed in Fig. 1, because the right margin of the chart is held from lateral movement, the progressive adjustment of the marking element 370 with respect to its carriage 300 is in proportion to the progressive change in chart dimension from right to left, as viewed in Fig. 1. Where the compensator is used with a single recording instrument the bar 368 carries a pin 376 at the right end, which projects through and is journalled in an aperture in end plate 175, the clip 307 for supporting the fountain pen 306 depends from the element 370, and the bar 368 is movable only for the purpose of effecting compensation in dimensional changes in the chart paper. The compensator as applied to a single recording instrument, is disclosed and claimed in the co-pending application, Serial No. 491,166, filed October 25, 1930, by Arthur W. Gray, for Compensator for recorders, now Patent No. 1,927,401, issued Sept. 19, 1933. Where the instrument is employed for making a plurality of records, the bar 368 may be and preferably is used not only to effect compensation, but also to effect the printing or record making action, as will be described hereinafter.

Miscellaneous details

If desired, the bar 368 may be provided with a cam surface upon which the roller 375 rides, of such contour as to compensate for the deviation from strict proportionality between the temperature measured and the electromotive force generated by the thermocouple, in which case the chart may be evenly graduated. As illustrated in Fig. 40, the indicating index 311 is fixed on the carriage 300 so that the humidity compensator does not act to adjust the position of the index 311, such compensation being unnecessary inasmuch as the indicating scale 310 may be made of material unaffected by changes in humidity.

It will be noted from Fig. 27, that the supply roll 337 for the chart is positioned a sufficient distance from the point at which the record is made upon the chart, as to allow sufficient time to elapse between the withdrawal of the chart from the roll 337, until the time the record is made, for the chart 309 to become thoroughly conditioned by the atmospheric conditions then obtaining.

As the chart 309 leaves the roller 313, it passes over a plate 377, supported at its ends in the end plates 175 and 297. The plate 377 provides a writing surface upon which the chart is supported when making notations on the chart. A glass bar 378 is supported at its ends by guard plates 336, providing convenient means for tearing the chart off, the bar being transparent so as not to obscure the record.

The standard cell 50 hereinbefore mentioned, is illustrated in Figs. 3 and 18, and fits into the recess 291 in the frame being held therein by the clip 293. The standard cell 50, as shown in Fig. 3, consists of a molded casing 379, into which cell 380, of conventional construction, is placed, padding 381 surrounding the cell to protect it from mechanical injury. A strip 382 is secured by screws 383 to casing 379 and supports the cell in place. The strip 382 carries electrical terminals 384 joined by conductors to the cell and to the cable from the terminal block 32.

Multiple record instrument; switch operating mechanism

The instrument so far described, except for certain parts referred to in Fig. 40, is adapted for use in making a single record upon the chart. Where it is desired that the instrument be used to make a plurality of records on the one chart, corresponding to a plurality of measured quantities, it is necessary to provide for changing the electrical circuits from one to another of the sources of electromotive force to be measured. In addition, in order that the records may be distinguished one from the other, it is desirable that the character of marking associated with any particular circuit, be different from that associated with another circuit. In the embodiment of the invention herein disclosed, the distinction between the record lines is made by variations in the color thereof. It is also desirable to provide mechanism for changing from one to another of the circuits in a regular succession. In order that the successive markings, forming a particular record line, be not too infrequent, it is desirable that the change from one circuit to another be made at least within a predetermined period of time, and accordingly mechanism for switching the instrument from one measuring circuit to another after a predetermined number of operating cycles of the mechanism, is provided. Inasmuch as the position of the slide wire contact and corresponding position of the pen carriage when the potentiometer measuring circuit is in electrical balance, is the true measure of the variable quantity under measurement, it is desirable and provision has been made for switching the instrument from one to another electrical measuring circuit as soon as a limited number of cycles of operation, showing a balance in the measuring circuit, have been completed. In the particular instrument shown in the drawings, the number of balanced strokes necessary before the switching operation is effected, is limited to two.

The mechanism which, when added to the single recording instrument hereinbefore described, so modifies that instrument as to adapt it for making a plurality of records upon a single chart, is shown in Figs. 38, 39, 40, and 41 of the drawings, in association with the proximate cooperating parts of the single record making potentiometer. The circuit diagram of Fig. 43 illustrates the circuit as associated with a plurality of thermocouples 15 and having a switch 23, by which any particular thermocouple may be associated with the measuring circuit. The physical embodiment of the switch 23 takes that form shown at 385 in Fig. 40. The switch is secured to the end plates 297 by the screws 386. The mechanism of the switch 385 is disclosed in the patent to Harrison, No. 1,770,918 of July 22, 1930, and a description of the interior construction and operation of the switch 385 is not necessary here. The switch 385 is provided with electrical terminals 387 which are connected by conductors (not shown) to the terminal block 32, from which the leads to the thermocouples extend, and also from which the leads to the galvanometer and other electrical parts of the instrument extend. The position of the switch 385 is shown by pointer 388, which is turned from numeral to numeral on dial 389 as the switch is operated from circuit to circuit, the numerals indicating the circuit connected for measurement and the background for the numerals on the dial being colored to show the color of the record corresponding to the circuit connected for measurement. The switch contact and the pointer 388 are driven from beveled gear 390 secured upon end of shaft 391, journalled in the end plates 175 and 297. The shaft 391 carries at its extremity, distant from the gear 390, ratchet wheel 392 and star cam 393, both of which are rigidly fixed upon the shaft 391 in any suitable manner. Rotation of the shaft 391 is effected through ratchet wheel 392, which is driven by pawl 394 rotatably mounted upon pivot 395. A spring 396 connected to pawl 394 and tensioned at its other end, maintains the pawl 394 in engagement with the ratchet wheel 392. A stop pawl 397 is pivoted on stud 398 fixed in the end plate 175 of the instrument, the pawl 397 resting under the force of gravity against the ratchet 392, and having a tooth 399 which prevents return movement of the ratchet 392 when the pawl 394 is being returned from a driving stroke into engagement with the next notch of the ratchet. Pivot pin 395 for the pawl 394 is fixed in plate 400, journalled on shaft 391 for oscillatory movement between the two extremes of movement, as illustrated in Figs. 38 and 39. Spring 396, operating through pawl 394, and pivot pin 395, tend to maintain plate 400 in the position shown in Fig. 38, the movement in a counterclockwise direction of the plate 400 being limited by the stop 401, which also serves as a journal for the shaft later to be referred to. The stop or journal 401 is mounted on the end plate 175 of the instrument. Pivotally mounted on the pivot pin 395 is a drive bar 402 which, by virtue of its balance, tends to fall to the right, as shown in Fig. 38 into the dot and dash line position, where it is supported by the pin 403 rigidly carried on plate 400. The dot and dash line position of the drive bar 402, in Fig. 38, is the position which it occupies when a previous thermocouple circuit has been disconnected and a new thermocouple circuit has been connected to the potentiometer instrument; that is, at the beginning of a cycle of a multiple recording operation. The crank 190, which is driven from cam 195, and which has the arm 333 arranged to engage and drive the wheel 331 of the adjustable chart driving mechanism, is, in the multiple recording form of the instrument, provided with an extension 404 arranged to engage the drive bar 402, as illustrated in Fig. 39, and to move the drive bar 402 from the full line position, shown in Fig. 38, to the position shown in Fig. 39, which operation of the drive bar 402 acts through a pivot pin 395 and pawl 394, to drive the ratchet 392 and to turn shaft 391 to effect the switching operation at switch 385, thereby changing the measuring circuit from one to another thermocouple circuit. It will be noted that when the drive bar 402 is in the position shown in dot and dash lines in Fig. 38, the extension 404 of the crank 190 moves clear of the driving bar 402 with each oscillation of the crank 190 by cam 195. Thus the operation of the drive mechanism of the potentiometer for adjusting the slide wire contact and for adjusting the carriage for the recording element, proceeds as if the mechanism for making multiple records were not present so long as the drive bar 402 is not in a position to be engaged by the extension 404.

As pointed out before, it is desirable, in order to preserve continuity of record, that even though the potentiometer circuit may not reach a state of balance, the recording function and the change from one to another of the thermocouple circuits will be effected after a predetermined time in-

terval. Inasmuch as the drive mechanism of the instrument operates at a regular time rate, it is convenient to provide mechanism for effecting the recording function and the switching function after a predetermined number of cycles of operation of the drive mechanism. Accordingly, the arm 191 of crank 190 is provided with a stud 405 fixed thereon, on which is pivoted a pawl 406 having tooth 407 arranged to engage with the teeth 408 of a ratchet lever 409, journalled on the stud 190' which supports the crank 190 on the end plate 175 of the instrument. The pawl 406 tends to move under the force of gravity into engagement with the teeth 408. The ratchet lever 409 is provided with arm 410 which, as the ratchet lever 409 is moved in a clockwise direction under the action of the pawl tooth 407, eventually engages a lug 411 upon drive lever 412 which is journalled upon the stud 190'. Drive lever 412 is provided with an upturned lug 413 arranged to engage portion 414 of drive bar 402, and to move the bar 402 from the dot and dash line position illustrated in Fig. 38 to the full line position shown in Fig. 38. The angular position of the ratchet lever 409 and the drive lever 412, illustrated in Fig. 39, is the position which those parts occupy at the beginning of a cycle of multiple recording operations. The steps between the teeth 408 of the ratchet lever 409 being small, a large number of oscillations of the crank 190, for instance twenty, are required to move the arm 410 first, into engagement with the lug 411, and second, to move the drive bar 402 from the position illustrated in dot and dash line to the position shown in full line in Fig. 38. However when the potentiometer circuit is not balanced, the ratchet lever 409 is advanced a step with each oscillation of the crank 190 so that at the end of a predetermined interval of time the recording and switching operation will be effected as before described. It will be noted from Fig. 39 that when the drive bar 402 is operated by extension 404 to advance the ratchet 392 through pawl 394, the plate 400 is moved from the position shown in Fig. 38 to the position shown in Fig. 39, and the finger 415 extending from plate 400 engages the lug 413 of the drive bar 412 and the projection 416 of the ratchet lever 409 so as to move those parts back to the initial positions which they retain due to the friction of the mounting of those parts upon the stud 190' and between the adjacent surfaces of the parts.

As pointed out before, when the drive mechanism of the instrument brings the measuring circuit to the state of electrical balance, the position of the recording carriage at that time is an accurate measure of the variable under measurement, and further operations of the drive mechanism are unnecessary at that time in order to determine the value of the quantity measured. Accordingly, when a limited number of balanced strokes are obtained, for instance two, it is desirable to operate the recording and switching mechanisms in order that there shall be a minimum lapse of time between the recording operations for each circuit. In order to operate the recording and switching mechanisms when a second balanced stroke has been made, the drive lever 412 is provided with teeth 417 arranged for engagement by the pawl tooth 407. In order that only the teeth 408, and not the teeth 417, be engaged by the pawl tooth 407 during the operation of the drive mechanism when the potentiometer is not in balance, a guard plate 418 is provided which is pivoted upon the stud 190' and carries a shield 419 over which the pawl tooth 407 rides in the initial part of its stroke. The guard plate 418 is provided with a cam face 420 which rides upon a pin 421 which rotatably secures the cam follower roller 208 to the lever 206. When the lever 206 moves forwardly, the cam surface 420 rides over pin 421 to allow shield 419 to cover the teeth 417 and thus shield them from the pawl tooth 407, the guard 418 following the pin 421 under the force of gravity. The cam surface 420 of the guard 418 is such that when the shield 419 covers the teeth 417, one tooth is unprotected and is engaged by the tooth 407 so as to advance the ratchet lever 410 a distance corresponding to the spacing between the teeth 408 with each stroke of the crank 190. When the slide wire contact has been adjusted to bring the measuring circuit into balance, the secondary pointer 177 is adjusted to the neutral position causing the foremost step 213 of the stepped finger 211 on the lever 206 to engage the lug 189 on the secondary pointer, thereby limiting the stroke of the lever 206 to that position illustrated in Fig. 38 where the pin 421 carried by the lever 206 is positioned beneath the low point on the cam surface 420 and supports the guard 418 in a position shown in Fig. 38 where the pawl tooth 407 may engage a tooth 417 to the drive lever 412, and thus advance the drive lever 412 directly from the movement of crank 190. The drive lever 412 is provided with only two teeth 417, spaced a considerable distance apart so that two balance strokes of the drive mechanism are sufficient to move the drive lever 412 so as to bring the drive bar 402 into driving relation with respect to the extension 404. When the pawl tooth 407 engages a large tooth 417, it may engage a tooth 408 and advance the ratchet lever 410 simultaneously. Where only one balance stroke is made, the operation is simply to hasten the operation of ratchet lever 408 by two or three steps, the operation from ratchet lever 408 continuing as before described. If the teeth 408 and 417 terminated in the same arc, and if a tooth 417 were positioned intermediately of a pair of teeth 408, the gap between the teeth 408 might be so bridged by tooth 417 as to prevent engagement of the pawl. In order to prevent such an event, the teeth 417 are made to terminate outside the terminal arc for teeth 408 so that, if such a condition as referred to should occur, the tooth 417 can be engaged by the pawl.

It will be observed that the driving action of pawl 406 from the crank 190, takes place when the crank is moving in a clockwise direction; therefore, that operation takes place at the completion of a cycle of operation of the crank 190; thus the actuation of the drive bar 402 and the consequent switching and recording operations do not take place on the same stroke, for example, a second balanced stroke, which sets the multiple parts in position for switching and recording operation. The next succeeding cycle of operation of the drive mechanism effects the recording and switching operations, and this occurs regardless of whether the measuring circuit remains in or deviates from the balanced position because the multiple mechanism is operated before adjustment of the slide wire contact is made. Thus on the multiple mechanism actuating cycle of operation of the drive mechanism, at the beginning of the cycle the instrument is connected to one thermocouple circuit. At the end of the cycle the instrument is ready for operation by virtue of the return of the parts of the multiple

mechanism to initial position, for operation in connection with a succeeding thermocouple circuit. Inasmuch as the driving stroke of pawl 394 is completed during the cycle of operation, the measuring circuit is switched from one to another of the thermocouple circuits during the course of the multiple actuating cycle of the drive mechanism.

Multiple record instrument; marking system

In order to make the record upon the chart, a ribbon 422 (see Fig. 40) is supported across the chart slightly spaced therefrom, by a frame composed of side arms 423 pivoted on studs 424 and 428 in end plates 175 and 297, respectively, of the instrument, and a cross bar 425 is fastened at its ends to the side arms 423 in order to give rigidity to the carriage. The ribbon 422 is trained over triangular supports 426 carried on side arms 423, and extends from the take-off spool 427, mounted on stud 428 to the take-up spool 429 mounted on axle 430 rotatable in journal 401 fixed to the end plate 175. The axle 430 carries spur gear 431 which meshes with spur gear 432 fast upon the shaft 314 of the chart drive roll 315. The mounting for take-off spool 427 is illustrated in Fig. 41 and consists of the stud 428 fixed in the member 423 and journalled in the frame plate, and having annular grooves 433 therein. The hub of spool 427 is provided with passages 434 accommodating balls 435 and spiral springs 436 pressing against the balls 435 and against screws threaded into the passages 434 in the hub of the spool. A face 437 of the hub is arranged to be thrust against the face of the collar 438 formed on stud 428. The passages 434 are slightly offset with respect to the grooves 433 when the spool is pressed tightly against the stud 438, and the pressure of the balls 435 against the walls of grooves 433 provide a wedging action forcing the spool 427 against the collar 438, thereby creating a frictional drag so as to maintain the ribbon taut as it is unreeled from the spool 427. The mounting of the take-up spool 429 is similar to that for spool 427, except for the omission of the friction clutch, the spool being positively driven from axle 430.

The ribbon 422 is provided with a plurality of differently colored sections, one or another of which is to be selected for making the record in a color which corresponds to the color associated with the circuit for which the record is to be made, and which color is indicated on the dial 389 of the switch 385. In addition, it is desirable to move the ribbon 422 back out of record making position at all other times except when the record making function is to be performed so that the record will not be obscured by the ribbon. It is for the purpose of permitting such ribbon shifting function that the side arms 423 are pivotally mounted on their respective end plates. The side arm 423 is mounted on the stud 428 carried by the end plate, and the oscillation of the ribbon frame takes place about stud 428 so that during the oscillatory movement of the ribbon carriage the ribbon spool turns with the carriage so as to impose no load on the ribbon. The ribbon 422, adjacent the take-up spool 429, is trained over a stud 424 which forms the pivotal support for the side arm 423, so that as the ribbon carriage is oscillated the ribbon 422 hinges about the stud 424 and the tension on the ribbon 422 does not affect the oscillation of the ribbon carriage.

When the parts of the drive and multiple mechanisms are in a non-record making position, the plate 400, which is held in the position shown in Fig. 38 by spring 396, engages a finger 439 on side arm 423, thus holding the ribbon carriage in a position illustrated in Fig. 38, where the ribbon is back out of record making position and the record may be viewed without obstruction by the ribbon. The ribbon carriage is so balanced about the pivot 424 that it rests against the plate 400 by force of gravity.

When the multiple mechanism is operated from the drive mechanism in order to effect the recording and switching operations, the plate 400 moves to the position illustrated in Fig. 39, thereby freeing the ribbon carriage for movement in a counterclockwise direction, as viewed in Fig. 39, and the ribbon carriage falls in a counterclockwise direction until the pin 440 carried by side arm 423 engages a face of the star cam 393, which positions the ribbon for the making of the record.

The record is made by member 370 supported upon the carriage 300 (see Fig. 40), the member 370 having a print hammer 441 arranged to strike the ribbon into contact with the chart and make a dot thereon. The print hammer 441 is operated by the bar 368, the bar being oscillated in an up and down direction, as viewed in Fig. 40, carrying the member 370 with it about the axle 369. When used to operate the print hammer 441 as described, the righthand end of the bar 368 is not supported by the previously described pin 376, but, as shown in Figs. 27 and 38, is carried on a bell crank 442 pivoted on stud 443 fixed in end plate 175. Bell crank 442 has a lug 444 projecting through aperture 445 in the end plate 175, the lug 444 being received in aperture 446 at the end of bell crank 447 pivoted on stud 398. The bell crank 447 is connected to spring 396, which tends to rotate the bell crank in a clockwise direction about the stud 398, and to correspondingly rotate the bell crank 442 in a counterclockwise direction about stud 443, thereby tending to depress bar 368 and to urge print hammer 441 into record making engagement with the ribbon 442 and chart 309. The other arm of bell crank 447 is provided with ear 448 which rides on the ratchet 392. As the ratchet 392 is advanced under the action of the multiple mechanism and the drive mechanism, the ear 448 rides into and out of one of the recesses in the ratchet 392 under the influence of spring 396, the action being a rapid snap action which snaps the print hammer 442 against the ribbon and makes a record on the chart.

As shown in Fig. 39, where the pin 440 is in engagement with the star cam 393, the pawl 394 has completed its ratchet driving stroke and the lock pawl 397 has engaged a successive tooth of the ratchet 392 so that the star cam 393 will remain in the position shown in Fig. 39 until the next recording and switching operation takes place. As the plate 400 is returned to its initial position, the ribbon carriage is moved to the position shown in Fig. 38. In the next recording operation, the stroke of the driving bar 402 moves the plate 400 out of engagement with the projection 439 and permits the pin 440 to drop into the position which it occupied at the end of the previous recording operation, as shown in Fig. 39. As the drive stroke of the driving bar 402 progresses, actuating the ratchet 392, the ear 448 rides into a recess of the ratchet and a printing operation is effected while the pin 440 remains upon the same projection of the star cam 393. The print ham-

mer is retracted as soon as the further rotation of ratchet 392 moves ear 448 out of the ratchet recess, and as the rotation of the ratchet 392 and the star cam 393 continues, the pin 440 rides on to the next succeeding cam surface, thereby preparing the position of the ribbon carriage for the next succeeding recording and switching operation.

It is undesirable to provide a ribbon having more than three different colors. When it is desirable to measure and record more than three variable potentials on one instrument, color combinations for a single record line are employed to distinguish the record lines. Such color combinations can be obtained by a proper arrangement of cam surfaces on the cam wheel 393 to cause the record for a particular circuit to be made in impressions of alternate color, in accordance with a well known practice of the art disclosed in the Grisdale Patent No. 1,564,558 granted December 8, 1925.

The multiple recording and switching mechanism, as provided by this invention, combines as far as is possible to do so, a plurality of functions in each of the elements and in various combinations of the elements, thereby simplifying the mechanism. The operation of the various parts of the switching and recording mechanism is effected through a single member 402 from the driving mechanism, which necessarily is of a periodically operating type, so that the multiple recording and switching mechanism is well adapted to make use of the inherent operating characteristics of the drive mechanism. The switching and recording, and ribbon retracting operations are all performed from a single means comprising the ratchet 392 and the star wheel 393, which may, if desired, be made unitary. The construction and cooperating arrangement of the parts are such as to make possible the use of sheet metal stampings almost wholly throughout the construction of the multiple recording and switching mechanisms, thereby facilitating the manufacture and assembly of those parts.

Miscellaneous features

The drive mechanism and the multiple mechanisms are arranged on the end plate 175, which is distant from the point of pivotal support for the instrument frame, so that when the frame is swung out of the casing of the instrument, the drive and multiple mechanisms are available for inspection, service, and repair. In order that the frame for the instrument may be firmly supported within the casing at a definite level so that the position of the galvanometer pointer will be unaffected by the level of the instrument, a latch for clamping the frame in position in the casing is provided and is shown in Figs. 1 and 34. The casing 24 is formed with a projecting lug 449 recessed at 450 to accommodate the edge 451 of the instrument frame. A stud 452 is secured in the instrument frame and a latch 453 pivoted by stud 454 on the side of the casing has projection 455 arranged for engagement with the stud 452 to force the edge 451 into the recess 450, and thereby to lock the instrument frame in a definite position in the casing. The door of the instrument casing is provided with a diagonally disposed rib 456 which engages end 457 of the latch 453 when the door is closed, so as to move and hold the latch 453 in engagement with the pin 452.

In order that the pen carriage and the slide wire contact may not be forced beyond their limits of movement when they are moved to their extremes of possible movement, the wheel 220 is provided with a knob 458 adapted to engage with lug 459 fastened to the gear 294 when the parts driven thereby have been operated to their limit of movement, thus stopping further movement in that direction.

Many of the features in principle of operation embodied in the disclosure of this invention, are disclosed and claimed in Patents Nos. 1,898,124 and 1,898,183, both granted February 21, 1933, on applications of Thomas R. Harrison, one of the joint inventors herein, which were filed prior to the present application. The instrument disclosed herein is a commercial embodiment of principles of construction and operation disclosed and claimed in said patents, embodying many novel features of construction and interrelation of the parts affording an optimum combination for facility of manufacture, economy of manufacture, efficiency, accuracy and dependability of operation together with accessibility for adjusting, inspection, service, and repair. While a specific embodiment illustrating the various features of invention is herein disclosed, it is not intended to limit the invention to the particular construction disclosed, as many variations may be made in the details of construction and arrangement without departing from the spirit and scope of the invention as defined in the following claims.

Certain novel features of construction and arrangement disclosed but not claimed herein, are disclosed in our applications, Serial No. 722,466, filed April 26, 1934, now Patent No. 2,122,370, issued June 28, 1938, Serial No. 727,630, filed May 26, 1934, now Patent No. 2,058,078, issued October 20, 1936, and Serial No. 109,124, filed November 4, 1936, as divisions of this application.

We claim:

1. In an instrument, a deflectable member, a frame, a gauging device supported on said frame for movement into and out of engagement with the member, a stop on said frame for limiting movement of the device away from the member, means tending to move said device into engagement with the member and yielding to permit the latter to arrest the movement of said device, means normally preventing but intermittently operated to permit the device to move into engagement with said member, the last mentioned means acting in one position of operation through a spring connection to hold said device against said stop.

2. In an instrument, a deflectable member, a clamping means arranged for movement to clamp the member, a gauging device arranged for movement into and out of engagement with the member, said gauging device controlling the movement of said clamping means.

3. In an instrument, a member adapted to deflect in a plane, an abutment, a clamping means arranged for movement to clamp the member against the abutment, a periodically movable element, a gauging device movable under control of said element transversely of said plane into and out of engagement with the member, means tending to move said clamping means into engagement with the member, and means normally preventing but actuated to permit movement of said clamping means into engagement with said member on movement of said gauging device into engagement with said member.

4. In an instrument, a member movable relative to a predetermined position in response to variations of a measuring force, a device movable

into engagement with said member to be positioned in accordance with the direction of deviation of said member from predetermined position, a pair of drive members, a single element adapted to be engaged and driven selectively by one or the other of said drive members, means operated by said device for selecting one of said drive members for engagement with the element, means for driving said selected drive member and element arranged to engage the first mentioned member for controlling the extent of driving action in accordance with the extent of deviation of the first mentioned member from predetermined position.

5. In an instrument, a member adapted to be positioned relative to a predetermined position in accordance with variations of a measuring force, a serrated wheel, a pair of pawls, a pair of pawl arms each pivotally carrying a pawl for driving engagement with said serrated wheel, a selector controlled by said member for selectively engaging one of said pawls with the wheel, means for operating said pawl arms through a cycle including forward and return strokes, said pawls being so constructed and arranged that the engaged pawl is held in engagement with the wheel by the driving force during the forward stroke and released from and maintained out of dragging engagement with the wheel during the return stroke.

6. In an instrument, a member adapted to be positioned in accordance with a measuring force, a serrated wheel, a pair of pawls, a pair of pawl arms each carrying a pawl for engagement with the wheel, means for oscillating said pawl arms to drive the pawls and wheel, a selector, said selector, pawls and pawl arms being so arranged as to clamp the selector between the pawls at the beginning of the driving stroke of said means, a device associated with the selector and cooperating with the member for actuating the selector according to the position of the member, said means operating during the driving stroke to release said pawls to permit selective engagement thereof with the wheel.

7. In a self balancing potentiometer instrument, a member adapted to be positioned according to variations of a measuring force, a driven rebalancing member, a pair of driving members adapted to operate the driven member in a direction determined by the driving member selected for engagement therewith, selector means for selecting one of said driving members for engagement with the driven member operating in accordance with the position of the first mentioned member, means arranged for cooperation with the first mentioned member to determine the extent of driving movement imparted to the driven member in accordance with the position of the first mentioned member, and a single device for operating the selector means, for engaging the driving and driven members, for effecting the driving action and for operating the means.

8. In a self balancing potentiometer instrument, a driven rebalancing member, a driving member for driving said driven member, a lever mounted for arcuate motion about a center, means for oscillating said lever from an initial position, connections between said lever and driving member arranged to pass through a dead center as the lever moves from the initial position, and means operating in accordance with variations in a measuring force for limiting the stroke of the lever.

9. In a self balancing potentiometer instrument, a driven rebalancing member, a pair of driving members, a lever mounted for arcuate motion about a center, means for oscillating said lever from an initial position, connections between said lever and driving members arranged to pass through a dead center as the lever moves from initial position, means operated by said lever as it moves from initial position in accordance with variations of a measuring force for selecting one of said driving members for driving engagement with the driven member.

10. In a multiple recording instrument, including a chart, a printing hammer, a ribbon arranged to be positioned between the chart and hammer, and means for moving the ribbon into and out of printing position, means for operating the printing hammer, comprising in combination, a lever, a drive bar and a pawl pivoted on the lever and adapted to actuate said printing hammer, intermittently operating means for engaging the bar and driving the bar, lever, and pawl, and means for moving the bar relatively to the lever from a non-actuable position into engageable relation with the intermittently operating means.

11. Apparatus of the character described comprising a deflecting element, means for intermittently clamping said element, a feeler, means for intermittently moving said feeler away from said deflecting element, and spring means effecting return movement of said feeler into engagement with said element while clamped.

12. Apparatus of the character described comprising a deflecting element, means for intermittently clamping said element, a feeler, cam structure for intermittently moving said feeler away from said deflecting element, and spring means for moving said feeler, when released from said cam structure, into engagement with said deflecting element while clamped.

13. Apparatus of the character described comprising a deflecting element, means for intermittently clamping said element, a feeler, means for intermittently moving said feeler away from said deflecting element, spring means effecting return movement of said feeler into engagement with said element while clamped, a member moved by said feeler to a setting determined by the position of said element when engaged by the feeler, a driven member, and a source of power for actuating each of said means and for actuating said driven member to an extent determined by the setting of the first mentioned member.

14. An instrument comprising a framework and a deflecting element including a pointer, and in combination therewith a pointer gauging mechanism unit removably mounted on said framework and comprising a supporting member detachably secured to said framework and a pointer engaging device mounted in said member for movements into and away from positions of engagement with said pointer which vary with the deflective positions of the latter.

15. An instrument comprising a framework and a deflecting element including a pointer, and in combination therewith a pointer gauging mechanism unit removably mounted on said framework and comprising a supporting member detachably secured to said framework and a pointer engaging device detachably mounted in said frame for movements into and away from positions of engagement with said pointer which vary with the deflective positions of the latter.

16. An instrument comprising a framework and

a deflecting element including a pointer, and in combination therewith a pointer gauging mechanism unit removably mounted on said framework and comprising a supporting member detachably secured to said framework and a pointer engaging device mounted in said frame for movements in one direction into, and in the opposite direction away from positions of engagement with said pointer which vary with the deflective positions of the latter, said element being biased for movements in one of said directions, and means engaging said element for intermittently moving it in the opposite direction.

17. In an instrument comprising a deflecting element including a pointer, a pointer position gauging mechanism comprising a supporting member and a pointer engaging device comprising spaced apart spring arms, said arms and member having parts normally engaging to provide a pivotal connection between each arm and said member, but disengageable by the flexure of said arms to permit the removal of said device.

18. In an instrument of the character described, a deflectable member, a composite gauging device for contacting therewith including a carrier part and a contacting part adapted to be secured to said carrier by flexing means.

19. In an instrument of the character described, a deflectable member, a second deflectable member, driving means associated with the first mentioned member to deflect the second said member in accordance with the deflection of said first member including a rotary driven member and means including a stud mounted on said driven member for preventing the deflection of the second mentioned member beyond a predetermined limit of its deflection.

20. A multiple recording instrument including a chart, a printing hammer, means for operating the printing hammer comprising in combination a lever, a driving bar adapted to actuate the lever, clutch means operated by said lever and connected to said printing hammer to actuate the latter, intermittently operating means for engaging the bar and driving the bar and lever to thereby operate said printing hammer, and means for moving the bar relative to the lever from a non-actuable position into an engageable relation with the intermittently operating means.

THOMAS R. HARRISON.
ERNEST H. GRAUEL.
J. ERNEST KESSLER.