C. F. HINDLE.

GALVANOMETER.

APPLICATION FILED JULY 2, 1917.

1,416,824.

Patented May 23, 1922.

4 SHEETS—SHEET 1.

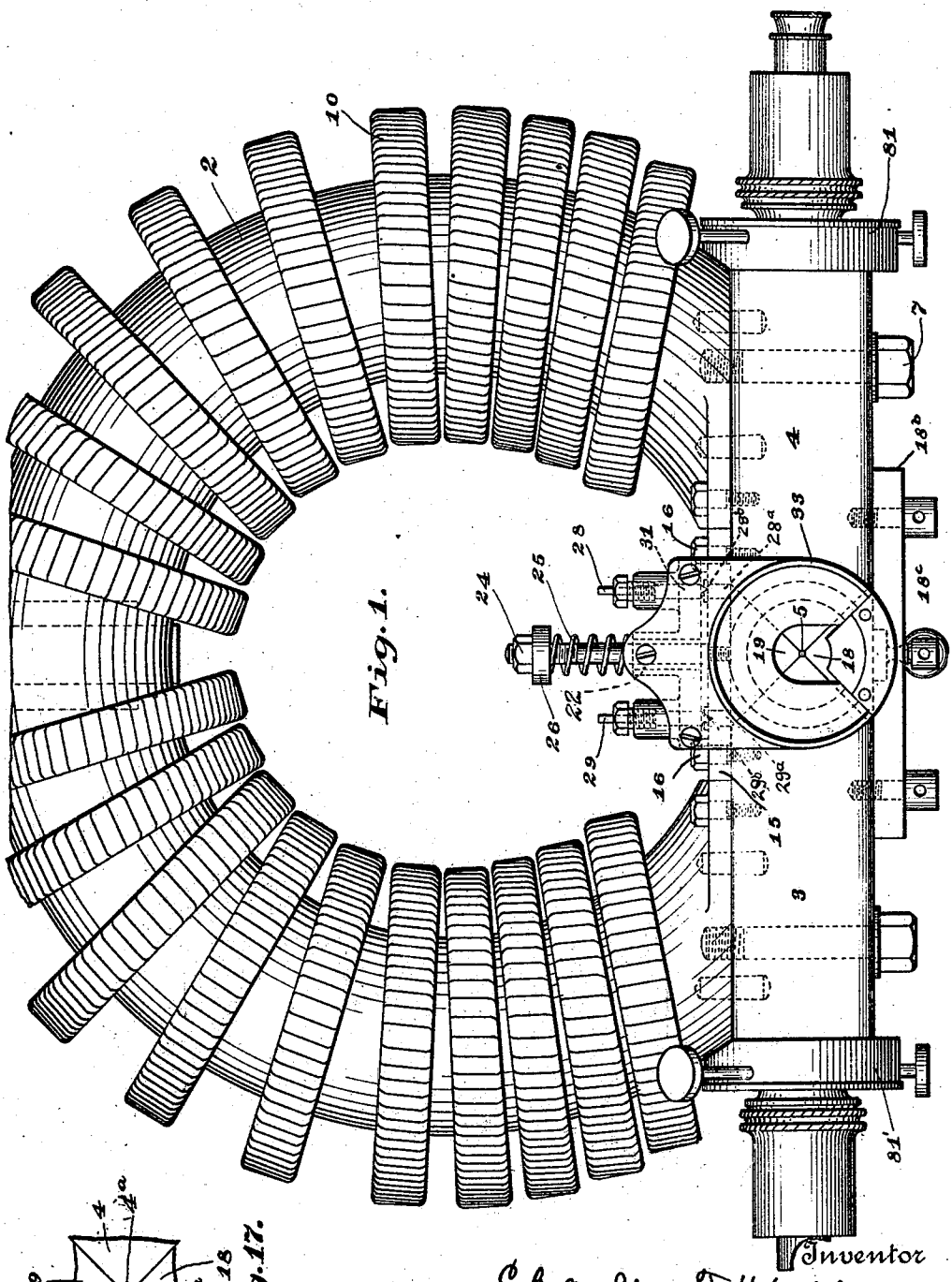

Fig. 1.

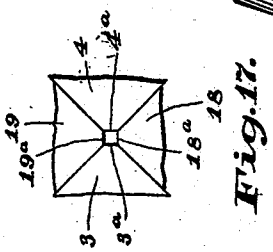

Fig. 17.

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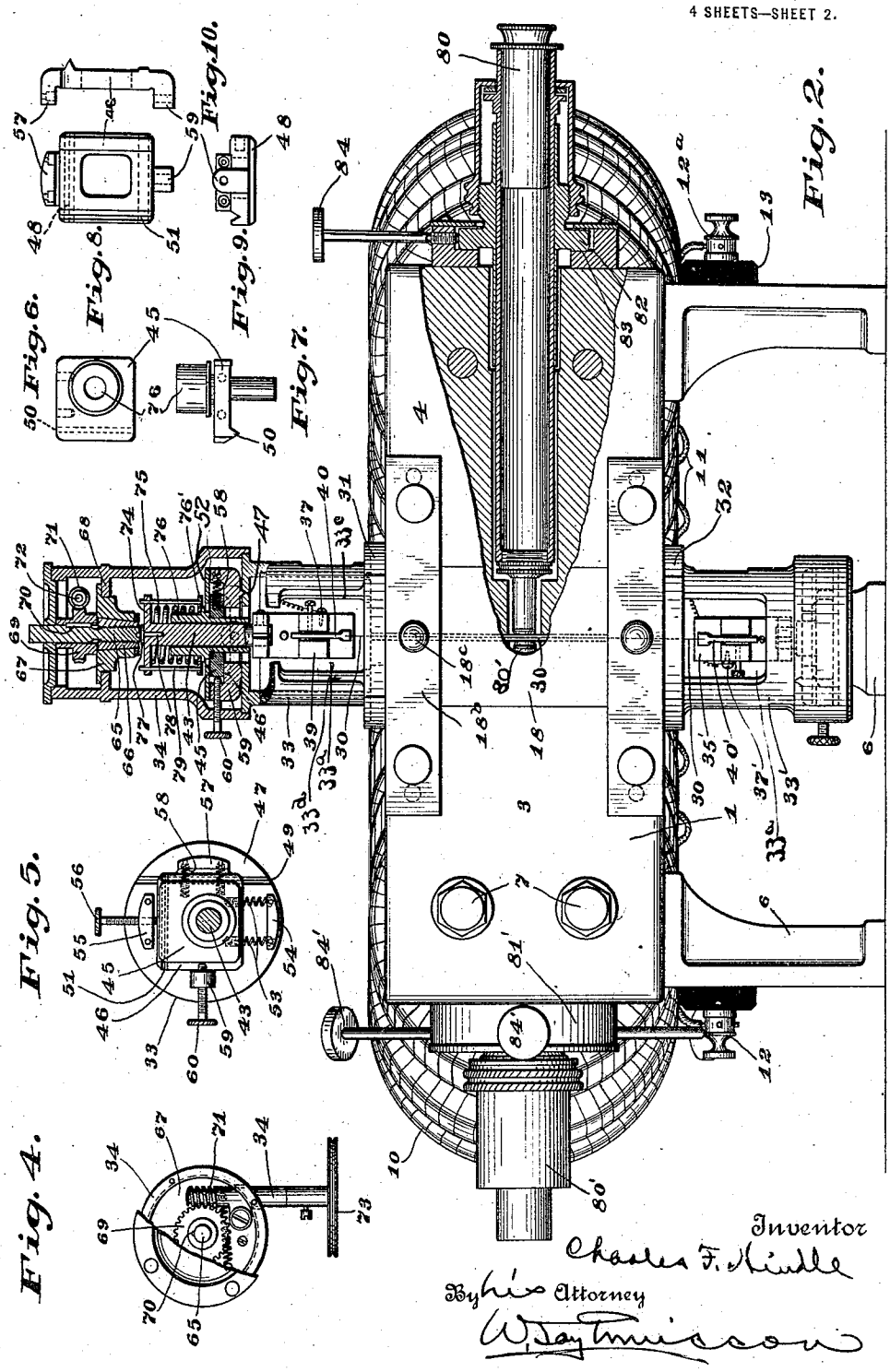

Fig. 2.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

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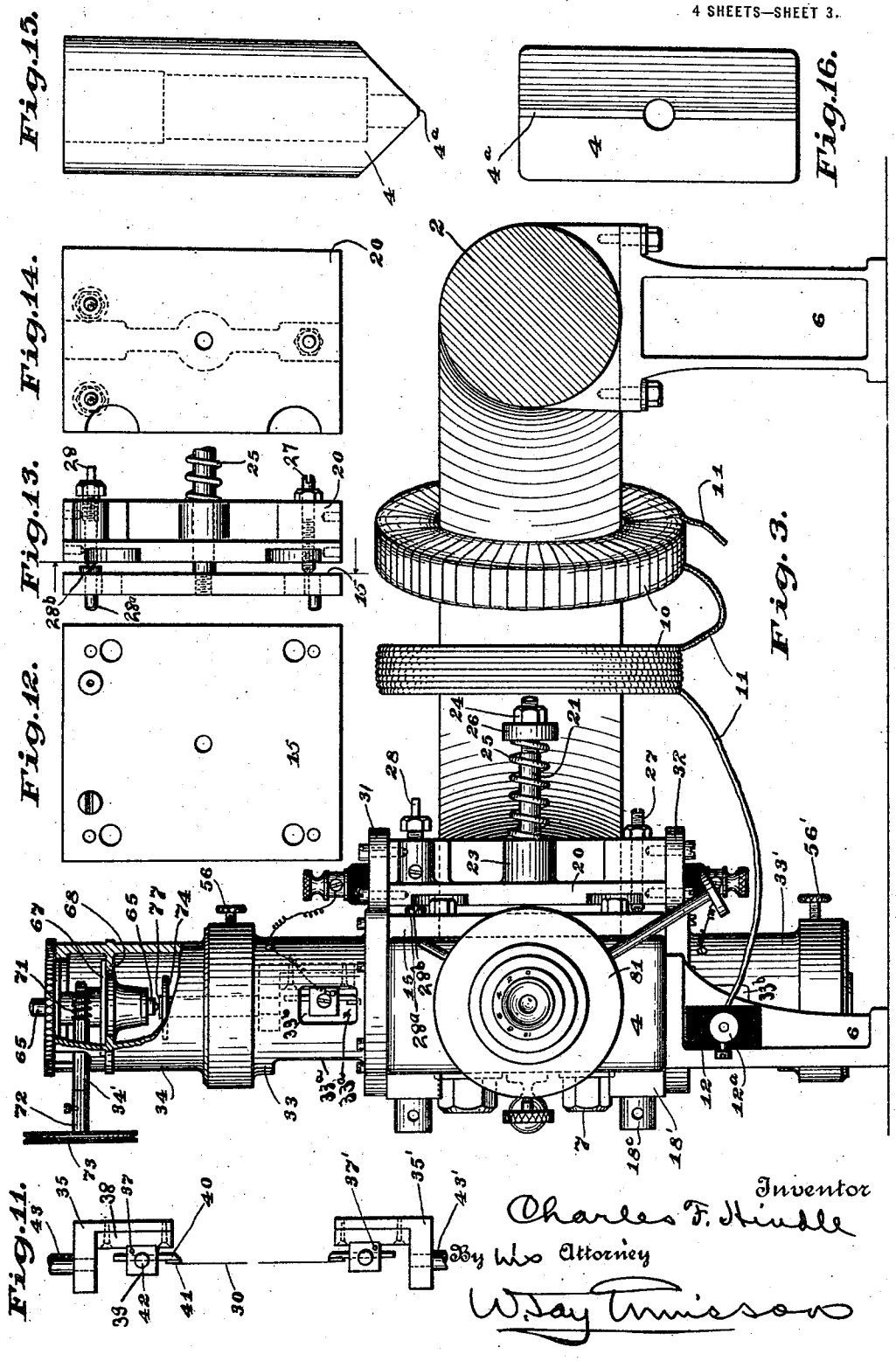

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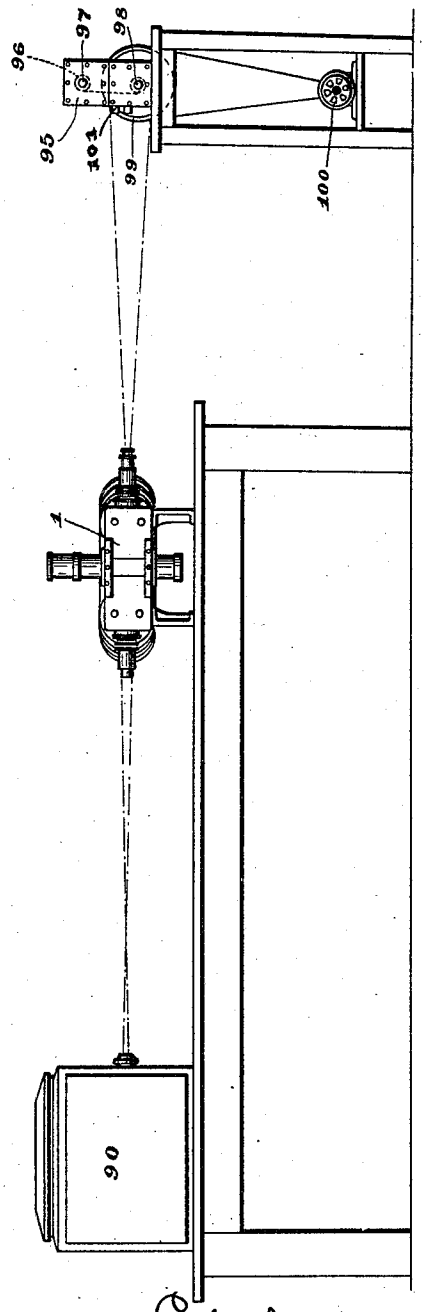

Fig. 18.

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UNITED STATES PATENT OFFICE.

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GALVANOMETER.

1,416,824. Specification of Letters Patent. Patented May 23, 1922.

Application filed July 2, 1917. Serial No. 178,136.

To all whom it may concern:

Be it known that I, CHARLES F. HINDLE, a citizen of the United States, residing at 110 Maurice Avenue, Elmhurst, Long Island, New York, have invented new and useful Improvements in Galvanometers, of which the following is a specification.

My invention relates to galvanometers or more particularly to those known as string galvanometers, which are devoted more or less extensively to medical and scientific uses.

My improvements have for an object to provide a string galvanometer of more perfect adaptability to the specific purposes for which it is designed, without affecting or sacrificing its essential operable features.

Another object is to produce a device of the class described of improved efficiency, and one in which greater facility and wider latitude of adjustment are combined with a high degree of accuracy and effectiveness, both with relation to the parts adjusted and to the mechanism as a whole.

A further object is to provide a string galvanometer in which the inner mechanism thereof, of which portions are necessarily of extreme fineness and delicacy, is adequately protected from atmospheric and other deleterious influences.

Galvanometers are made of various designs and are employed for different purposes, the type to which my present invention relates being known as the string galvanometer, in which vibrations of a delicate cord or string are employed to detect the presence of and definitely to measure minute values of electric current or voltage. Such instruments, in their fundamental construction, are based upon the familiar phenomenon of the definite tendency of an electric conductor (the string of the galvanometer) to move laterally within a magnetic field, the deflection thereof being proportionate to the strength of the current passing through such conductor, the strength of the field remaining constant. The extent and frequency of the deflections of the string of this type of galvanometer, are ascertained and measured by means of having shadows of the lateral vibrations thereof recorded photographically in highly magnified form upon a moving film. The string galvanometer is therefore particularly adapted to being employed to detect and accurately evaluate extremely weak electrical impulses by the use of a correspondingly delicate filament or string of suitable material which is held as indicated between the poles of a magnet of predetermined strength transversely to the lines of force thereof. To obtain this result the string thus connected is etsablished in series with the source of electric energy to be investigated, and while suspended within the magnet field as described is also placed in focal arrangement so as to intercept the direct rays of an intense white light that is introduced through telescopic tubes and focussed upon the string in such manner that the latter will cast a minute shadow which in turn by magnifying lenses is projected upon a sensitized film that moves at a predetermined rate before the shutter of a camera, such film having graduations or other markings previously applied thereto provides means for establishing and recording the relative widths and recurrencies in point of time of the successive shadowgraphs recorded thereon.

Therefore my invention considered in its more general aspect comprises a horse-shoe electromagnet supported horizontally upon standards provided therefor, having its respective poles oppositely disposed and in relatively close proximity, and having adjustably supported thereon the frame-work or housing that contains the string and also the mechanism for adjustably retaining that delicate member in proper focal position for the proper projection of the shadow to be photographed therefrom.

Improved means are also contemplated in my invention in the open form of the electromagnet windings employed whereby a constant strength of magnetic field is maintained at a high tension without unduly heating the apparatus while in use and through unequal expansion of portions of the magnet, thereby disturbing the proper relationship between the positions of the string and the photographic apparatus.

At a suitable distance from the shadow projecting mechanism to obtain the desired multiplication thereof, is placed any suitable type of camera adapted to present a moving film for photographing continuously vibratory movements of the string.

For convenience of description, my invention will be considered as comprising two branches, that relating to the galvanometer, and the apparatus for photographing the movements of the string of the galvanometer: and in like manner the galvanometer

itself will be described first with reference to the features pertaining to the magnet proper, and then to the mechanism for properly containing the string in an airtight compartment in combination with means for variously adjusting that member.

Referring to the drawings illustrated of a preferred embodiment of my invention, Figure 1 is a plan view of the galvanometer proper;

Fig. 2 is a front elevation of the galvanometer with portions shown in vertical sectional views;

Fig. 3 is a partial side elevation and sectional view of the device shown in Figs. 1 and 2 showing internal string adjusting mechanisms and detail of the winding upon the magnet.

Fig. 4 shows in plan the detail of a vertical string adjusting mechanism seen in Figs. 2 and 3;

Fig. 5 is a detail of the lateral string adjusting mechanism seen in Figs. 2 and 3;

Figs. 6 and 7 are respectively plan and side views of a member of the adjusting mechanism shown in Figs. 2 and 5;

Figs. 8, 9 and 10 are respectively plan, side and end views of the under member of the lateral adjusting mechanism, supporting the part shown in Figs. 6 and 7.

Fig. 11 shows the insulated supports to which the string is attached; Fig. 12 is a rear view of the string bracket supporting plate detached from the magnet;

Fig. 13 is an end view of the plate shown in Fig. 12 with upright member of string bracket supported thereon;

Fig. 14 is a front view of the upright plate of string bracket; Figs. 15 and 16 are respectively top plan and wedge end views of a pole piece;

Fig. 17 is a partial detail of parts shown in Fig. 1; and

Fig. 18 is a front elevation of the galvanometer illustrated in comparatively reduced form in connection with a lamp and camera apparatus shown at the respective sides.

The electromagnet, in the preferred form of my invention, illustrated in the drawings to which reference is made, is represented by the numeral 1, which is designed to be energized by direct electrical current in the usual way, the soft iron body of which is composed of a casting 2, annular in form, and having circular cross-sectional areas. The forward portion of the casting 2 has been cut away as by a vertical plane intersecting the casting to form the horseshoe type of magnet required by my invention, and thereby providing suitable surfaces for receiving two similar pole pieces 3, 4, constituting the respective poles of the magnet. The pole pieces are secured rigidly to the member 2 by the bolts 7, and are oppositely disposed in longitudinal alignment relatively one to the other, presenting wedge-like faces at the point of approach, the respective apexes of which are slightly flattened to constitute two of the walls forming the narrow rectangular chamber 5 for containing the string of the galvanometer.

The magnet proper is adapted to be supported in a horizontal position upon the three legs 6, one attached directly to the rear portion of the casting 2, and one similarly connected with each of the pole pieces 3, 4. The wiring coils of the magnet are applied in a series of separable windings which I may designate as spools 10, each spool preferably composed of copper wire 11, insulated in the usual manner, and all spools being wound in the same general direction, the windings of each independent spool being separately insulated in a convenient manner, the respective ends projecting from the spools, being united to form a continuous metallic circuit connecting several spools; thus the end of the wire of one spool connects with the oppositely disposed end of the next adjoining spool, which order is followed in connecting adjacent spools throughout the series surrounding the casting 2 of the magnet. The several spools have been separated one from the other in the manner indicated, to permit free circulation of air in and around the windings, thus preventing over-heating of the magnet and allowing an appreciably higher degree of electro motive force to be maintained in the electric magnet. The continuous circuit thus extending from one end of the magnet to the other, terminates at its opposite ends in binding posts 12 and 12a, the latter having been suitably attached to the insulating blocks 13 on respective legs 6 of the magnet to which binding posts are connected the opposite poles of the source of direct current electric energy employed to energize the magnet.

The necessity for obtaining a high magnetic field in devices of this class has made it practically necessary to use current in such quantity as to produce excessive heating of the magnet, disturbing the adjustment of the string in proper focal relationship, with the result frequently of incapacitating the entire mechanism. For this reason in using other forms of magnet winding it has been found necessary to operate the device at a lower tension than was required to produce the desired results. Therefore, to obviate this difficulty, I have provided the means described for obtaining high electric efficiency with a minimum of the heating disturbances referred to.

While I have thus described the construction of the preferred form of magnet to be used in connection with the galvanometer of my invention, other modifications may obviously be made to obtain the same general re-

sult, although not as effectively and completely as in my preferred embodiment. I desire nevertheless in thus describing completely a preferred form, not to limit myself to that particular design of electromagnet, or in fact to a magnet of the general type illustrated.

The adjustable string supporting and containing mechanism, as has been pointed out, is more or less intricate, due to the concentration of the diverse structural and functional elements by which it is characterized. The first requisite of its designing is to supply a draft-proof chamber for the string; next it must be provided with means for introducing horizontal rays of light focused at a point to be intercepted by the string, so as to form a shadow to be projected in the opposite direction through magnifying lenses on a camera mechanism to be described in another connection; also the position of the string requires frequent readjustments from side to side to keep it in exact focal alignment with the light rays; and furthermore, delicate means are equally important for regulating the tension of the string, which is exceedingly fine and fragile, but must nevertheless be maintained at the required tautness.

In describing the string mechanism I will first refer to the means employed in forming the string chamber and supporting the shadow projecting lenses in suitable relationship therewith; and then proceed to describe the mechanism employed in effecting the adjustments of the string.

The wedge-shaped ends of the pole pieces 3, 4, instead of terminating in a sharp edge, are flattened slightly to form the narrow walls 3^a and 4^a upon the respective apexes thereof, and when the pole pieces are in place normally the surfaces 3^a and 4^a are separated by a small gap between the poles of the magnet, of approximately two millimetres in width, thus constituting the two side walls of the string chamber. The front and rear walls of the chamber 5 are supplied by filler blocks 18, 19, similar in form to the tapered ends of the pole pieces, and thereby adapted to fit into the wedge-shaped gap formed at the two sides thereof, having flattened apexes 18^a and 19^a corresponding to the surfaces 3^a and 4^a of the pole pieces, (see Figs. 1 and 17). Thus when the filler blocks are in place the walls supported by their respective surfaces 18^a and 19^a when brought into proper relationship with the walls 3^a and 4^a, the rectangular vertical chamber 5 will accordingly be formed. The front block 18 is secured to the pole pieces by means of the bars 18^b to which the block is attached by screws, and which in turn is secured by similar screws to the respective pole blocks; the rearward wedge block 19 is in like manner held in place by means of the pole connecting plate 15 secured to the rear walls of the pole pieces by means of the screws and bolts 16 upon which plate it will be seen is supported another vertical bracket to which are attached the upper and lower housings of the string supporting mechanism next to be described.

The extreme niceties of the adjustments of the delicate string member I have found to have been frequently disturbed by reason of the almost imperceptible flexures of the pole binding plate 15, and other changes in the relative arrangement of these parts and to remedy such defective design of this important feature of the string galvanometer construction adopted, I have provided a bracket plate 20 and have thereby eliminated the rigid attachment of this plate bracket to the pole connecting plate 15 so that any displacement or movement of the former may not be communicated to the latter. Thus I employ a single stud 21 (Figs. 1 and 3) which is secured rigidly to the central portion of the plate 15 (see Fig. 13) projecting rearwardly through an orifice 22 in the plate 20 and the boss 23. The orifice 22 is made larger than the diameter of the bolt so that any tendency of the latter to move out of its normal place will not be communicated to the plate 20, and thereby communicated to the string supporting mechanism and disturbing the delicate setting of the string. Upon the threaded outer end of the stud 21 is the nut 24 by means of which a compression spring 25 is adjustably held against the boss 23 on the bracket plate 20, a collar 26 having been provided as a bearing for the end of the spring.

The action of the spring 25 is therefore adapted to press the plate 20 in the direction of the pole binding member 15, but the adjacent surfaces of the two plates do not come into immediate contact but instead three projecting members on the plate 20 are employed in the manner of supporting feet to rest against the plate. The three contact members or feet of the plate 20 comprise the three screws 27, 28 and 29, each preferably of hardened steel, suitably held in the correspondingly threaded orifice in said plate. At the lower central portion of the plate is placed the screw 27 the rounded end of which bears directly upon the surface of the plate 15 and projects beyond the outer surface of the plate 20, having a lock-nut at its end. The other two feet 28 and 29 are similarly supported in threaded orifices at the upper portion of the plate 20 at the respective sides thereof, and instead of having a rounded end as provided for the lower screw, 27, each has a conical or pointed end; the point of screw 29 resting in a corresponding conical depression 29^b in the disk like head of a hardened screw 29^a in the plate 15, while the similar point of the screw

28 is held within the horizontally disposed V-shaped groove 28^b of the flat head pin 28^a.

It is thus provided that the plate 20 is held in normal position against vertical displacement by means of the point of the screws 28 and 29 being firmly held in the groove 28^b and depression 29^b, while in case of any tendency of the plate 15 to expand or contract or otherwise become distorted, the groove 28^b permits the lateral sliding of the screw point 28 therein, and to maintain its normal position unaffected thereby. Likewise the round nose screw 27 at the bottom of the plate 15 being free to slide on the surface thereof, similarly prevents any possible modification or displacement of, or flexure in, that plate to affect the plate 20 in the manner indicated.

The bracket plate 20 has upon its top and bottom edges extending immediately above and below the pole pieces 3 and 4, and bearing against the respective upper and lower surfaces thereof, are the two similar horizontal plate members or base portions 31 and 32 (see Figs. 1 and 2; the upper member 31 being best shown in plan in Fig. 1) to which are attached or made integrally therewith the cylindrical boxes or housings of the string mechanism, which are thus operably supported upon the pole pieces immediately above and below the string chamber 5. The rectangular string chamber 5 thus constitutes a communication between the respective chambers of the said housings which contain the supports to which the string 30 is attached, which supports, as has been pointed out, are insulated from the electric-conductive portions of the apparatus, and are further made adjustable so as to move the string in all directions, and to regulate its tension by means of a longitudinal adjustment of one of the string supports. I will now describe the string supporting mechanism.

Upon the respective bracket plates 31 and 32 are supportably mounted the two hollow cylinders or shells 33 and 33^1, similar as to their general aspect both in form and in function, with the exception that the upper shell 33 has at its top an extension or chamber 34 within which, as will presently be seen, is housed the mechanism for controlling the tension of the string, the shells 33 and 33^1 containing the similarly acting means for moving the string laterally, which I will now describe more in detail, in connection with the string supporting mechanism.

The string 30 is a thread-like formation of quartz drawn to extreme fineness and having a metallic coating usually of gold or silver to render it electrically conductive, the diameter of string thus coated rarely exceeding .003 millimetres, and its length approximately 13 centimeters. The string is attached at each end, by a suitable adhesive, to the flattened side 41 of a pin 40, held in insulated brackets or string holders 35, 35^1, (see Fig. 11). The construction of the string holding brackets being identical in form, I will therefore describe in detail as applicable to both the mechanisms, the upper holder bracket 35. The string bracket holder, it will be seen by reference to Figs. 2 and 11, comprises an L-shaped metallic body piece 35 upon the vertical arm of which is attached in any convenient manner a block 38 of insulating material which in turn has suitably mounted upon its outer surface a slotted clamping block 39 into which the pin 40 is held by means of the small thumb screw 42; a second small screw 37 having been fitted in a suitably threaded aperture in the block 39 performs the function of a binding post of the wire over which is conducted the current to be measured.

Into the horizontal arm of the body piece 35, 36 is secured the stem 43 which in turn is slidably secured to the upper laterally slidable member 45 of the two way slides constituting the string adjusting mechanism next to be described, the stem 43^1 of the lower adjusting mechanism being rigidly attached to the corresponding member 35′ of that mechanism.

The mechanism employed for moving the string into the focal point of the shadow projecting mechanism, excepting as to a feature presently to be explained, is likewise composed of similar parts for the respective ends of the string 30, and the uppermost mechanism will accordingly be described as applying to the similar parts and features of both mechanisms.

Thus for the lateral adjustment of the string holding bracket 35 I employ a two way slide member 45 into which slidably fits the stem or shank 43 of the string bracket 35 which slide 45 is seated upon a second slide 46, which in turn is seated upon the plate 47 of the shell or housing 33, suitable clearance apertures having been centrally provided in the slide 46 and plate 47 to permit the stem 43 free passage therethrough. The member 46 is guided so as to be slidable in one direction only by means of a V-shaped gib 48 on its under surface which fits into a corresponding V-shaped groove 49 provided in the plate 47. Likewise upon the under surface of the slide 45 is a similar gib 50 adapted to be guided by a correspondingly formed groove 51 in the slide 46, the direction of the groove 49 in the top surface of the slide having been disposed at right angles to that of the gib 48 on the bottom of the slide, limiting the movement thereof to two directions and permitting the like movement of the slide 45 seated thereon in the two opposite directions. As pointed out, the stem 43 of the

string holder bracket 35 is adjustably supported by the slide 45 and for this purpose a bushing 76 is secured thereto into which the stem 43 slidably fits. The slides 45 and 46 are firmly held in their respective seats by means of a top plate 52 supported upon side pieces which hold it parallel to the surface of the plate 47 against the under surface of which the slide 45 bears. The slides 45 and 46 are movable against spring action in effecting adjustments, the supporting slide 46 being held by two compression springs 53 similarly supported at one end by the lip piece 54, their opposite ends bearing against the adjacent side of the slide. A similar lip piece 55 is also provided upon the top plate 47 having the thumb screw 56 suitably mounted therein for engaging the side of the slide opposite the spring, the stem of the screw projecting beyond the housing 33, to render it accessible to the operator for adjustment. A like spring holder lip 57 is similarly provided upon the slide 46 having compression spring 58 adapted to engage the slide 45, a lug 59 on said slide 46 holding a thumb screw 60 in suitable arrangement to engage the side of the slide 45 opposite the spring, the thumb screw 60 also projecting through beyond the shell 33.

Thus are provided means for adjustably moving the string holding bracket forward or back and to the right or left by means of two thumb screws 56 and 60.

Thus far the parts described in connection with the string adjusting mechanism which are contained within the housing 33 above the pole pieces, have their exact counterpart in the similarly acting mechanism housed in the lower shell 33′ excepting that the order of arrangement of the parts of the latter is inverted relatively to that of the upper mechanism and as already referred to, the stem 43 of the upper string bracket 35 is longitudinally adjustable in the sliding member 45, while the stem 43′ of the lower bracket 35′ is rigidly attached to the slide 45′, thus supplying means for controlling the tension of the string 30.

The string tension regulating means also comprises the vertical screw shaft 65 held by the threaded bushing 66 in the head 67 secured to the annular rib 68 internally disposed in the upper portion of the housing shell 34, which shaft has upon its shank above the thread the worm gear 69 mounted to slide longitudinally thereon but held from rotating relatively thereto by means of a spline 70. The gear 69 rests upon head 67 and is held longitudinally in place by means of the top plate of the shell 34, and is actuated for the purpose of rotating the screw shaft 65 within its threaded aperture, by means of a worm 71 pinned to the end of a shaft 72, suitably mounted in a bushing 34′ in the walls of the housing extension 34, having the knurled wheel 73 upon its outer end accessible to the operator for turning between thumb and finger to manipulate the vertically adjusting screw 65.

Immediately beneath the adjusting screw 65 is the flat head 74 of the vertically slidable stem 43 which is normally held against the adjusting screw by action of the compression spring 75 resting upon the flange 76′ of the bushing 76 through which the stem 43 passes, and bearing upwardly against the disk-like head 74 of the stem 43. The end of the screw itself, however, does not bear directly upon the head 74, but upon a small hardened steel plate 77 resting centrally upon that member, being held in place thereon by means of a short stem 78 extending into the top of the shaft 43. In the end of the screw 65 is embedded securely a small hardened steel ball, which is brought into immediate contact with the top surface of the small plate 77. The diameter of the disk plate 77 is determined by the extent of lateral adjustment required of the stem 43 in its movements both to the right and left, and forward and back; and the stem 43 is held against whatever tendency to rotate the same may be caused when the adjusting screw 65 is turned, by means of two pins 79 extending upwardly from the bushing 77 into suitable apertures in the head 74 thereof.

In the pole pieces 3, 4 are the telescoping tubes 80 and 80′ that are longitudinally disposed centrally thereof. The tube 80′ in the pole piece 3 in the form illustrated, receives the light and by means of the usual arrangement of suitable lenses is adapted to bring the rays from a lamp apparatus 90 (as shown in Fig. 18) or other source of light, into focus at the point to be traversed by the string 30; and in like manner the tube 80 is held by the pole piece 4 and receives the rays of light as they diverge from such focal point, and project them, highly magnified, upon the photographic film of a suitable camera.

The respective tubes 80, 81 are inserted in longitudinally disposed cavities in the respective pole pieces to which they relate, and have the usual means for adjusting the relative arrangement of the lenses, my invention having no especial reference to those particulars further than stated. It has been found, however, that the telescopic tubes themselves require lateral adjustment at times, and for this purpose I have mounted the respective tubes upon annular bearings 81, 81′ which are attached in like manner to the outer ends of the pole pieces 3, 4. The mechanisms for supporting the respective tubes are identical in structure and operation, and I will describe in detail the parts attached to the pole piece 4 shown in section

in Fig. 2, supporting the tube 80, with the intention that such specification apply also to the adjustable supporting means for the tube 80, 80′ upon the pole piece 3. The annular bearing 81 has two parallel inner surfaces 83 adapted to receive therein a corresponding member 82 which is made in the form of a collar surrounding the tube 80 to which it is rigidly attached substantially midway of its length, the end surfaces of which are adapted to bear against the inner faces of the annular member 81, the width of the collar 82 being designed to fill the space between said surfaces, and the diameter of the central opening of the latter having been made larger than that of the tube, to admit of the necessary latitude of adjustment thereof. In the periphery of the annular bearing 81 are three threaded orifices equally spaced circumferentially thereof, into which are inserted three similar thumb screws 84 except that the stem of the one at the front projects less from the surface of the bearing than those in the rear of that member. Thus it is provided that by loosening or withdrawing one, or, it may be, two of the screws and tightening the remaining screw or screws, the tube may be shifted bodily in all directions laterally thereof.

The rays of light passing through the tubes 80, 80′ when properly adjusted will by action of the lenses of the tube 80 be projected through the shutter of the camera 95, in which is a moving sensitized film, preferably having graduations both transversely and longitudinally, which film is caused to pass before the usual shutter of the camera at a predetermined rate of speed, and that when the string 30 has been properly brought in to the focal point between the tubes 80 and 80′, successive shadows thereof will be photographed. It is deemed sufficient for the purposes of the present specification to indicate the general type of camera used, and means for actuating any of the familiar types of cameras adapted to photographically record successive views. Thus, I employ a camera box 96 having two shafts 97 and 98, the latter having pinned thereon a pulley 99 which may be driven by any convenient means, such as the small electric motor 100 from a small pulley on the shaft of which is the belt shown in Fig. 18. The film is then placed in the camera box upon the usual spool upon the shaft 97 and brought immediately in front of the shutter indicated at 101 and attached to a second spool on the shaft 98, upon which it is wound after passing before the shutter of the camera.

In the front of the casings 33, 33′ are similar openings 33^a extending all the way to the base of each housing, and at the respective sides thereof are small openings 33^b. A rotatable inner shell or door 33^c is held within the respective shells 33 and 33′, which have openings 33^d and 33^e corresponding in size, shape and relative arrangement with the openings 33^a and 33^b so that when the closure shell 33^c is rotated to the proper position, its opening 33^d coincides with the opening 33^a, thereby bringing the openings 33^b and 33^e into coincidence, as shown in Fig. 2.

When the doors are thus opened and the wedge filler 78 has been removed, the string holding mechanism is sufficiently exposed to admit of free access in removing and replacing strings when required. Thus also it will be seen when the piece 18 is replaced and the door member closed by rotating the same into such position, the string containing cavity has been rendered immune against air drafts or the accumulation of moisture or other damaging effects.

Having described my invention, what I claim is:

1. In a galvanometer having an electro-magnet with oppositely disposed pole members, adjustable means for suspending a string between said pole members, said means being laterally and longitudinally adjustable relatively to said pole members into a plurality of parallel positions relative to itself.

2. In a galvanometer for measuring feeble electrical currents, an electro-magnet and oppositely disposed pole pieces thereon; an electro-conductive string member suspended between said pole pieces adapted to carry electric currents therethrough; means for projecting rays of light through said pole pieces, comprising lenses in telescopic tubular cases; and enclosed means for adjusting into a plurality of parallel positions, said string relatively to itself and to said pole pieces and said lenses.

3. In a galvanometer for measuring feeble electric currents, an electro-magnet and oppositely disposed pole pieces thereon; an electroconductive string member suspended between said pole pieces; means for projecting rays of light through said pole pieces, comprising telescopic tubes with lenses adapted to cause said rays to converge at a focal point intermediate said pole pieces; self-adjusting means mounted upon said pole pieces for adjustably suspending said electro conductive string member transversely through said focal point intercepting a portion of said rays thereby to cast a shadow of said string; and means for controlling the tension of said string.

4. In a galvanometer for measuring feeble electric currents, an electro magnet and oppositely disposed pole pieces thereon; means for projecting rays of light through said pole pieces, comprising telescopic tubular cases with lenses adapted to cause said rays

to converge at a focal point intermediate said pole pieces; self adjusting means mounted upon said pole pieces for adjustably suspending an electro conductive string transversely through said focal point, intercepting a portion of said rays thereby to cast a shadow of said string; means comprising a sensitized moving film for photographing said shadow in a succession of exposures; and means for controlling the tension of said string.

5. In a galvanometer for measuring feeble electric currents, an electro magnet and oppositely disposed pole pieces thereon; means for projecting rays of light through said pole pieces and focussing said rays intermediate said pole pieces; self adjusting means carried by said pole pieces for adjustably supporting an electro-conductive string in the focus of said rays; insulated supports for said string; means for housing said string and the supports thereof, said housing means adapted to prevent air currents contacting said string; and spring actuated means for regulating the tension of said string and a thumb screw for controlling said spring actuating means.

6. In a galvanometer for measuring feeble electric currents, an electro-magnet and pole pieces thereon; an electro-conductive string having terminals adaptable to form electrical connections with animal bodies; insulated brackets and means carried by said pole pieces for adjustably supporting said brackets to which brackets the respective ends of said string are attached; and independent means for laterally adjusting the positions of said respective brackets, each comprising a pair of slides, one of said slides operably supported upon the other thereof.

7. In a galvanometer for measuring feeble electric currents, an electro-magnet and pole pieces thereon; an electro-conductive string having terminals adaptable to form electrical connections with animal bodies; insulated brackets and means carried by said pole pieces for adjustably supporting said brackets to which brackets the respective ends of said string are attached; independent means for laterally adjusting the positions of said respective brackets, each comprising a pair of slides, one slidably supported upon the other of said slides; and means for adjustably moving the bracket at one end of said string longitudinally relatively to the bracket at the other end of said string.

8. In a galvanometer for measuring feeble electric currents, an electro-magnet having oppositely disposed pole pieces; telescopic tubes with lenses adapted to focus rays of light projected therethrough; supporting means for interposing a string of minute cross-sectional area of electro-conductive material in said focus; insulated brackets for supporting said string; manual means for adjusting said brackets laterally; and manual means for adjusting one of said brackets relatively to the other.

9. In a galvanometer for measuring feeble electric currents, an electro-magnet and pole pieces thereon; means for focussing rays of light intermediate said pole pieces; self-adjusting means mounted on said pole pieces for supporting insulated brackets adjacent said pole pieces; an electro-conductive string attached to said brackets for receiving the electric current to be measured; manual means comprising slides each adapted to move at right angles relatively to the other for laterally adjusting said brackets intermediate said pole pieces; means for controlling the tension of said string.

10. In a galvanometer having an electro-magnet with spaced opposed pole members, a conducting string, means for supporting said string under tension in the space between said pole members, and means for shifting said string supporting means in a plurality of directions transversely of the string without varying the tension of the string.

11. In a galvanometer having an electro-magnet with spaced opposed pole members, spaced terminals, a conducting string passing between the pole members and connected to said terminals, and supporting means for each terminal comprising a stationary member, an element adjustable thereon in one direction and in a plane transverse to the string, and a second element in a direction different from that of said first element and in a plane also transverse to the string, said terminal being carried by said second element.

12. In a galvanometer having an electro-magnet with spaced opposed pole members, spaced terminals, a conducting string passing between the pole members and connected to said terminals, supporting means for each terminal comprising a stationary member, an element adjustable thereon in one direction and in a plane transverse to the string, and a second element in a direction different from that of said first element and in a plane also transverse to the string, said terminal being carried by said second element, resilient means carried by the second element of the supporting means for one of the terminals and exerting a tensioning force on the string, and means carried by the stationary member and operative in all adjusted positions of the elements for varying the effect of the resilient means upon the string.

13. In a galvanometer having spaced opposed pole members, a conducting string, means for supporting said string in the space between the pole members and under

tension, optical mechanism extending through the pole members for observing the movement of the conducting string when a current passes therethrough, and means for adjusting the optical mechanism in said pole members in a direction transverse to itself to place the image of the string in any desired portion of the observation field of the mechanism.

14. In a galvanometer having spaced pole members, supports carried by said pole members, a conducting string passing between said supports and in the space between the pole members, the connection between the string and one of the supports comprising an element adjustable on said one support in one direction transverse to the string, a second element adjustable on said first element in a direction transverse to the string and also in a direction different from the direction of movement of the first element, a sleeve carried by the second element and parallel with the string, a terminal member to which an end of the string is connected slidable in said sleeve, and spring means between the sleeve and the terminal member for shifting the latter to tension the string.

15. In a galvanometer having spaced pole members, supports carried by said pole members, a conducting string passing between said supports and in the space between the pole members, the connection between the string and one of the supports comprising an element adjustable on said one support in one direction transverse to the string, a second element adjustable on said first element in a direction transverse to the string and also in a direction different from the direction of movement of the first element, a sleeve carried by the second element and parallel with the string, a terminal member to which an end of the string is connected slidable in said sleeve, resilient means between the sleeve and the terminal member for shifting the latter to tension the string, and means adjustably carried by said one of the supports and co-acting with said terminal member in all of the adjusted positions of the member for varying the effectiveness of the resilient means upon the string.

16. In a galvanometer having spaced pole members, a conducting string for connection to an external circuit arranged across the space between the pole members, terminals to which the ends of said string are connected, a sleeve in which one of the terminals is slidably mounted for movement in the direction of the string; a spring acting between the said one of the terminals and the sleeve for tensioning the string, a plate upon which the sleeve is mounted, means for adjusting the plate in one direction transversely of the string, means for shifting said means in a direction transverse to the string but different from the other direction of movement of the plate, a contact member adjustable to variable extents against the end of said one of the terminals throughout all of its transverse movements with the plate for varying the effect of the spring upon the string.

17. In a galvanometer having spaced pole members, a conducting string, terminals between which the string is stretched with the string extending across the space between the pole members, means for shifting one of said terminals in a plurality of directions transverse to the string, resilient means tending to tension said string, a thrust member against which the said one of the terminals abuts in all adjusted positions, and means for adjusting said thrust member to negative to various extents the effect of the resilient means upon the string.

18. In a galvanometer having spaced pole members, a conducting string, terminals between which the string is stretched with the string extending across the space between the pole members, means for shifting one of said terminals in a plurality of directions transverse to the string, resilient means tending to tension said string, a thrust member against which the said one of the terminals abuts in all adjusted positions, and means including a worm wheel carried by the thrust member and a worm meshing therewith for feeding the thrust member slowly toward or from the terminal to negative to various extents the effect of the resilient means upon the string.

19. In a galvanometer having spaced pole members, spaced terminals, a conducting string connected between the terminals and extending across the space between the pole members, housing means carried by the pole members and enclosing the string and terminals, a plate mounted on said housing, means for movement in a single direction transversely of the string, a screw for forcing the plate in this direction, resilient means for opposing this movement of the plate, a second plate mounted on said first plate for movement in a direction at an angle to that of the first plate, a screw for forcing the second plate in its direction of movement, resilient means opposing the movement of the second plate by the screw, a sleeve carried by said second plate with its axis substantially parallel with the string, one of said terminals being slidingly mounted in said sleeve, spring means acting between the sleeve and said one of the terminals for shifting the latter in the sleeve to tension the string, and means for varying the tensioning effect of the spring means upon said string.

20. In a galvanometer having spaced pole member, spaced terminals, a conducting string connected between the terminals and extending across the space between the pole members, housing means carried by the pole

members and enclosing the string and terminals, a plate mounted on said housing, means for movement in a single direction transversely of the string, a screw for forcing the plate in this direction, resilient means for opposing this movement of the plate, a second plate mounted on said first plate for movement in a direction at an angle to that of the first plate, a screw for forcing the second plate in its direction of movement, resilient means opposing the movement of the second plate by the screw, and means for securing one of said terminals to said second plate.

In testimony whereof, I have signed my name to this specification, this 25th day of May, 1917.

CHARLES F. HINDLE.