L. T. ROBINSON.

OSCILLOGRAPH.

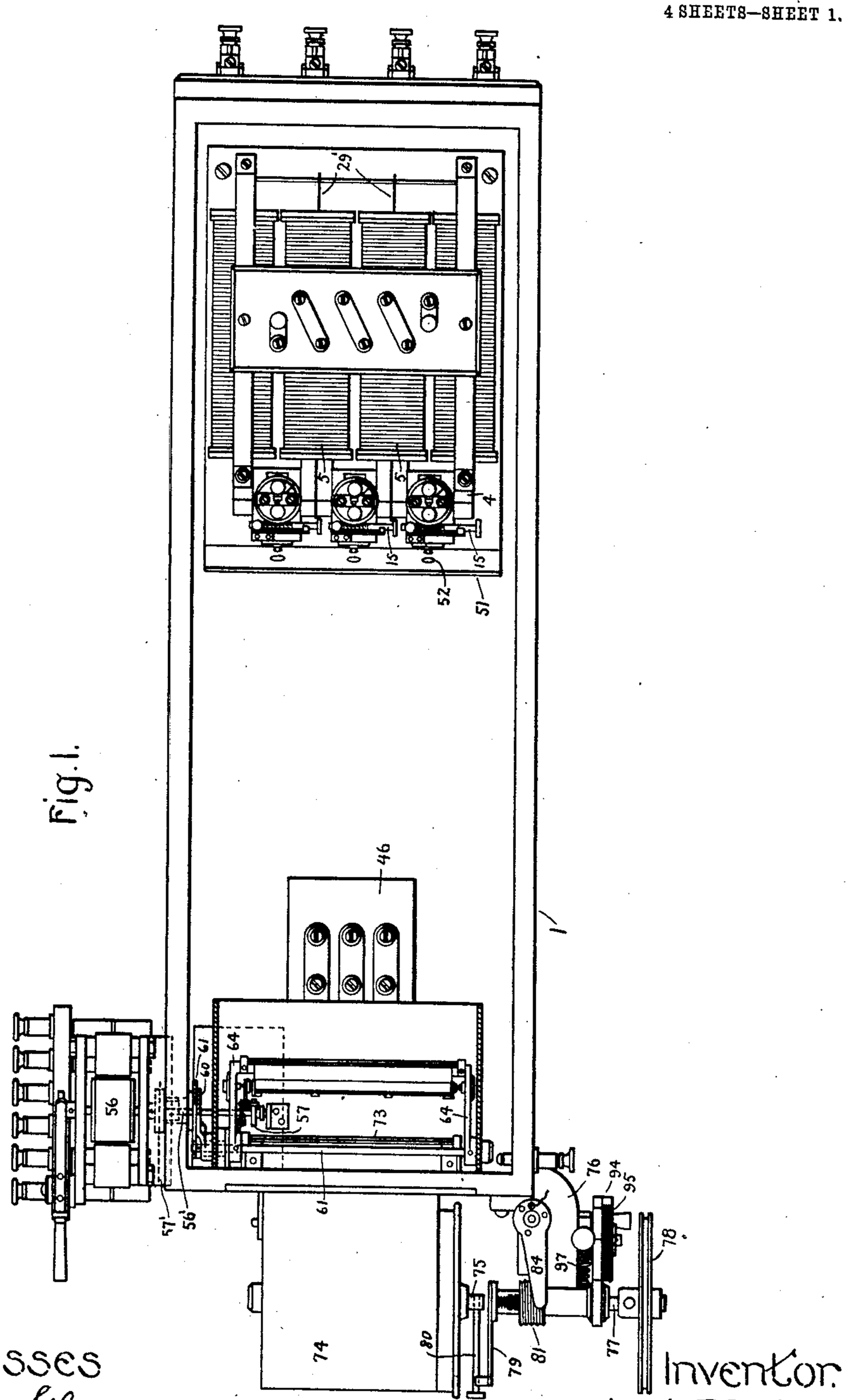
APPLICATION FILED MAR. 13, 1905.

919,467.

Patented Apr. 27, 1909.

4 SHEETS—SHEET 1.

Fig. 1.



Witnesses

J. Ellis Glen.

Helen Alford

Inventor

Lewis T. Robinson

by Albert G. Davis

Atty.

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4 SHEETS—SHEET 2.

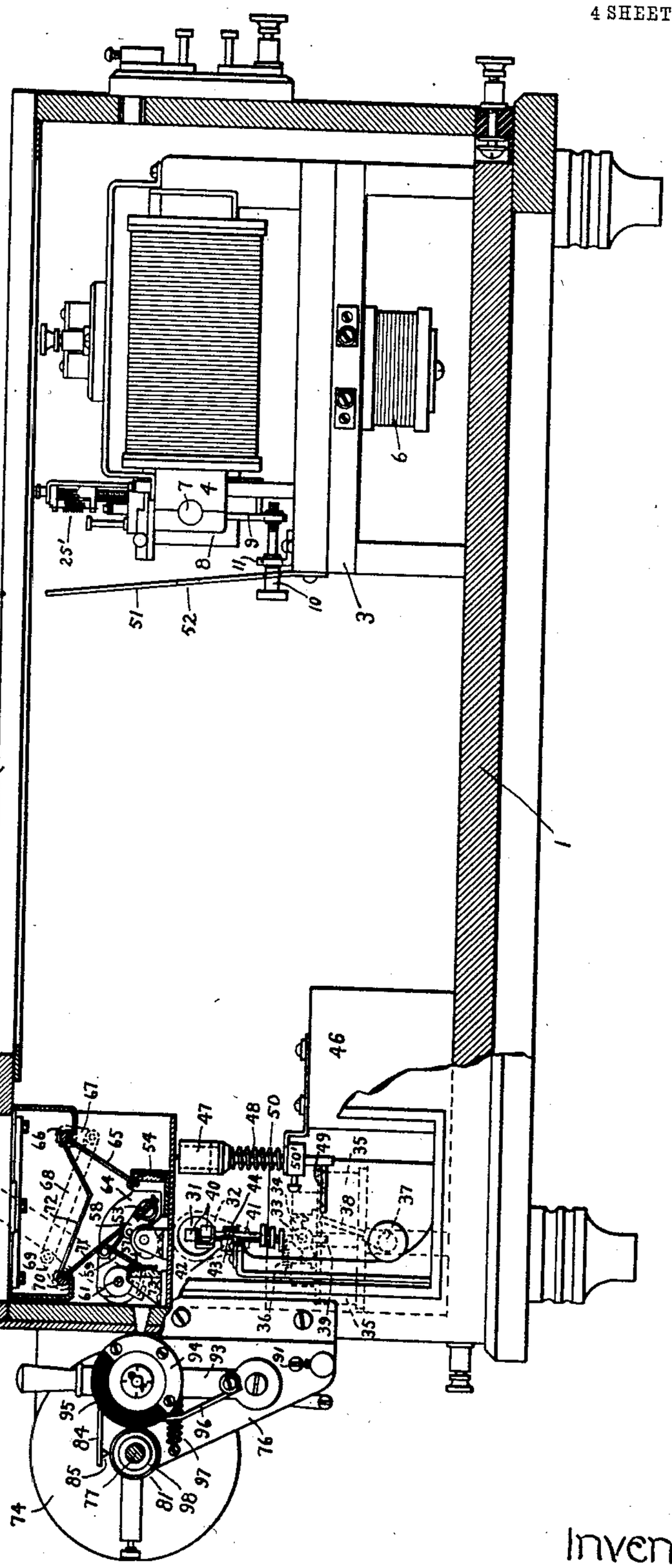

Fig. 2.

Witnesses
J. Ellis Glen
Green Alford

Inventor:
Lewis T. Robinson.
by Albert G. Davis
Atty.

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4 SHEETS—SHEET 3.

Fig. 3.

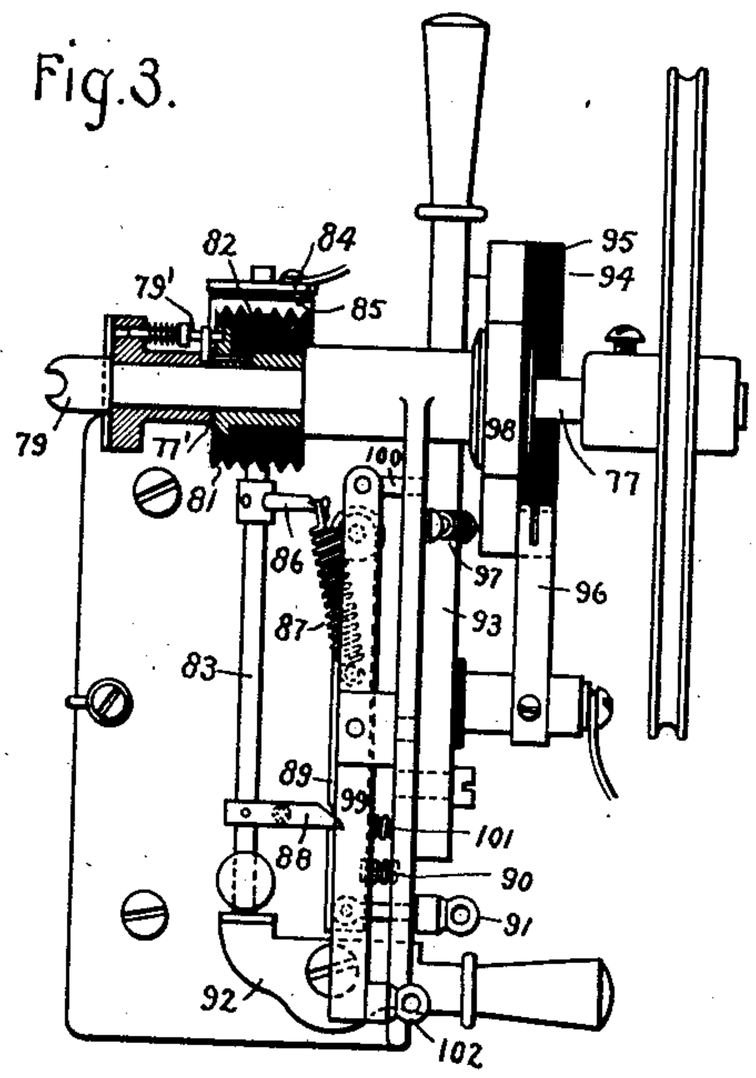


Fig. 4.

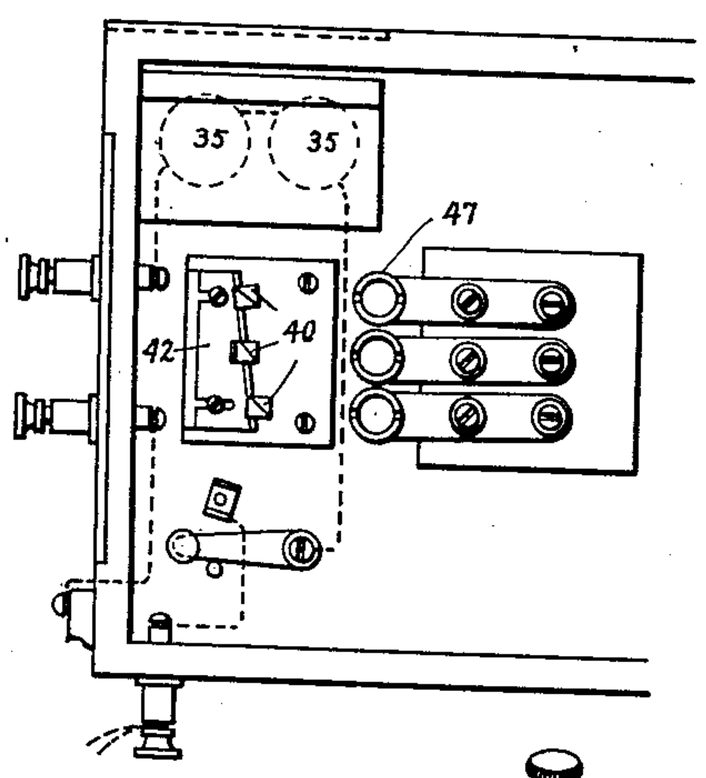
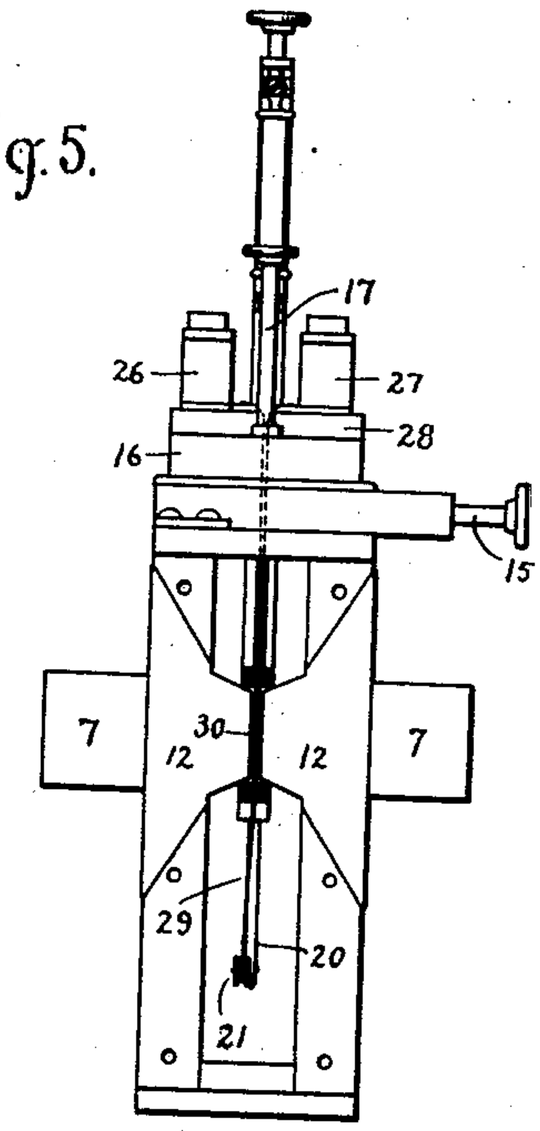


Fig. 5.



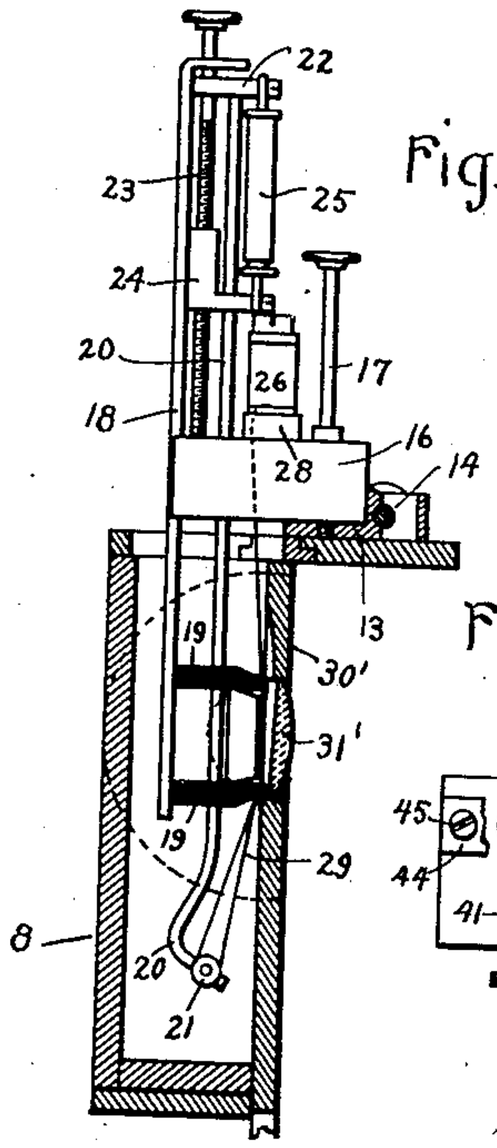


Fig. 6.

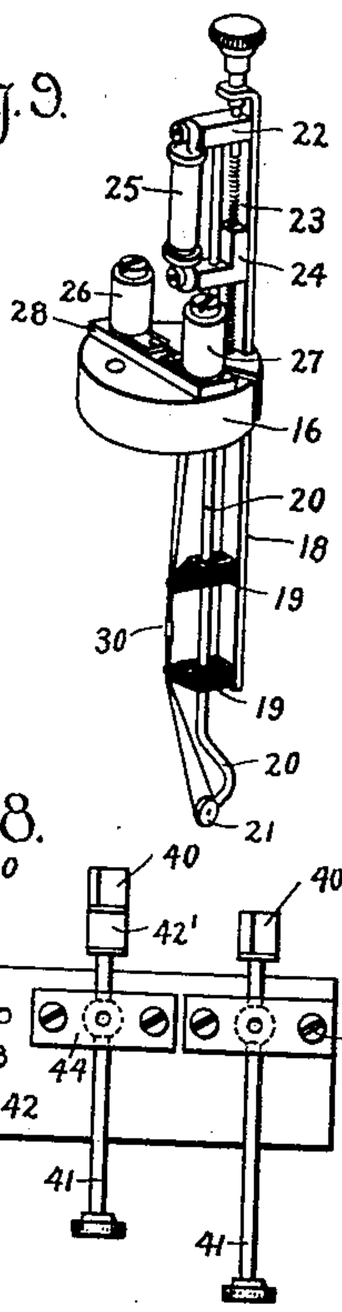
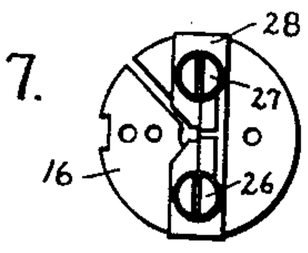


Fig. 8.

Fig. 7.



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4 SHEETS—SHEET 4.

Fig. 10.

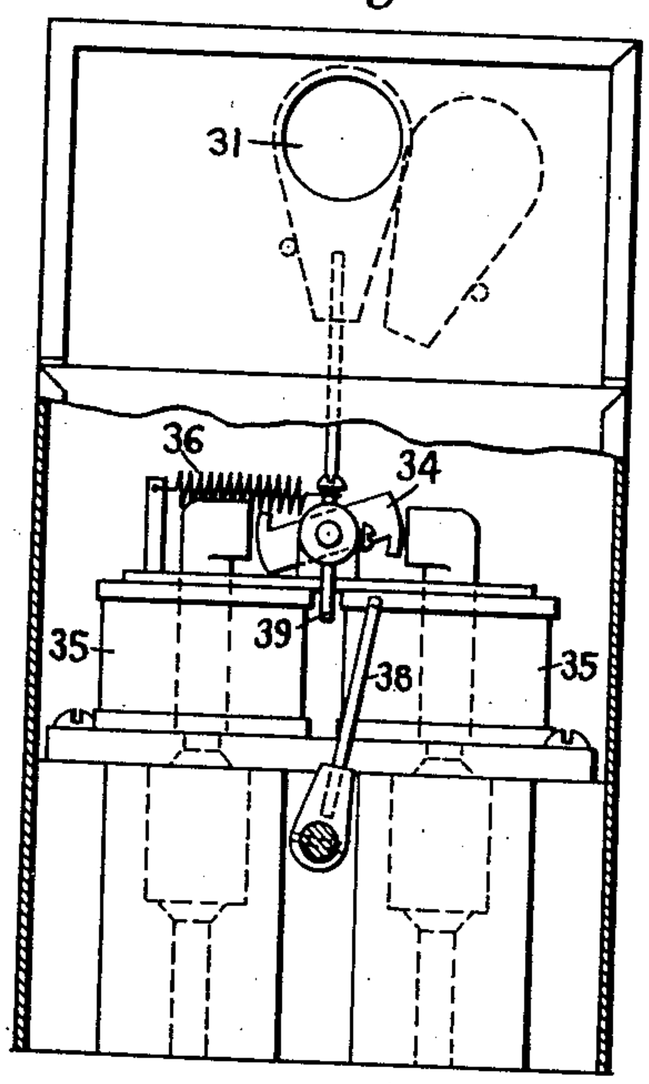


Fig. 11.

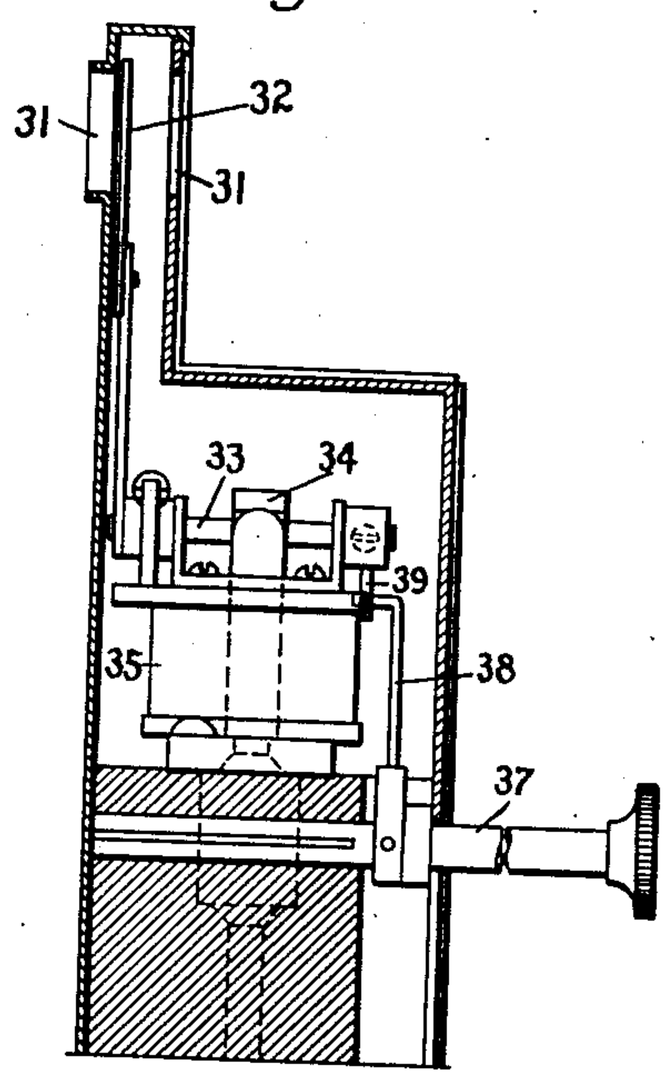
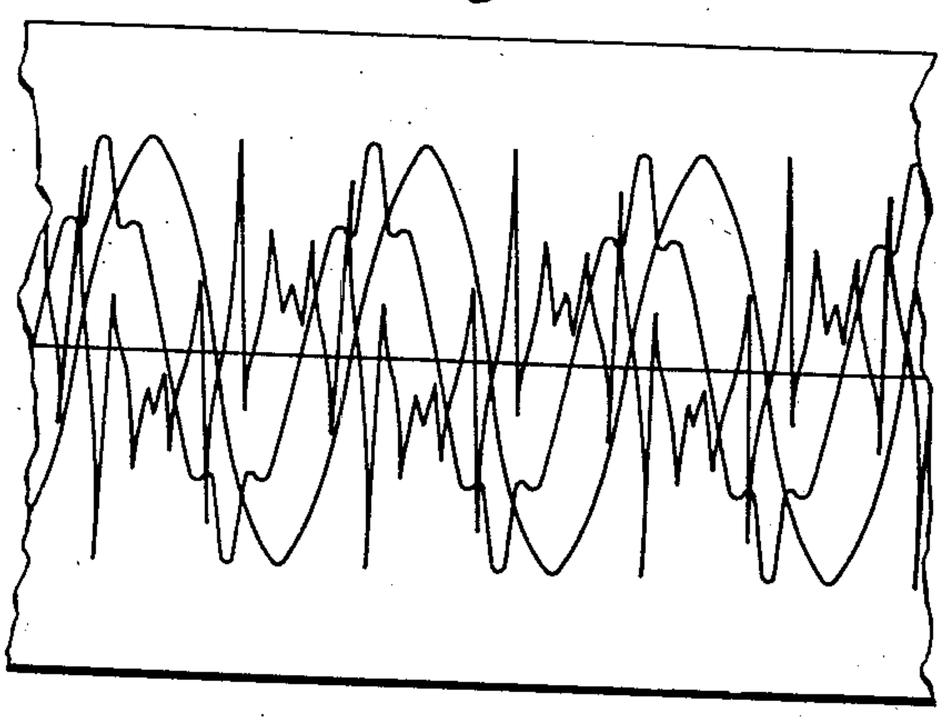


Fig. 12.



Witnesses:
Irving E. Steers.
J. Ellis Glen.

Inventor
Lewis T. Robinson,
by Allen & Davis
Atty's

UNITED STATES PATENT OFFICE.

LEWIS T. ROBINSON, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

OSCILLOGRAPH.

No. 919,467. Specification of Letters Patent. Patented April 27, 1909.

Application filed March 13, 1905. Serial No. 249,744.

To all whom it may concern:

Be it known that I, LEWIS T. ROBINSON, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Oscillographs, of which the following is a specification.

This invention relates to instruments for indicating or measuring rapid changes in the position or value of a varying quantity or element.

More particularly, my invention relates to instruments of the type commonly known as "oscillographs" for obtaining curves of the instantaneous values of voltage and current or other characteristics which may be derived therefrom.

The instrument consists of a reflecting galvanometer of extremely high period and suitably damped, placed in a light-tight box in which is an opening provided with a shutter for admitting light rays from an arc lamp or other suitable source. Lenses and mirrors may be arranged in position to concentrate the rays on the mirror of the galvanometer from which they are reflected onto either a photographic film for making a permanent record of the oscillations or a suitable screen in order that the varying values may be observed.

In the preferred form of my invention I employ three reflecting galvanometers and means whereby the rays from the mirror of each one can be focused on the same point so as to take three waves simultaneously showing each in its proper phase relation to the others.

The novel features of my invention will be definitely indicated in the claims appended hereto.

The details of construction and the mode of operation of my improved oscillograph will be better understood by reference to the following description, taken in connection with the accompanying drawings, which show the preferred embodiment of my invention.

In the drawings, Figure 1 is a plan view of the instrument; Fig. 2 is a sectional elevation of the same; Fig. 3 is a sectional elevation of the film and shutter operating mechanism; Fig. 4 is a plan view of the prisms and slits; Fig. 5 is a front view of one of the vibrators and its chamber; Fig. 6 is a sectional elevation of the same; Fig. 7 is a plan view of the supporting member of the vibrator; Fig. 8 is a detail view of the prisms and their supports; Fig. 9 is a perspective view of the moving element; Fig. 10 is an elevation of the combined hand and electromagnetic shutter mechanism shown in dotted lines in Fig. 2; Fig. 11 is a sectional view at right angles to the plane of Fig. 10; and Fig. 12 shows three alternating current curves traced simultaneously on one film by the instrument, one curve being a close approximation to a sine curve, the second being irregular near the peak of the curve, and the third being very irregular.

Referring to the drawings, 1 indicates a light-tight box having a removable cover 2 and doors in the sides which may be opened in order to adjust the parts. In the end of the box on a raised platform 3 are mounted three galvanometers. The magnetic field for each of the galvanometers is supplied by a strong electro-magnet 4. These three electro-magnets are arranged side by side and two of the energizing coils 5 5 are each wound about the adjacent legs of two of the magnets. The magnets are thus arranged in a very compact manner. Beneath the platform 3 is a resistance 6 which may be connected in circuit with the coils 5 5, when necessary, to obtain the proper energizing current. Also, the coils of the magnets may be connected in series and parallel for this same purpose. Between the legs of each magnet 4 is supported a closed chamber 8 carrying the vibrator which forms the moving element of the galvanometer. In order that the position of the vibrator may be adjusted I form trunnions 7 on the side of each chamber 8 and provide openings in the ends of the legs of the magnets to receive these trunnions. Each chamber has an extension 9 at its lower end, and a screw 10 having a knurled head passes through a pivoted nut in standard 11 on the platform 3 and into a threaded opening in a nut swiveled in the extension 9 so that by turning the screw the chamber and the various parts thereof are rocked on a horizontal axis. In the sides of each chamber 8 are pole-pieces 12 12 which carry the lines of force of the magnet and on which the trunnions 7 are formed. These pole-pieces have relatively large outer surfaces in contact

with the legs of the magnet, as shown in Figs. 5 and 6, and they are tapered so that the adjacent surfaces are comparatively small and the air-gap between these surfaces is a very narrow one. The pole-pieces 12 12 thus concentrate the lines of force in a very narrow field and therefore the field is a very strong one. Another important advantage obtained by this construction is that in adjusting the vibrator carried within the chamber 8 on a horizontal axis the auxiliary pole-pieces 12 12 are adjusted with it so that the relation of the vibrator and the magnetic field is in no way changed. In the top of the chamber 8 is a circular opening and mounted for movement about the edge of this opening is a holder 13, a portion of the periphery of which is cut to form a worm-wheel with which meshes a worm 14 on a shaft 15 provided with a knurled head. The vibrator is detachably secured on the holder 13 and therefore when the shaft 15 is rotated, it operates through the gearing to turn the holder and the vibrator carried thereby on a vertical axis.

The parts of the vibrator are assembled on a cylindrical supporting member 16 and a threaded screw 17 having a knurled head extends through this member and into a threaded opening in the holder 13 to detachably secure the vibrator in place thereon. Secured to the back of the supporting member 16 is a frame 18 which at its lower end carries two blocks 19 of insulating material, preferably ivory, over which the wires of the movable member of the galvanometer extend. A rod 20 passing loosely through the member 16 and the two blocks 19 carries a small pulley 21 at its lower end. This pulley is supported on the rod 20 from only one side, as shown in Fig. 5. At its upper end rod 20 is secured to a follower 22 having an opening therethrough.

A threaded shaft 23, rotatable in bearings in the frame 18 and the member 16 and having a knurled head, passes loosely through the follower 22 and a second follower 24 is threaded on this shaft. Secured to the followers 22 and 24 are the two members of a telescoping casing 25 in which is a spiral spring 25′ (Fig. 2) the ends of which are attached to the two members of the casing. Thus the spring in the casing 25 acts on the follower 22 to force the rod 20 downward through the opening in the member 16.

Mounted on member 16 are two binding-posts 26 and 27 suitably insulated by a strip of ivory 28 to which are attached the terminals of a looped conductor 29, preferably a strip of thin ribbon conductor, which forms the moving element of the instrument. In the member 16 is a radial opening, as shown in Fig. 7. The loop 29 is mounted in position by soldering one end to the binding post 26, then drawing the wire through the radial opening in member 16, then carrying it down over the blocks 19 19, around pulley 21, back over blocks 19 19 and through the slit in member 16, and then soldering its other end to the binding-post 27. Shallow notches are cut in the ivory blocks 19 to hold the two lengths of the conductor parallel to each other and very close together and at the same time prevent them from coming in actual contact. This looped conductor 29 is made of a material of low resistance but of considerable elasticity, so that it will be springy and have a high rate of vibration when put under tension. Heretofore it has been considered necessary to use for this purpose a conductor of phosphor-bronze or steel because of its greater strength but the high resistance causes considerable heating of the conductor and a gradual creeping of the beam of light across the scale, so that the beam of light does not come back to zero when the current is cut off. I have found, however, that a looped conductor of silver or of silver alloyed with a small amount of some other metal can be made sufficiently strong for the purpose and its lower resistance is of great advantage as the heating is so slight that it produces practically no effect. In practice it is frequently necessary to use the instrument for obtaining curves on a circuit carrying a very large current. To do this the conductor 29 is connected in parallel to a shunt inserted in the main line. If the conductor is made of phosphor-bronze or steel the shunt in the main line must be very large and a large amount of energy is lost therein, whereas by making the conductor of silver or other material having a very low resistance the size of the shunt can be greatly reduced and the great decrease in the voltage drop between the terminals of the shunt effects a corresponding decrease in the energy loss therein. The spring 25′ in the casing 25, tending to push the rod 20 downward, holds the looped wire under tension. Turning the shaft 23 by its knurled head moves the follower 24 up or down and thus changes the tension of the spring 25′ on the loop 29. The inner member of the casing 25 may be graduated to assist the operator in securing the desired tension on the loop. The member and frame 18 form a conductor support which can be moved back from the pole pieces when the screw 17 is loosened, since the clearance between the frame 18 and the casing 8 is great enough, as shown in Fig. 6, to permit the conductor to be moved transversely of the axis of the pole pieces and brought out toward the center of the casing 8, after which the conductor support can be removed longitudinally of the casing without any danger of injuring the conductor. The pulley 21 is mounted out of alinement with the axis of the pole pieces, as

shown in Figs. 6 and 9, and if desired, the conductor can be moved longitudinally from between the pole pieces without the pulley 21 catching on the pole pieces, but the preferable arrangement is as above described, in which the conductor can be backed out from between the pole pieces before it is moved longitudinally, and thereby the chances of injuring the conductor by striking it against the pole pieces are lessened. Thus the vibrator may be quickly removed from the chamber if desired, its parts are all perfectly accessible and the tension of the loop can be observed and regulated without removing the vibrator from the chamber. The tapering pole-pieces 12 12 concentrate the lines of force of the electro-magnet on the portion of the loop 29 between the two blocks 19 19 and midway between these two blocks a small mirror 30 is secured to the two lengths of the wire by cement. A detachable plate 30′ closes the front of the vibrator chamber and is provided with an opening over the mirror 30 in which a lens or glass 31′ is mounted. When the instrument is to be used the vibrator chamber is filled to a level above the mirror 30 with a damping liquid such as castor oil to dampen the oscillations of the mirror.

It will be seen that when the vibrator is removed from its chamber, the two lengths of the looped conductor 29 are perfectly accessible on all sides about the point where the mirror 30 is secured thereto. In instruments of this type as heretofore constructed the vibrator has not been removable independently of the parts which are mounted close to the mirror such as the pole-pieces inserted in the sides of the chamber, so that it is extremely difficult to mount a new mirror in place owing to the very limited space in which to work. On account of the delicacy of the parts, securing a new mirror 30 to the two lengths of the looped conductor is difficult even under the best conditions but by so constructing the vibrator that when removed from its chamber the conductor is accessible on all sides about the point where the mirror is secured thereto this can be much more readily accomplished.

Between adjacent galvanometers a sheet 29′ of insulating material is inserted as shown in Fig. 1. This sheet is of such a thickness that it will withstand a high potential, preferably as much as 5000 volts, so that the several galvanometers are effectually insulated one from another. I consider this a feature of considerable importance as in practice it is often found desirable, and sometimes almost necessary in order to get accurate curves, to carry to the several galvanometers currents differing greatly in potential, and this can be done with safety when the galvanometers are individually insulated one from another.

In the box 1 is an opening 31 normally closed by a shutter 32 inside the box secured on a shaft 33 which also carries the armature 34 of a pair of electro-magnets 35. Thus when the magnets are energized the armature is rocked on its shaft and the shutter 32 is moved away from the opening, and when the magnets are deënergized, a spring 36 brings the shutter back so as to close the opening as is shown in Fig. 10. Extending through the box is a shaft 37 carrying an arm 38. This shaft may be turned by hand from outside the casing to bring the arm 38 into engagement with a finger 39 depending from the shaft 33 so as to move the shutter away from the opening 31. The parts may be left in this relation, friction in the bearing of shaft 37 serving to hold them against the tension of spring 36. The light entering the opening 31 when the shutter is moved away is received by three prisms 40 (Figs. 2 and 8), each carried by a post 41 held on a support 42 which is secured on a standard within the box 1. In each of the posts 41 is an enlargement forming a ball 43. Plates 44 are secured to the support by screws 45 and the posts 41 are each held between the support and one of the plates 44. In the support and the plates are slight depressions to receive the balls 43. The prisms are thus supported in a manner permitting adjustment in any direction, a button being provided on the lower end of each post 41 for this purpose. The support 42 for these prisms is arranged at a slight angle so that the first prism does not obstruct the passage of the rays of light to the third prism and the second one is arranged above the level of the first and the third on a holder 42′ which is bent so as not to obstruct the rays to the third prism, so that each of the three prisms receives the rays of light through the opening 31 direct from an arc lamp or other suitable source located outside the box 1.

The prisms 40 reflect the rays upon the mirror of the galvanometer through adjustable slits located one in front of each of the three prisms. Each of these adjustable slits 47 is carried on a post 48 which extends down through an opening in a support mounted on a raised platform 46, and at its lower end is provided with a pin 49 by which the slit may be angularly adjusted. A spring 50 coiled about the post 48 keeps the slit in any position to which it is moved, a collar 50′ secured on post 48 serving to hold the post against upward movement. These adjustable slits have been constructed heretofore from solid cylindrical blocks by cutting a slot with straight sides therethrough. With such a construction even though the slit be painted black, the rays of light are reflected to some extent by the walls of the slot. I avoid this by making the slit from a tube by cutting slots of a width less than the inner

diameter of the tube in the walls of the tube at diametrically opposite points, as shown in Figs. 2 and 4, thereby forming a slit or passage with concave walls, having its greatest cross-section midway between the ends. In this way, rays which enter the slit at one side at somewhat of an angle strike on the concave wall and are not reflected out through the other end of the slit, and the only rays of light coming through the adjustable slit are the direct rays. By turning the slit by means of the pin 49 more and more of these direct rays may be cut off and the width of the beam of light thus adjusted. To further shut off all rays of light but the useful ones, a screen 51 is secured to the support for the magnets 4 in which are three openings 52, one for each beam from the prism 40 to the mirror of the galvanometer corresponding thereto.

From the mirror the rays are reflected back through the opening 52, either upon a film for taking a photographic record or upon a mirror 53 by which they are reflected directly upward upon a ground glass 55 or other translucent sheet mounted over an opening in the cover of the box 1. The drawings show the parts in position for the rays of light from the galvanometer mirror to be reflected by mirror 53 upon ground glass 55. With the parts thus arranged it will be seen that as the mirror of the galvanometer turns back and forth on a vertical axis the spot of light on the mirror 53 will move back and forth across the mirror and the spot reflected by the mirror 53 on the ground glass 55 will move from side to side. In order to obtain a curve of the oscillations, the mirror 53 is supported on pivots and means are provided for rocking it so as to give a movement of the spot of light up and down on the ground glass 55.

In order to get an accurate curve the frequency of the rocking movement of mirror 53 should bear a definite ratio to the frequency of the oscillations of the mirror of the galvanometer, and I therefore employ a synchronous motor 56 secured to the box 1 on the outside thereof and connected in the same circuit with the loop of the galvanometer to effect this movement. The shaft of this motor extends through the box 1 and on its inner end carries a cam 57. Rigidly secured to the mirror 53 is an arm 58 with which the cam 57 coöperates. A spring 59 is secured to arm 58 and normally holds it down upon the surface of the cam 57. Thus when motor 56 drives cam 57 the mirror 53 is turned on its pivots and then brought back to its initial position. Turning the mirror in this way moves the spot of light lengthwise on the ground glass and the movement of the galvanometer mirror moves the spot of light from side to side, so that a curve is projected upon glass 55. To avoid confusion the spot of light should not show as the mirror is being returned to its initial position by spring 59 as the cam passes under arm 58, and I therefore provide a shutter 57′ on the shaft 56′ of the motor 56 outside the box 1 which covers the opening 31 for the rays of light from the arc lamp while the return of mirror 53 is being effected. The other end of the spring 59 is secured in a block on the end of a lever 60 which is loose upon a pivoted shaft 61. A handle 62 is secured to this shaft, and has a slot formed therein through which a pin in the lever 60 having a locking nut on its end extends. Rigidly secured to the shaft 61 are two arms 64, between which are secured the pivoted mirror 53 and a lens 54 to concentrate the rays of light. Above the lens 54 is a shutter 65 carried by a shaft 66 with its free end resting upon the top of the lens. Secured to the shaft 66 is a crank 67 and a link 68 is pivotally connected at one end to this crank and at the other end to a crank 69 on a shaft 70 which carries a shutter 71 similar to the shutter 65.

In the position of the parts shown in Fig. 2 the rays of light reflected from the galvanometer mirror are concentrated by the lens 54 on the mirror 53 and are reflected upward thereby on the ground glass 55. The curve showing the oscillations may be observed on the ground glass or a sheet of thin paper may be placed over the ground glass and the curve traced thereon. If it is desired to take a photographic record of the oscillations the handle 62 is pulled back. This turns shaft 61 and thus raises the arms 64 which carry upward with them the lens 54 and mirror 53. In its upward movement lens 54 raises the shutter 65 thus turning shaft 66 which by means of the crank 67, link 68 and crank 69, turns shaft 70 and thus raises shutter 71. When the edges of the shutter 65 and 71 come together the opening for the light rays up to the ground glass 55 is closed. Strips 72 (Fig. 2) are arranged at the sides of the shutters so as to insure a complete closure of this opening. When the parts are in this position, the light rays are reflected by the mirror of the galvanometer onto a lens 73 by which they are concentrated and from which they pass through a narrow opening in the back of the box 1. Detachably supported on the back of the box is a light-tight casing 74 in which is a drum carried by a shaft 75. This drum or holder is provided with means for holding a photographic film or other sensitized sheet tightly thereon. Secured to the back of the box is a frame 76 forming a bearing for a shaft 77 carrying a pulley 78 arranged to receive a belt by which the shaft 77 is driven from any suitable source of power. On the end of shaft 77 is a crank 79 which coöperates with a pin 80 on the shaft 75 to rotate the drum which carries the photographic film. The position of

this crank on shaft 77 may be adjusted as desired, and it is held in any adjusted position by a spring-pressed pin 79′ arranged to enter one of a number of openings in a collar 77′ on the shaft.

In order to prevent a confusion of the record by running over the film several times I provide means for opening the shutter 32 automatically and holding it open during exactly one revolution of the film-carrying drum. Two distinct means are provided for accomplishing this, one of which opens the shutter at the instant the end of the film passes the slot in the back of the box 1, and the other of which opens it at any part irrespective of the position of the film. The former is useful when making investigations in which the events are recurring or their beginning known or under control, and the latter when the time of the event is not under control, such as the blowing of a fuse or the opening of a circuit-breaker. On the shaft 77 is a threaded sleeve 81 of insulating material. A wire 82 has one end embedded in this sleeve and extends around the sleeve one complete turn in the bottom of the thread thereon. The other end of the wire is connected to the shaft 77 so that the wire is electrically connected to the frame 76. Vertically movable in suitable guides is a rod 83 carrying an arm 84 at its upper end on the under side of which is a tooth 85. Secured to rod 83 is another arm 86 to which is attached one end of a spring 87 the other end of which is secured to a pivoted lever 89. Also secured on rod 83 is a latch 88 adapted to enter a notch in the lever 89. A spring 90 is arranged to press the lower end of lever 89 toward the rod 83. A link 91 is connected to the lower end of lever 89 and in its end is an eye to facilitate connecting it to a circuit-breaker or any other device by which it is to be operated. A lever 92 having an operating handle is pivoted so that its end is directly below the lower end of rod 83. When it is desired to take a photographic record of the oscillations of the galvanometer mirror and to make the record begin at one end of the photographic film and end at the other, the link 91 is pulled to the right in Fig. 3 either by hand or by attaching it to any device which is to operate it. This draws the lower end of lever 89 to the right against the tension of spring 90, thus releasing the latch 88 and spring 87 then draws the rod 83 downward in its guides until the tooth 85 on the under side of arm 84 enters the threads on sleeve 81. As the shaft 77 is continuously rotating the rod 83 is turned in its guides as the tooth 85 travels along on the sleeve 81. When the tooth 85 engages the wire 82 arm 84 and the frame 76 are electrically connected and this closes circuit through a battery and the coils of the magnet 35 which rocks its armature 34 to move the shutter 32 away from the opening 31. When shaft 77 has made one complete revolution the tooth 85 rides off of the wire 82 and this circuit is broken, whereupon the spring 36 draws the shutter 32 back over the opening 31. The light rays from the source outside the box 1 have thus been allowed to enter the box and have been reflected by the mirror of the galvanometer upon the photographic film during one complete revolution of the drum which carries the film and this period began as the beginning of the film passed the slot in the back of the box 1 and ended as the end of the film passed this slot. After the record has been taken, the handle of lever 92 is depressed and the rod 83 is thus raised until the tooth 85 is out of engagement with the sleeve 81. When this occurs spring 87 turns the rod 83 in its guides to bring the parts back to their former positions, the latch 88 serving to hold them in this position by catching in the notch in lever 89.

Pivoted on the side of the frame 76 is a lever 93 on the side of which is pivotally mounted a roller 94. A portion 95 of the periphery of this roller is made of insulating material and a brush 96 supported on the lever 93 below roller 94 but insulated therefrom bears on the periphery of the roller. A spring 97 is arranged to turn the lever 93 on its pivot in a direction to bring the roller 94 into engagement with a roller 98 on shaft 77. A pivoted lever 99 carries a pin 100 in its upper end which extends into the path of movement of lever 93, a spring 101 being arranged to move the parts to this position. Secured to the lower end of lever 99 is a stud 102 having an eye in its end by which the lever may be connected with a circuit-breaker or any other device which is to control the time of taking the record. When it is desired to take a photographic record and the time of the event that is to be recorded is not under control, the operation of the device whose effect is to be noted is made to pull the lower end of lever 99 to the right in Fig. 3. This carries the pin 100 out of the path of movement of lever 93 and spring 97 turns the lever on its pivot so as to bring roller 94 into engagement with roller 98. The roller 94 is thus made to rotate and the brush 96 moves off the insulating segment 95 and upon the metal portion of the roller. This closes the circuit of the electro-magnet 35 as before and this circuit is retained closed while shaft 77 is making one complete revolution when brush 96 moves upon the insulating segment 95 again. In this position a depression in the roller 94 (Figs. 1 and 2) comes opposite the roller 98 and roller 94 comes to rest. The lever 93 is then pushed back by its operating handle and spring 101 then turns lever 99 on its pivot so as to bring pin 100 again into the path of movement of lever 93. Roller 94 is thus carried

away from roller 98 and may be turned by hand to its former position as shown in Fig. 2. A record is thus obtained covering the entire film but this record may begin at any portion of the film and run to the end and then from the other end down to a point close to where it began.

The operation of the device will be readily understood from the foregoing description. The terminals of the circuit, the energy characteristics of which are to be examined, are connected to the binding-posts 26 and 27 so that the current flows through the loop 29. The coils 5 of the electro-magnets are connected in circuit so that a strong magnetic field is produced between the pole-pieces 12 12. The influence of the magnetic field upon the loop 29, one side of which carries current in one direction and the other side carrying current in the opposite direction, causes the two sides of the loop to move in opposite directions in the magnetic field and as the current alternates the two wires will move back and forth. This oscillates the mirror 30 on a vertical axis. The strength of the field and the lightness of the parts and the delicate way in which they are mounted causes the mirror to respond to every variation in the current flowing in the loop. The damping liquid fills the chamber 8 and thus entirely surrounds the mirror 30; the viscosity of the liquid should be just sufficient to make the indications accurate. While adjusting the parts the shaft 37 is turned by hand from outside the box 1 so as to move the shutter 31 and the light from an arc lamp or other suitable source enters the box through this opening and is reflected by the prisms 40 upon the mirrors of the three galvanometers. The width of the beams of light may be adjusted by the adjustable slits 47; the prisms 40 may also be adjusted to bring them into the exact position desired. The vibrator of each one of the three galvanometers can be adjusted on both a vertical and horizontal axis by means of the screws 10 and 15 to direct the beam of light from the mirror 30 in the exact direction desired. With the parts in the position shown in Fig. 2 the vibrator should be adjusted so that the beam of light is reflected upon the lens 54 which concentrates the rays upon the mirror 53 and this mirror reflects the rays upward upon the ground glass 55. The circuit of the motor 56 is closed and the motor drives cam 57 which operates the arm 56 to rock mirror 53 on its pivots. Thus as the galvanometer mirror turns on a vertical axis and the mirror 53 is turned on its horizontal pivots a curve is projected upon the glass 55 corresponding exactly to the variations of the current in the loop 29. When the mirror 53 is being returned to its initial position the shutter 57′ closes the opening 31 in box 1. The curve may be observed upon the glass 55 or if desired a paper may be laid over the glass and the curve traced thereon. By moving the lever 60 independently of the handle 62 the tension of spring 59 may be varied. If it is desired to take a photographic record of the curve the handle 62 is pulled back thus turning shaft 61 and raising the arms 64 which carry with them lens 54 and mirror 53 and as the lens 54 moves upward it closes the shutters 65 and 71. The rays of light are then reflected by the galvanometer mirror upon the lens 73 which concentrates them upon a photographic film in the casing 74, the latter being provided with a narrow opening and a door for closing the opening light-tight. To take the record this door is opened and after taking the record the door is again closed so that the casing may be removed from the box 1 and carried to a dark room without admitting light to the film.

If the event to be recorded on the film is recurring or its time under control, the record is taken by pulling the link 91 to the right in Fig. 3 by hand or in any other suitable manner and spring 87 pulls the arm 84 down upon the sleeve 81. When the finger 85 makes contact with the wire 82, the circuit of the magnets controlling the shutter 32 is closed and the magnet opens the shutter and holds it open during exactly one revolution of the film-carrying drum. The wire 82 is so positioned on the sleeve 81 that the shutter is opened just as the beginning of the film passes the slot in the casing 74 so that the record extends from one end of the film to the other. After the record is taken, the handle of lever 92 is pushed down to restore the parts to their initial positions. If the time of the event to be recorded is not under control, as for instance the blowing of a fuse or the opening of a circuit-breaker, the movement of the parts the effect of which is to be recorded is made to pull the stud 102 to the right in Fig. 3. This releases the lever 93 and spring 97 turns it on its pivot until roller 94 is brought into engagement with roller 98. Roller 94 is thus caused to rotate bringing brush 96 into engagement with the metallic part of the roller and thus closing the circuit of the magnet controlling the shutter 32, as before. The length of the metallic portion of roller 94 is such that this circuit is retained closed during exactly one revolution of shaft 77 and the film-carrying drum. The record thus taken extends over the entire film but may begin at any point throughout the length thereof. When roller 94 has turned far enough to bring the brush 96 again upon the insulating segment 95, a depressed portion of the roller comes opposite the roller 98 so that the latter is no longer driven by roller 94. Lever 93 is then pressed back by its handle and is held in the retracted position by pin 100, and roller 94 is turned back by hand to the position shown in the

drawing so as to be ready for a repetition of the operation. As there are three galvanometers, three curves can be obtained at the same time. It is thus possible to take curves of voltage or current in each phase of a multi-phase circuit simultaneously. Also, since the vibrators are adjustable in all directions, the beams of light from the three mirrors 30 may be focused on the same point and then the curves obtained give the phase relation of each with respect to the other.

I do not wish to be understood as limited to the precise construction which I have herein shown and described, as many modifications can be made therein all of which I consider within the scope of my invention and aim to cover in the claims appended hereto.

What I claim as new and desire to secure by Letters Patent of the United States, is,

1. An oscillograph comprising a light-tight box, a reflecting galvanometer therein, means for obtaining a visible indication of the movements of the galvanometer mirror, means for obtaining a photographic indication of said movements, and means operative without opening the box for changing from one manner of obtaining indications to the other.

2. An oscillograph comprising a box having an opening therein to admit a beam of light, a plurality of reflecting galvanometers therein, means for directing a beam of light upon the mirror of each galvanometer, means for obtaining a visible indication of the movements of the galvanometer mirrors, means for obtaining a photographic indication of said movements, and means for changing from one manner of obtaining indications to the other.

3. An oscillograph comprising a box having an opening therein to admit a beam of light, a reflecting galvanometer in the box, a prism in the box opposite said opening to reflect the light on the mirror of the galvanometer, a post on which the prism is supported, a ball formed in the post, plates between which said ball may be clamped to hold the prism and permit adjustment of its position, and means coöperating with said galvanometers for obtaining an indication of the movements of the galvanometer mirrors.

4. An oscillograph comprising a reflecting galvanometer, means for directing a beam of light upon the mirror of the galvanometer, a rotatable shutter for regulating the width of the beam arranged to admit light through a passage shaped to have the greatest cross section near the middle and thereby prevent access to the galvanometer of rays reflected from said beam of light, and means coöperating with said galvanometer for obtaining an indication of the movements of the galvanometer mirror.

5. An oscillograph comprising a box having an opening therein to admit a beam of light, a plurality of reflecting galvanometers therein, means for directing a beam of light upon the mirror of each galvanometer, a tube having a slot therethrough adjustably arranged in the beam of the light for regulating the width thereof, and means coöperating with said galvanometers for obtaining an indication of the movements of the galvanometer mirrors.

6. An oscillograph comprising a light-tight box, a plurality of reflecting galvanometers therein, means for directing a beam of light upon the mirror of each galvanometer, a translucent screen, a photographic device, and means operative when the box is closed for directing the oscillating beam either to the screen or the photographic device.

7. An oscillograph comprising a light-tight box, a plurality of reflecting galvanometers therein, means for directing a beam of light upon the mirror of each galvanometer, a translucent screen, a photographic device, a mirror for reflecting the beam of light from the galvanometer upon said sheet, and means for moving the mirror into or out of the path of the beam of light whereby the screen and the photographic device are alternatively thrown into and out of operation.

8. An oscillograph comprising a light-tight box, a plurality of reflecting galvanometers therein, means for directing a beam of light upon the mirror of each galvanometer, a translucent screen, a photographic device, a mirror for reflecting the beam of light from the galvanometer upon said screen, a shutter, and means for moving the mirror out of the path of the beam and closing the shutter whereby the screen is rendered inoperative and the photographic device operative.

9. An oscillograph comprising a light-tight box, a plurality of reflecting galvanometers therein, a translucent screen, a mirror for reflecting the beams of light from the galvanometers upon the screen, means for rocking the mirror, a photographic device, and means for moving said mirror into or out of the path of the beam of light whereby the screen and the photographic device are alternately thrown into and out of operation.

10. An oscillograph comprising a light-tight box, a plurality of reflecting galvanometers therein, a translucent screen, a mirror for reflecting the beams of light from the galvanometers upon the screen, means for giving the mirror a rocking movement the frequency of which bears a definite ratio to the frequency of the oscillations of the mirror of the galvanometer, a photographic device, and means for moving said mirror into or out of the path of the beam of light whereby the screen and the photographic device are alternately thrown into and out of operation.

11. An oscillograph comprising a light-

tight box, a plurality of reflecting galvanometers therein, a translucent screen, a pivoted mirror to reflect the beams of light from the galvanometer upon said screen, a synchronous motor arranged to rock said mirror, a photographic device, and means for moving said mirror into and out of the path of the beam of light whereby the screen and the photographic device are alternately thrown into and out of operation.

12. An oscillograph comprising a light-tight box, a plurality of reflecting galvanometers therein, a translucent screen, a mirror for reflecting the beams of light from the galvanometers upon the screen, means for rocking the mirror, means for shutting off the beams of light from the screen while the mirror is rocking in one direction, a photographic device, and means for moving said mirror into or out of the path of the beam of light whereby the screen and the photographic device are alternately thrown into and out of operation.

13. An oscillograph comprising a light-tight box, a plurality of reflecting galvanometers therein, a translucent screen, a mirror for reflecting the beams of light from the galvanometers upon the screen, means for giving the mirror a rocking movement the frequency of which bears a definite ratio to the frequency of the oscillations of the galvanometer, means for shutting off the beams of light while the mirror is rocking in one direction, a photographic device, and means for moving said mirror into or out of the path of the beam of light whereby the screen and the photographic device are alternately thrown into and out of operation.

14. In an oscillograph, the combination with means arranged to coöperate with a galvanometer to obtain an indication, of a reflecting galvanometer comprising a movable mirror, a support for said mirror adjustable about two perpendicular axes which intersect at a point in said mirror, and means for adjusting said support.

15. In an oscillograph, the combination with means arranged to coöperate with a galvanometer for obtaining an indication, of a reflecting galvanometer comprising a mirror mounted to rotate, a support for said mirror mounted to rock on an axis which intersects the axis of rotation of the mirror at a point in the mirror, and adjusting means for rocking said support.

16. In an oscillograph, a reflecting galvanometer comprising a movable mirror and pole pieces adjacent thereto, a magnet with its poles in metallic contact with said pole pieces, a support for said mirror and pole pieces mounted between the poles of the magnet to rock about an axis transverse to the axis of movement of the mirror and slide said pole pieces over the poles of the magnet, and adjusting means for rocking said support about its axis.

17. In an oscillograph, a plurality of reflecting galvanometers comprising a plurality of moving elements, a plurality of electromagnets, one leg of each magnet being arranged adjacent to one leg of another magnet with a single energizing coil on each of said pairs of adjacent magnet legs, and means cooperating with said galvanometers for obtaining an indication.

18. In an oscillograph, the combination with a plurality of galvanometers having moving systems arranged side by side, each moving system comprising pole pieces and a current-carrying conductor movably mounted between said pole pieces, of insulation between said moving systems to permit the application of widely different potentials to the current carrying conductors of adjacent systems.

19. In an oscillograph, a plurality of galvanometers having magnets and moving systems arranged side by side and strips of insulating material between adjacent magnets and moving systems, and common means cooperating with said galvanometers for obtaining a simultaneous indication therefrom.

20. In an oscillograph, a reflecting galvanometer comprising a magnet, a chamber pivotally supported on the legs thereof, a moving element for said galvanometer mounted in said chamber at right angles to the pivot of the chamber, means for rocking the chamber and the moving element carried thereby about the pivot of the chamber, and means coöperating with said galvanometer for obtaining an indication.

21. In an oscillograph, a reflecting galvanometer comprising a magnet, a chamber, means for horizontally pivoting said chamber, a moving element for said galvanometer supported in said chamber, means for adjusting said moving element on a vertical axis, means for rocking said chamber and the moving element carried thereby on a horizontal axis, and means coöperating with said galvanometer for obtaining an indication.

22. In an oscillograph, a reflecting galvanometer comprising a magnet, a chamber pivoted between the legs of the magnet, pole-pieces located in the sides of the chamber and in contact with the legs of the magnet throughout the range of movement of the chamber about its pivot, said pole-pieces having a relatively large surface on the outside of the chamber and being contracted so as to concentrate the magnetic lines in a narrow gap between their adjacent surfaces, a moving element for said galvanometer removably mounted in said gap, and means cooperating with said galvanometer for obtaining an indication.

23. In an oscillograph, a reflecting galva-

nometer comprising a magnet, a chamber supported between the legs of the magnet, pole-pieces located in the sides of the chamber, trunnions formed on the pole-pieces, openings in the legs of the magnet to receive said trunnions, an adjusting device for rocking said chamber on said trunnions, a moving element for the galvanometer in said chamber in the gap between said pole-pieces, and means coöperating with said galvanometer for obtaining an indication.

24. In an oscillograph, a reflecting galvanometer comprising a magnet, a chamber located between the legs of the magnet, pole-pieces in the sides of the chamber in contact with the legs of the magnet, a moving element mounted in the chamber and arranged to be removable therefrom independently of said pole-pieces, and means coöperating with said galvanometer for obtaining an indication.

25. In an oscillograph, a galvanometer including means for establishing a magnetic field, a moving element mounted in the field comprising a supporting member, a rod extending downward therefrom, a pulley on the lower end of the rod, a looped conductor extending around the pulley and having its ends electrically connected to parts above said member, a reflecting device carried by said conductor, means above said member to press said rod downward, and means coöperating with said galvanometer for obtaining an indication.

26. In an oscillograph, a galvanometer including means for establishing a magnetic field, a moving element mounted in the field comprising a supporting member having a central opening therethrough and a slot leading to said opening, a rod extending downward from the member, a pulley pivotally mounted on said rod near its lower end and supported from only one side, and a looped conductor passing around said pulley and extending up through the opening in said member, reflecting means carried by said conductor, and means coöperating with said galvanometer for obtaining an indication.

27. In an oscillograph, a plurality of galvanometers comprising a plurality of oscillatory mirrors and conductors on which they are mounted, insulation between adjacent conductors a plurality of field magnets insulated from one another the fields of which cut the conductors, and means coöperating with said galvanometers for obtaining an indication.

28. In an oscillograph, a galvanometer comprising means for producing a magnetic field, a conductor capable of oscillatory movement in said field, a mirror mounted thereon, a chamber for damping liquid inclosing the conductor, a support for the conductor capable of withdrawal from said chamber, the moving element and its support being so related that a free space surrounds the conductor to permit ready mounting of the mirror, and means coöperating with said galvanometer for obtaining an indication.

29. An oscillograph comprising a light-tight box, a reflecting galvanometer therein, a holder, a sensitized sheet thereon, means for rotating the holder, and means for regulating the exposure of the sensitized sheet to the oscillating beam from the galvanometer to begin and end at the two ends of the sensitized sheet.

30. An oscillograph comprising a light-tight box, a reflecting galvanometer therein, a holder, a sensitized sheet thereon, means for rotating the holder, and means for regulating the exposure of the sensitized sheet to the oscillating beam from the galvanometer to last during only one revolution of the holder.

31. An oscillograph comprising a light-tight box, a reflecting galvanometer therein, a holder, a sensitized sheet thereon, means for rotating the holder, a shutter, and means for keeping the shutter open during only a single rotation of the holder.

32. An oscillograph comprising a light-tight box, a reflecting galvanometer therein, a holder, a sensitized sheet thereon, means for rotating the holder, a shutter, and means for opening the shutter when the end of the sheet is in position to receive the indication and closing it after a single revolution of the holder.

33. An oscillograph comprising a reflecting galvanometer, a holder for a sensitized sheet, actuating means for moving the holder, and mechanism operating in definite relation to said actuating means for obtaining an indication of the movements of the galvanometer mirror on said sheet during the definite part of the movement of said holder.

34. An oscillograph comprising a light-tight box, a reflecting galvanometer therein, a holder, a sensitized sheet encircling the holder, means for rotating the holder, and means for admitting light to the mirror of said reflecting galvanometer during only one revolution of the holder.

35. An oscillograph comprising a reflecting galvanometer, a holder for a sensitized sheet, actuating means for moving the holder, and means for admitting a beam of light from the galvanometer mirror to said sheet when one end of the sheet is in a predetermined position and cutting off the light when the other end of the sheet reaches said position.

36. An oscillograph comprising a light-tight box, a reflecting galvanometer therein, a sensitized sheet, means for obtaining on said sheet an indication of the movements of the galvanometer mirror, and electrically-operated means controlling the time of said indication.

37. An oscillograph comprising a light-

tight box, a reflecting galvanometer therein, a holder, a sensitized sheet thereon, means for rotating the holder, means for obtaining on said sheet an indication of the movements of the galvanometer mirror, and means controlling the time of said indication operative to start the indication instantly or when the end of said sheet is in position to receive the indication.

38. An oscillograph comprising a light-tight box, a reflecting galvanometer therein, a holder, a sensitized sheet thereon, means for rotating the holder, means for obtaining on said sheet an indication of the movements of the galvanometer mirror, and means controlling the time of said indication operative to start the indication instantly or when the end of said sheet is in position to receive the indication and to discontinue the indication when the holder has made one revolution.

39. An oscillograph comprising a light-tight box, a reflecting galvanometer therein, a holder, a sensitized sheet thereon, means for moving the holder, a shutter controlling the admission of light to the galvanometer mirror, a magnet controlling the shutter, and means for energizing the magnet during a definite movement of the holder.

40. An oscillograph comprising a light-tight box, a reflecting galvanometer therein, a sensitized sheet, a holder for supporting the same in the path of the beam of light from the galvanometer mirror, means for rotating the holder, a shutter controlling the admission of light to the galvanometer mirror, an electromagnet to operate the shutter, and means for closing the magnet circuit when the end of said sheet is in position to receive the indication and holding it closed during one revolution of the holder.

41. In an oscillograph, a reflecting galvanometer comprising a support having an opening at an angle to one surface of the support extending from the periphery to a point near the middle thereof, terminals on said surface of said support near said point, and a looped conductor carried by said support to extend through said opening at said point with its ends held by said terminals.

42. In an oscillograph, a reflecting galvanometer comprising a support having an opening therethrough and a slot extending through said member to said opening, terminals mounted on said support on opposite sides of said opening, a rod extending parallel to the axis of said opening, and a looped conductor passing around the free end of said rod and through said opening with its ends engaged by said terminals.

43. In an oscillograph, a reflecting galvanometer comprising a supporting member having an opening therethrough extending from the periphery of said member to a point near the middle thereof, terminals adjacent said point on one side of said member, a rod extending from the other side of said member, and a looped conductor passing around the free end of said rod and through said openings with its ends secured to said terminals.

44. In an oscillograph, a reflecting galvanometer comprising a support, a looped conductor attached to said support at two points, a mirror secured to said conductor, and insulating blocks on said support in engagement with the conductor on each side of the mirror, said blocks being proportioned to hold the mirror at a distance from the support great enough to permit easy access to every part of the mirror.

45. In an oscillograph, a reflecting galvanometer comprising a support, terminals on said support, insulating blocks on said support, a rod slidably mounted on said support, a pulley on one end of said rod, a tension device mounted adjacent said terminals and connected to the other end of the rod to move it longitudinally, and a looped conductor with its ends connected to said terminals passing over said blocks and around said pulley.

46. In an oscillograph, a galvanometer comprising a support, terminals on said support, a conductor connected to said terminals, means for resiliently holding the conductor under tension, and a device adjacent said terminals for controlling the action of said means.

47. In an oscillograph, a galvanometer comprising a support, terminals on said support, a looped conductor with its ends connected to said terminals, a resilient device carried by said support for holding said conductor under tension, and means mounted on said support adjacent said terminals for controlling the action of said resilient device on the conductor.

48. In an oscillograph, a reflecting galvanometer comprising a support, terminals mounted on said support, a member movably mounted on said support, a conductor connected to said terminals and put under tension by the movement of said member, a mirror carried by said conductor and a tension device mounted adjacent said terminals for yieldingly moving said member to put the conductor under tension.

49. In an oscillograph, a reflecting galvanometer comprising a support, terminals and a tension device mounted at the same end of said support, a looped conductor with its ends connected to said terminals, a mirror carried by said conductor, and a movable member in engagement with said conductor connected to said tension device and movable thereby away from said terminals to put the conductor under tension.

50. In an oscillograph, a reflecting galvanometer comprising a support, terminals and a tension device mounted on one side of said

support, a member connected to said device and mounted to be moved away from the other side of said support by said device, a conductor looped around said member and having its ends secured to said terminals, and a mirror carried by said conductor.

51. In an oscillograph, a reflecting galvanometer comprising a support, terminals secured to said support, a rod extending perpendicularly through said support adjacent said terminals and mounted to move longitudinally away from said terminals, a device secured to said support for yieldingly moving said rod longitudinally away from said terminals, a looped conductor supported by said rod with its ends secured to said terminals, and a mirror carried by said conductor.

52. An oscillograph provided with a tense conductor carrying a light mirror carried on a support removable from the magnetic field, said support and conductor being so related that a free space is provided about the mirror which is large relatively to the mirror and its support to permit ease of repair.

53. In an oscillograph, a reflecting galvanometer comprising a magnet, a conductor in the field of said magnet, a support for holding said conductor under tension between two points and cut away between said points to leave a relatively large space around the conductor to permit free access to all sides of the conductor, and a mirror secured to said conductor between said points.

54. In an oscillograph, a reflecting galvanometer comprising a magnet having pole pieces for producing an intense magnetic field, a support adjacent said pole pieces, a conductor mounted on said support between said pole pieces, said support and said pole pieces being relatively movable both transversely and longitudinally of the axis of the pole pieces to permit access to the conductor, and a mirror carried by said conductor.

55. In an oscillograph, a reflecting galvanometer comprising a magnet, a casing mounted adjacent the poles of said magnet, pole pieces in said casing, a support removably mounted in said casing to permit said support to be moved both transversely and longitudinally of said casing, and a looped conductor on said support arranged to extend between said pole pieces when said support is in normal position whereby said conductor may be removed from between said pole pieces before said support is withdrawn longitudinally from said casing.

In witness whereof I have hereunto set my hand this 11th day of March, 1905.

LEWIS T. ROBINSON.

Witnesses:

BENJAMIN B. HULL,

HELEN ORFORD.