CROSS REFERENCE

EXAMINER

250-203.R

56

May 31, 1949. W. J. KINDERMAN 2,472,019

FOLLOWING AND RECORDING

Filed Aug. 29, 1946 9 Sheets-Sheet 1

Fig. 1.

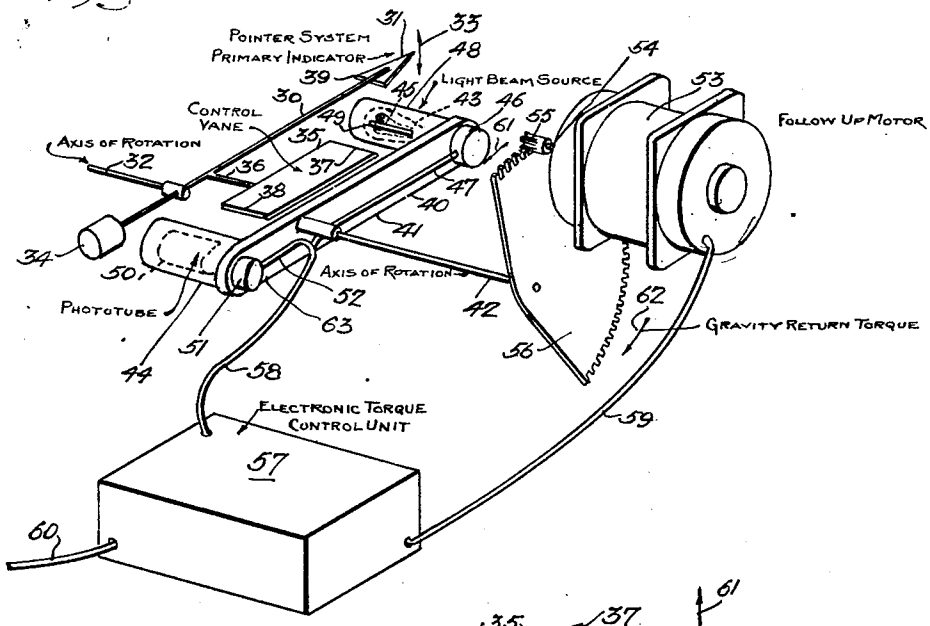


Fig. 2

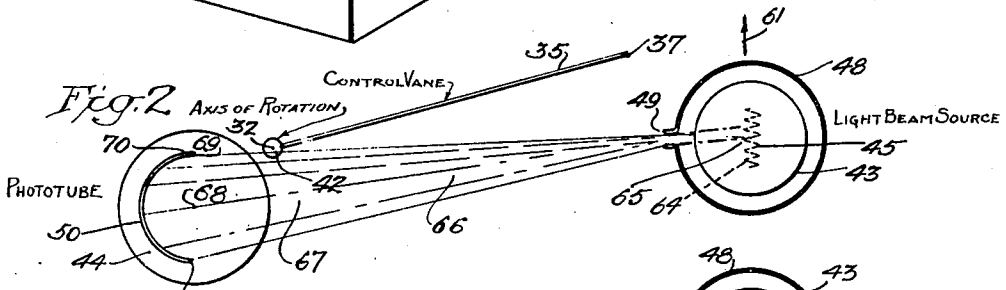


Fig. 3

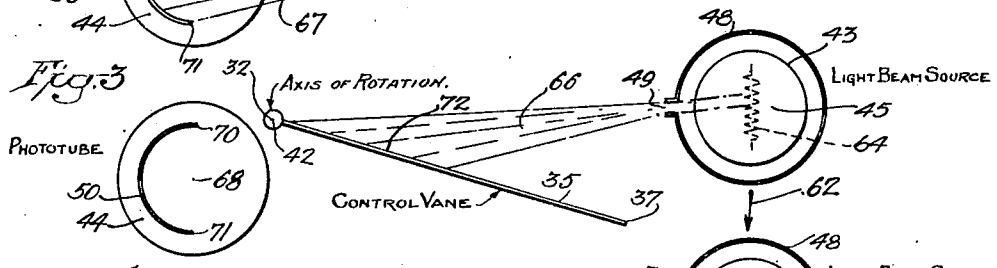
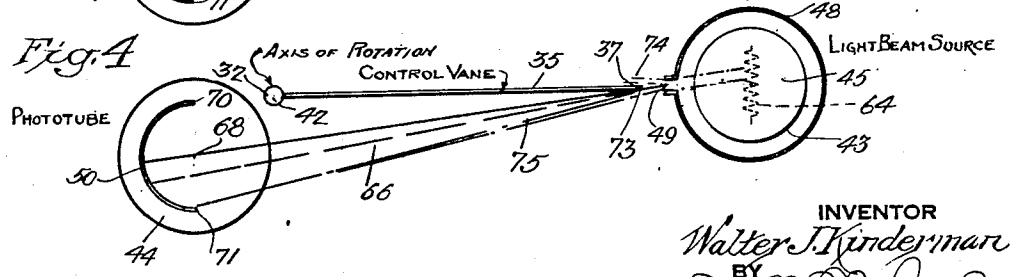


Fig. 4



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250-203

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May 31, 1949. W. J. KINDERMAN 2,472,019

FOLLOWING AND RECORDING

Filed Aug. 29, 1946 9 Sheets-Sheet 2

Fig. 5

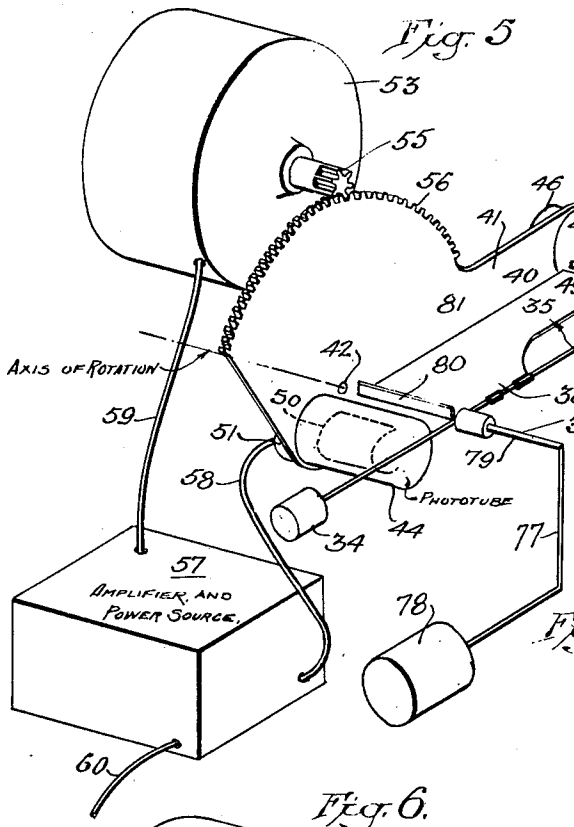


Fig. 9.

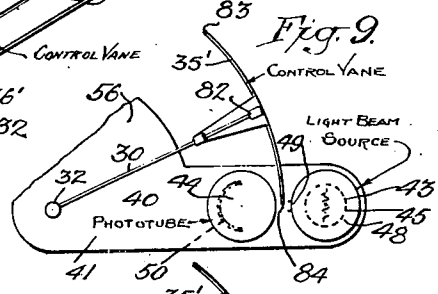


Fig. 7

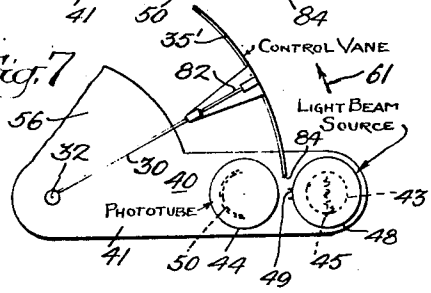


Fig. 6.

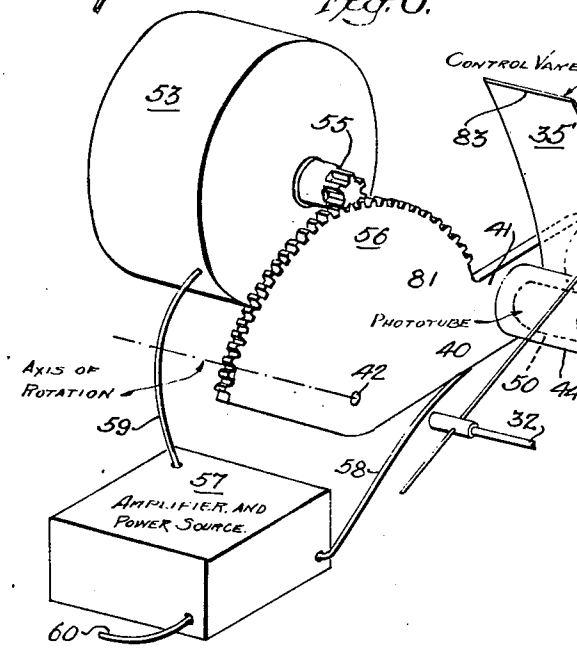
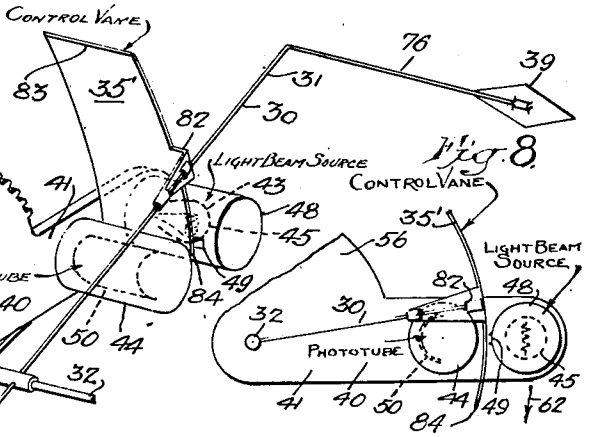


Fig. 8.



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May 31, 1949. W. J. KINDERMAN 2,472,019

FOLLOWING AND RECORDING

Filed Aug. 29, 1946 9 Sheets-Sheet 3

Fig. 10

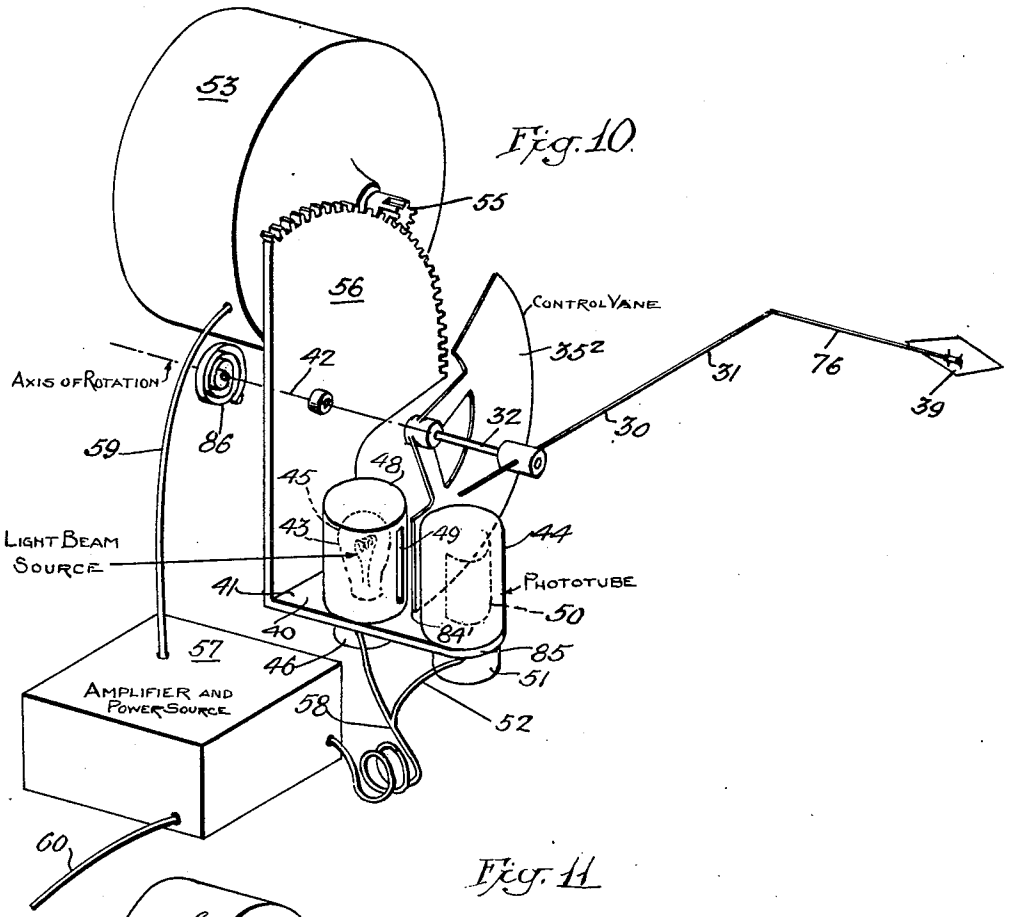
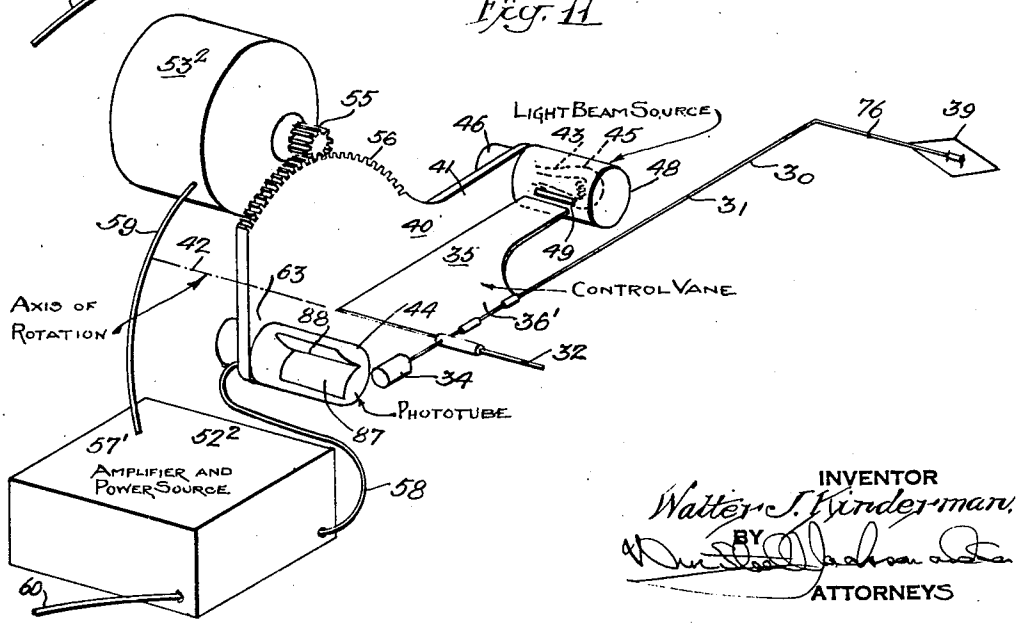


Fig. 11



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May 31, 1949. W. J. KINDERMAN 2,472,019

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Filed Aug. 29, 1946 9 Sheets-Sheet 4

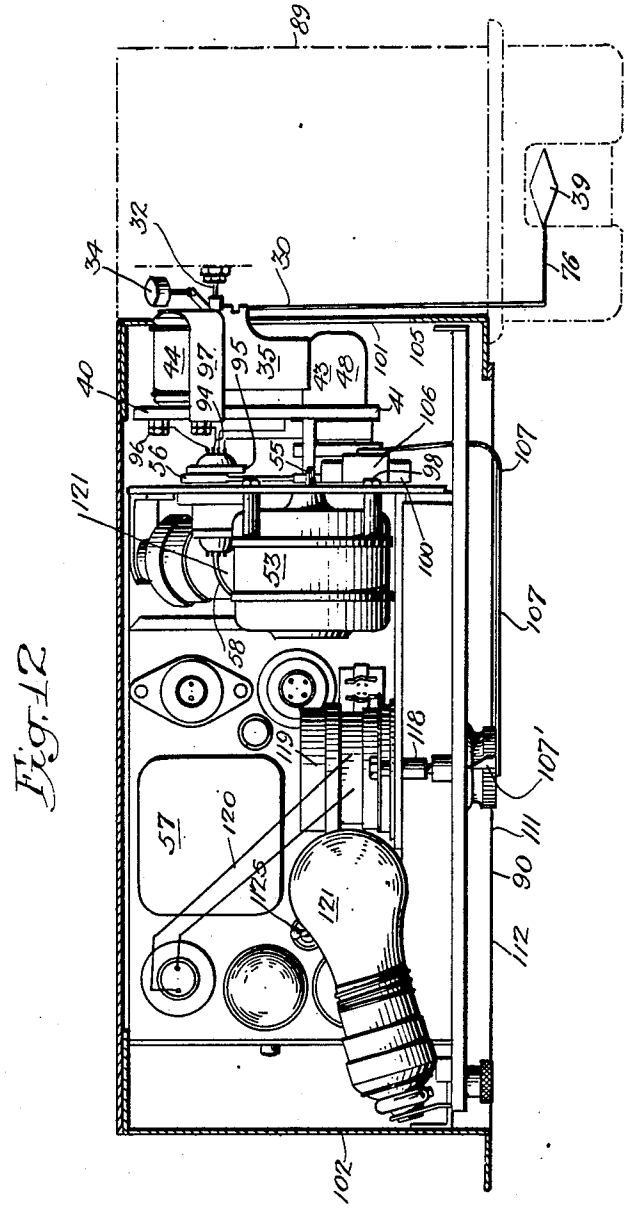


Fig. 12

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May 31, 1949. W. J. KINDERMAN 2,472,019

FOLLOWING AND RECORDING

Filed Aug. 29, 1946 9 Sheets-Sheet 5

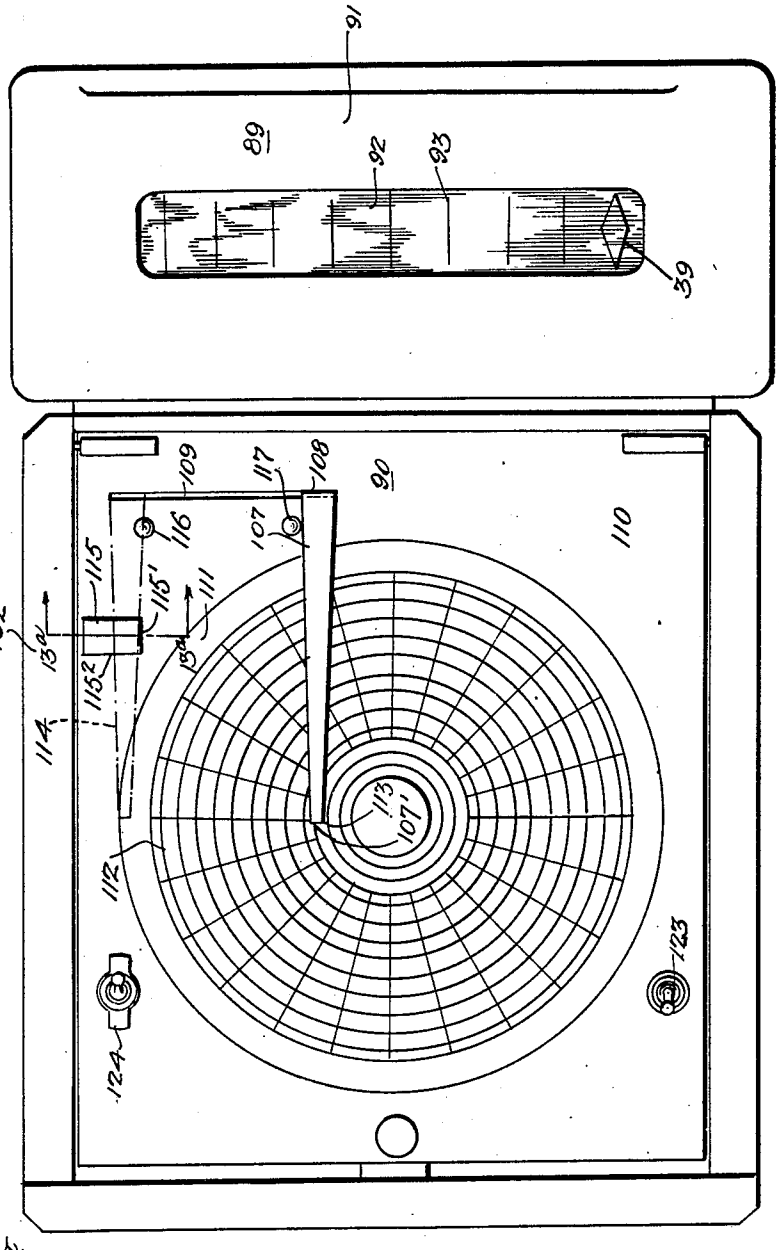


Fig. 13.

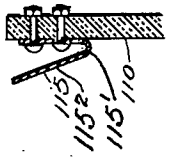


Fig. 13a

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May 31, 1949. W. J. KINDERMAN 2,472,019

FOLLOWING AND RECORDING

Filed Aug. 29, 1946 9 Sheets-Sheet 6

Fig. 14.

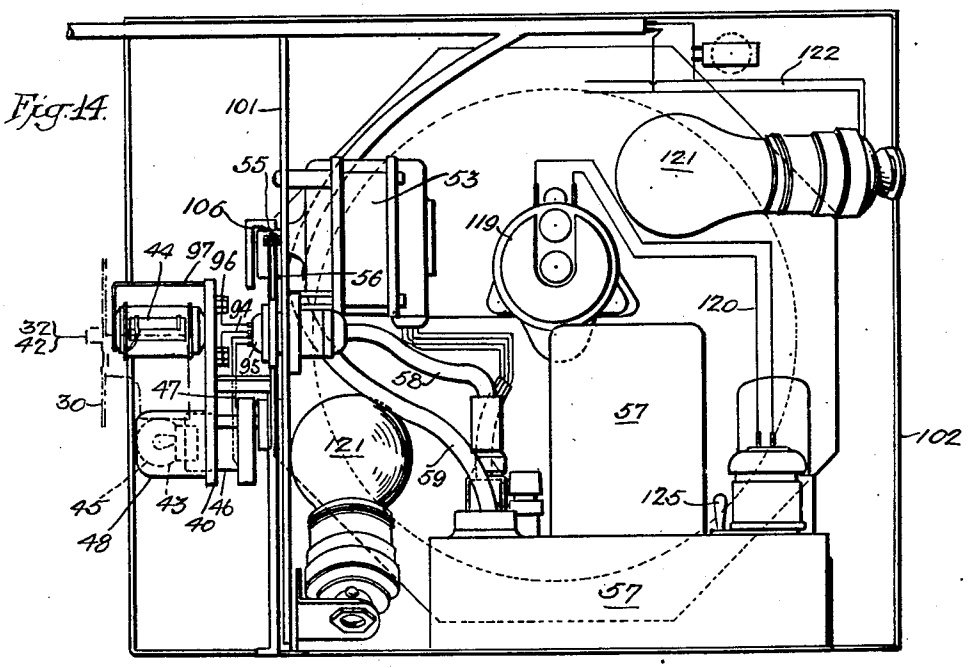


Fig. 15.

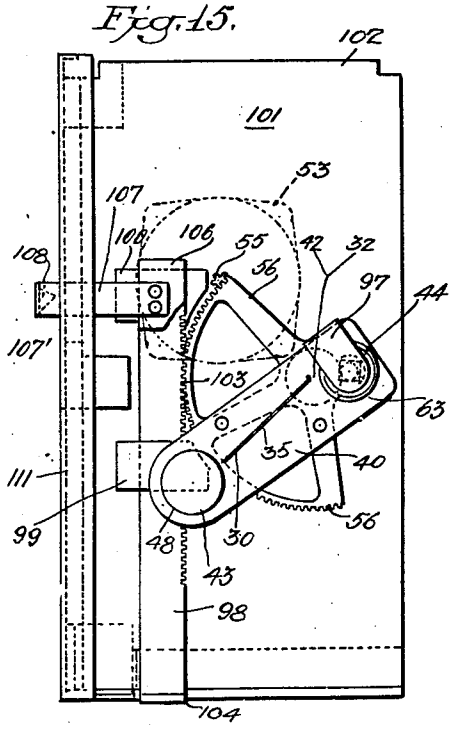
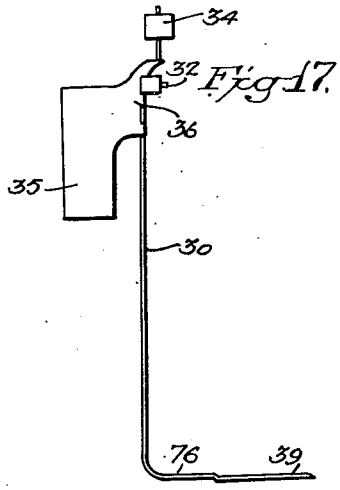


Fig. 17.



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250-203 CROSS REFERENCE EXAMINER

May 31, 1949. W. J. KINDERMAN 2,472,019

FOLLOWING AND RECORDING

Filed Aug. 29, 1946 9 Sheets-Sheet 7

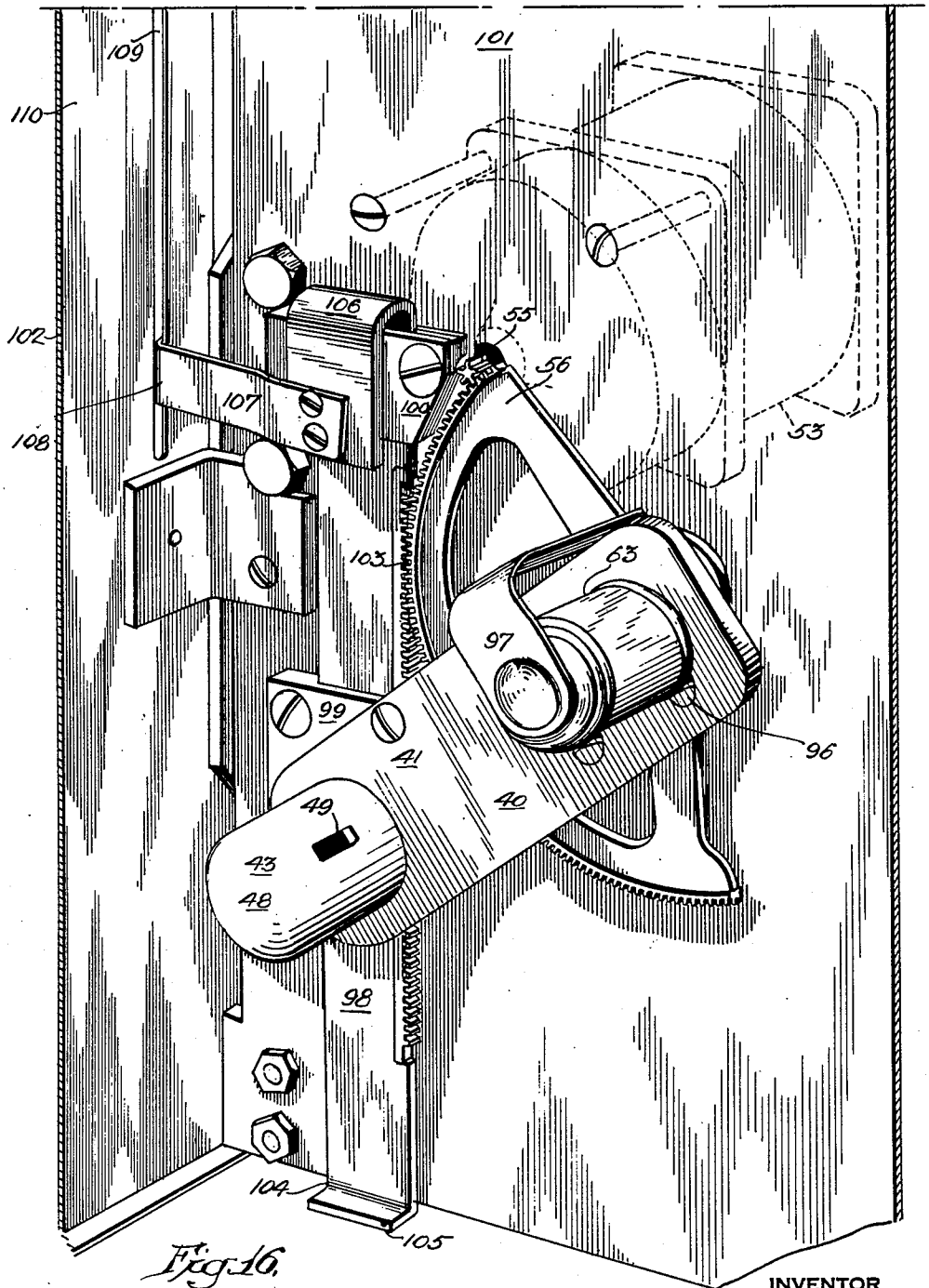


Fig. 16.

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250-203 CROSS REFERENCE EXAMINER

May 31, 1949. W. J. KINDERMAN 2,472,019

FOLLOWING AND RECORDING

Filed Aug. 29, 1946 9 Sheets-Sheet 8

Fig. 18.

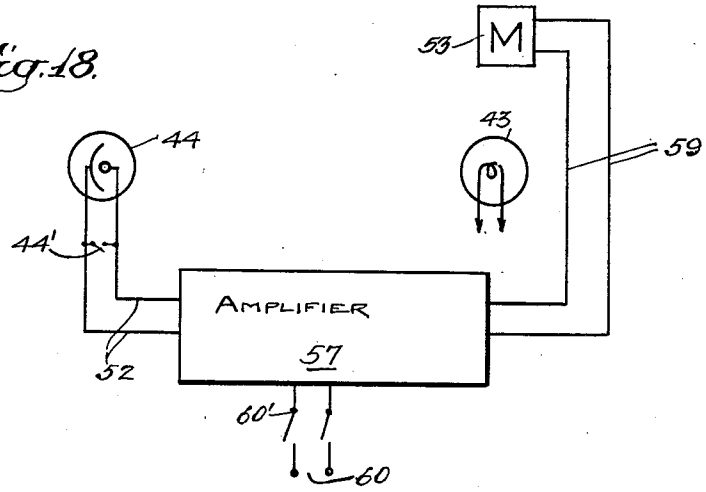


Fig. 19.

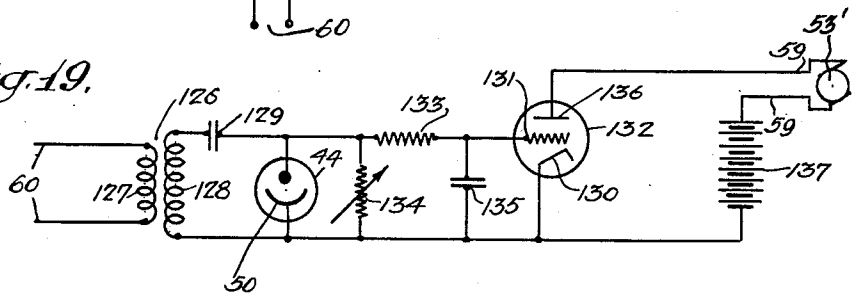


Fig. 20.

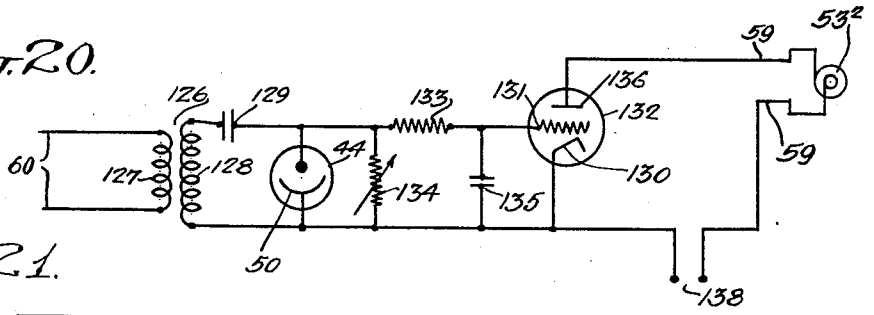
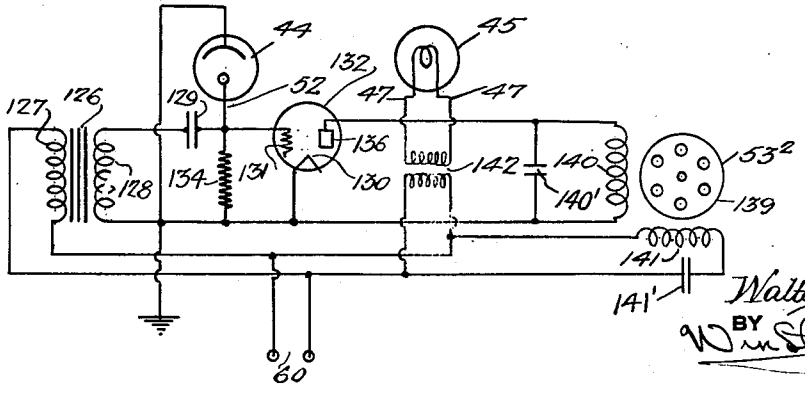


Fig. 21.



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May 31, 1949. W. J. KINDERMAN 2,472,019

FOLLOWING AND RECORDING

Filed Aug. 29, 1946 9 Sheets-Sheet 9

Fig. 22.

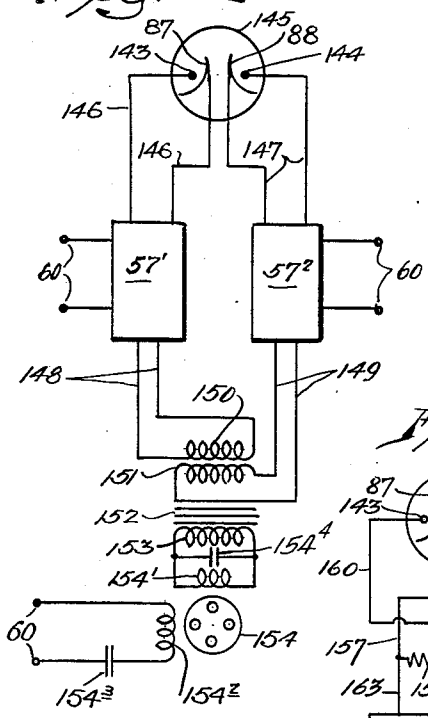


Fig. 23.

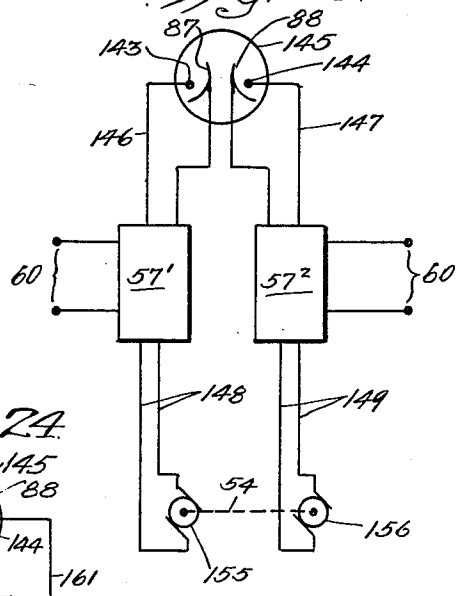
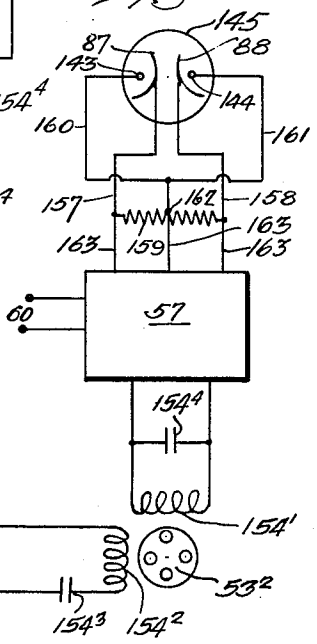


Fig. 24.



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Patented May 31, 1949

2,472,019

UNITED STATES PATENT OFFICE

2,472,019

FOLLOWING AND RECORDING

Walter J. Kinderman, Philadelphia, Pa., assignor to Yarnall-Waring Company, Philadelphia, Pa., a corporation of Pennsylvania

Application August 29, 1946, Serial No. 693,795

35 Claims. (Cl. 250—41.6) 346/31

1

My invention relates to follow-up mechanism and recorders for instruments, and processes of follow-up and recording.

A purpose of my invention is to avoid all restraint on a primary indicator by a follow-up mechanism, while at the same time permitting great accuracy in reproduction of the motion of the primary indicator, and marked simplification in the equipment required.

A further purpose is to produce a follow-up mechanism which can be applied to existing primary indicators without the necessity of any marked change in the primary indicators.

A further purpose is to obtain reasonably high speed response, by the follow-up mechanism, to change in the position of the primary indicator.

A further purpose is to make available in the follow-up mechanism ample force to operate any auxiliary equipment such as alarms, controllers, or the like without the possibility of imposing a force reaction on the primary indicator.

A further purpose is to produce a device which is comparatively insensitive to calibration of phototubes employed.

A further purpose is to produce a device which will permit the recorder to move conveniently to limiting positions, suitably an "off" position and a position for changing the record.

A further purpose is to employ a primary indicator having angular movement, a follow-up element having angular movement, preferably on the same axis as the primary indicator and generally conforming to that of the primary indicator, means for producing a beam of light which moves with the follow-up element and is preferably mounted thereon, means such as a vane on the primary indicator for variantly eclipsing the light beam in accordance with the relative angular position of the primary indicator and the follow-up element, and phototube means for continuously angularly shifting the follow-up element as the primary indicator shifts angularly and in response to the extent of the eclipsing of the beam.

A further purpose is to employ, on the primary indicator, means for cutting the beam of light in one relative angular position, with respect to the follow-up element, for clearing the beam in another relative angular position and for partially cutting the beam in an intermediate relative angular position, in combination with a phototube responding to the quantity of light, if any, passing in the beam, a power source for the phototube, an amplifier for the phototube, means for providing a counter-torque on the follow-up element and a motor driving the follow-up element against the counter-torque in continuous response to the amplified output of the phototube.

2

A further purpose in instruments of the character mentioned is to employ phototube means for maintaining the primary indicator and the follow-up element in the relation of equilibrium in which the beam is partially cut.

A further purpose is to control the follow-up in response to the quantity of light in order to restore equilibrium conditions of initial illumination.

A further purpose is to use a single straight direct beam of light for control of the follow-up element.

A further purpose is to mount both the light source and the phototube on the follow-up element, with one nearer to the axis of rotation than the other, and the vane between, preferably placing the light source farther from the axis than the phototube, and placing the phototube on the opposite side of the axis from the light source.

A further purpose is to employ a sheet metal vane having considerable radial length.

A further purpose is to locate the phototube out of the line of centers between the light source and the axis, whereby the photoelement in one position of the vane may receive the full beam of the light.

A further purpose is to employ a light cut-off surface on the vane which excludes a portion of the beam at all times, in cooperation with a vane which selectively eclipses the light.

A further purpose is to use a segmental vane describing a circumferential path.

A further purpose is to employ a vane in a plane perpendicular to the axis.

A further purpose is to control the following by double photoelements.

A further purpose is to operate a recorder to a limiting position in which the pen is removed from the record by means of the follow-up mechanism.

Further purposes appear in the specifications and in the claims.

In the drawings I have chosen to illustrate a few only of the embodiments of my invention, the forms shown being chosen from the standpoints of convenience in illustration, satisfactory operation and clear demonstration of the principles involved.

Figure 1 is a diagrammatic perspective of the preferred embodiment of my invention.

Figure 2 is an enlarged diagrammatic elevation of a portion of Figure 1, showing the relations between the light source, the phototube and the vane in one position.

Figure 3 is a view similar to Figure 2, taken in another position.

Figure 4 is a view similar to Figure 2 in a still different position.

Figure 5 is a diagrammatic perspective of a variant embodiment of the invention.

Figure 6 is a diagrammatic perspective of a still different form.

Figures 7 to 9 inclusive are fragmentary diagrammatic elevations showing the light source, the phototube and the vane in various positions of the structure of Figure 6.

Figure 10 is a diagrammatic perspective showing a further variation.

Figure 11 is a diagrammatic perspective of an embodiment using double photoelements.

Figure 12 is a plan of a recorder and follow-up mechanism conforming with the invention, and employing the structure of Figures 1 to 4 inclusive, with a placement view of a water level gauge attached.

Figure 13 is a front elevation of the mechanism of Figure 12, omitting the cover from the recorder, but adding a water level gauge in front elevation.

Figure 13ª is a fragmentary enlarged section of Figure 13 on the line 13ª—13ª.

Figure 14 is a rear elevation of the form of Figures 12 and 13, omitting the rear portion of the case.

Figure 15 is a right end elevation of Figure 12, omitting the liquid level gauge except for the control vane.

Figure 16 is an enlarged fragmentary perspective of the follow-up mechanism shown in Figures 12 to 15 inclusive.

Figure 17 is a detail top plan view of the primary indicator of Figures 12 to 16.

Figure 18 is a circuit diagram.

Figure 19 is a more detailed circuit diagram which may conform with Figure 18.

Figure 20 is a variation of Figure 19.

Figure 21 is a variant circuit diagram for a capacitor type induction motor.

Figures 22 to 24 inclusive illustrate variant circuit diagrams for use in connection with the form of Figure 11.

Like numerals refer to like parts throughout.

Describing in illustration but not in limitation and referring to the drawings:

In the prior art, following mechanisms have been employed for reproducing the motion of a primary indicator, but in the main they have not been widely applicable because of the complicated mechanism, the necessity of making radical and often unacceptable changes in the primary indicator, and in some cases because of imposition of drag or other force reaction on the primary indicator.

It will be understood that wherever a primary indicator is referred to, it may be any suitable member of an instrument which moves in response to variation in a quantity or quality being measured, determined or indicated. In the present case the primary indicator will normally be a pointer, scale arm or other indicating element, preferably of a boiler or other suitable water level indicator, but suitably of some other device indicating some different quantity such as flow, volume, pressure or the like. The primary indicator may also merely indicate a reference angle

such as azimuth, elevation or some reference angle used in levelling or surveying.

By the present invention it is possible to follow a primary indicator with very high accuracy, without imposing any drag, friction or other force reaction on the primary indicator. Since the operation is entirely by intersection of a light beam, it will be evident of course that this can be accomplished without any interference with the operation of the primary indicator.

The present system is capable of response with considerable speed, the minimum speed of response in one desirable embodiment being about one second for movement from end to end of the instrument scale.

The device is extremely simple and normally does not necessitate bending of light beams and aligning of beams progressing at various angles. The controlling factor to which the device responds is change in quantity of light, and the device is comparatively little affected by normal change in calibration of phototubes. When photo tubes are mentioned, any suitable photosensitive electronic tube is included.

In order to apply the follow-up mechanism of the invention to existing primary indicators, it is not necessary to make any radical change in such existing equipment. Ample force is provided in the follow-up system to operate auxiliary equipment such as high-low alarms, level controllers or the like, entirely without reaction on the primary indicator. The follow-up mechanism itself may be used to perform auxiliary functions, such as moving the recording pen to an off position or to a limiting position for changing the record.

Referring to the form of Figures 1 to 4 inclusive, the primary indicator 30 consists of a pointer 31 moving on an axis 32, over an angular path indicated by the arrow 33, and suitably counterweighted at 34. While the primary indicator may move over any desired arc greater or lesser than a circumference, the device is intended to be applied in the forms shown to an application having a range of movement of the order of 100°.

In order to aid the function of following the primary indicator, the primary indicator is provided with a control vane 35 suitably mounted at 36 on the pointer.

In the preferred embodiment the control vane suitably consists of sheet metal extending radially of the primary indicator, having considerable radial length and very little thickness, cut off at the outer radial end at 37, and terminating at the inner radial end at 38 in line with the axis 32. While in the form shown the vane 35 is likely to be a special vane designed for the purpose and applied to the primary indicator, it will be understood that in many cases a surface of the primary indicator existing prior to the installation of the follow-up system may be used to serve the follow-up function. For example where location and dimensions permit, a portion of the head 39 of the pointer arrow may serve this purpose. In any case the installation of a vane 35 on the primary indicator can readily be accomplished in most instances without seriously impairing the structure of the primary indicator and usually with mere necessity to change the counterweighting.

As previously explained, the primary indicator 30 may respond to any suitable impulse measuring or indicating some quantity or fact in respect to any of a wide variety of attributes, but in the preferred embodiment it is desirable that

the axis shaft 32 be the shaft of a water level indicator of the type shown at 71 in my United States Patent application, Serial No. 517,242, filed January 6, 1944, for Differential pressure gauge. The disclosure of this application is incorporated herein by reference and made a part hereof.

The follow-up mechanism includes a follow-up element 40 comprising an arm 41 suitably pivoted at 42 on an axis, which is preferably, although not essentially, the same as the axis 32 of the primary indicator. If any differences between the axes exist, however, the results will be much more complicated, and therefore it is decidedly advantageous to have the axes 32 and 42 coincident, as shown. Preferably mounted on and moving with the arm 41, I provide a co-operating light source 43 and phototube 44, respectively at different distances from the axis, on either side of the vane 35, and preferably one near the radial outer end of the arm 41 and the other at the opposite end thereof adjacent the axis, as shown.

I find that the sensitivity of the device is considerably increased by locating the light source at the radial outer end remote from the axis, and locating the phototube nearer the axis. This is true because a large amount of eclipsing of the light is accomplished by a small movement of the end of the vane when, as shown, the moving end 37 of the vane is close to the light source.

In order that the device may function properly, it is important that the vane 35 be between the light source 43 and the phototube 44, so that the vane can control the passage of light from the source to the phototube.

The light source is preferably an electric incandescent lamp 45 mounted in a socket 46 and lighted by electrical connections 47. Surrounding the lamp is a metallic cover or shield 48 provided with a preferably narrow rectangular slit 49 which is suitably directed toward the axis in a general radial direction in this form.

It has been found that the most effective light source is a thin diverging flat ribbon light beam which travels in the general direction of the vane in equilibrium position. The narrow slit in the lamp cover provides a simple way of securing this beam.

For best results the slit in the lamp cover should be located as near to the light source as practicable, and the slit should be as narrow as possible consistent with full illumination of the phototube element by divergence of the beam. The adjoining end of the vane should be close to the slit, and this provides for sharp cut-off of light by the control end 37 of the vane with minimum movement of the vane, resulting in a very sensitive response. The controlling end of the vane will preferably be substantially closer to the slit than one-half of the length of the vane.

The phototube has a photoelement or cathode 50 and is mounted on a socket 51 having electrical connections 52 to an amplifier.

In order to drive the mechanism and produce the required follow-up, I provide a follow-up motor 53 having a shaft 54 carrying a pinion 55 which is intergeared with a gear (actually in this case a segment) 56 on the shaft 42. The light source 43 is supplied with power, and the motor is operated in accordance with the amplified impulse from the phototube, by an electronic torque control unit or amplifier 57 connected by a suitable flexible cable 58 to the lamp and phototube and by a suitable cable 59 to the motor, and receiving power from a suitable source at 60, preferably of alternating current at 60 cycles and 110 volts.

The follow-up motor 53 is actuated as later explained in response to the quantity of light picked up by the phototube, and is preferably a torque motor which has substantially zero torque when the quantity of light received by the phototube is substantially zero and a maximum torque when the quantity of light received by the phototube is a maximum.

Although the motor 53 may be either of the alternating or direct current type, and if alternating may be either of the conventional type or a special type, in the preferred embodiment as shown in Figure 1, the followup motor is preferably a capacitor type squirrel cage induction motor, which is in itself well known in the art.

Where a capacitor motor is employed, any suitable capacitor type induction motor may be used. In a motor of this type, the direction of rotation is determined by the direction of phase displacement, and the motor is a two-phase motor in the sense that the motor itself is operating on two different displaced phases, although a two-phase power source is not required. Any other two-phase motor may be used with a two-phase power source if desired. One suitable type of capacitor induction motor is the drag cup type, well known in the art.

Instead of actuating the follow-up element by direct drive on the motor shaft, it will be noted that gearing at 55 and 56 has been interposed, permitting the use of a smaller motor with mechanical advantage from the gearing and permitting reduction in the cost and power of the electronic torque control unit, without serious sacrifice of the speed of response.

As later explained, the motor 53 drives in only one direction, and is opposed by a counter-torque on the follow-up mechanism. In the preferred embodiment the counter-torque is provided by gravity acting in unbalanced relation on the follow-up mechanism. Thus if the drive of the motor 53 is in the direction to turn the segment 56 and the follow-up element counterclockwise as shown by the arrow 61, the counter-torque applied by gravity will be clockwise or in the direction of the arrow 62. While gravity provides the preferred form of counter-torque, in Figure 10 I illustrate counter-torque applied by a spring, and in other devices I show electrical means for applying counter-torque.

The counter-torque will be substantially less than the maximum available torque, and substantially greater than the friction in the mechanism. It is often desirable to maintain the counter-torque at about one-half the torque on full motor operation.

Referring particularly to Figures 2 to 4, it will be noted that in each of these figures the phototube is not located in the line between the axis and the light source, but is preferably deliberately placed out of this line. While, if desired, the phototube may be in some other position with reference to the light source, it is preferred to locate it on an extension 63 of the arm 41 on the opposite end of the arm from the light source and beyond the axis 42. Not only is the phototube beyond the axis, but it is preferably out of the line between the axis and the light source as well shown in Figures 2 to 4. Thus in these forms, if the coincident axis is at 32, 42, and the center of the filament 64 of the lamp 45 is at 65, the light

beam 66 is preferably directed so that, taking account of its divergence at 67, it will fully illuminate the photoelement 50 of the phototube 44, missing the vane 35, when the vane is in the clear position as shown in Figure 2. In other words, in this form the line from the center 65 of the light source to the center 68 of the phototube extends to one side and in this case below the axis, and the outer edge 69 of the light beam nearest to the axis is permitted in the clear position of the vane to contact the limiting edge 70 of the photoelement 50.

Thus it will be evident that since the edge 70 of the photosensitive element (cathode) 50 is closest to the pivot of the vane, the side of the photosensitive element adjoining the edge 70 will be most frequently cut off by the vane, while the side adjoining the opposite edge 71 will be less frequently obscured.

Thus it will be evident that in the preferred embodiment shown in Figures 1 to 4 inclusive, one edge 70 of the phototube element, rather than the center of the phototube, is brought into approximate alignment with the line of centers between the axis and the center of the light source.

This construction has the advantage that there is no possibility of the phototube receiving light from both sides of the vane, and a long thin sheet metal vane, without other structural complication, is permitted, while at the same time, since the lever arm of the vane from the pivot is so long, the follow-up mechanism is very sensitive to slight changes of the angular position of the vane, since they produce very marked valving or eclipsing of the light. At the same time it will be evident that the location of the outer end of the vane closest to the light is preferable because a slight change in the angular position of the vane produces a very marked change in the eclipsing, since the beam is at its very narrowest point at the slit where it issues through the cover 48. The reverse arrangement with the phototube upon the outer end of the follow-up element is markedly less sensitive since the outer end of the vane is acting on the light at a point where it is widely diverging, as shown by the beam in Figure 2, which enters the phototube. Because of these advantages, as well as the great simplicity, low cost, reliability and low maintenance, the form of Figures 1 to 4 utilizing gravity counter-torque above referred to is considered to be preferable.

In operation of the form of Figures 1 to 4, it will be evident that the vane and follow-up mechanism will reach an equilibrium position somewhat as shown in Figure 4. If now the primary indicator moves counterclockwise, causing the outer end of the vane to move up into the position of Figure 2, the effect is to completely free the light beam 66 from the eclipsing effect of the vane 35, greatly increasing the amount of light reaching the phototube element 50. Increase in the amount of light reaching the phototube element increases the electric impulse passing from the phototube to the electronic torque control unit 57 and increases the amplified impulse leaving the unit 57 and passing through connections 59 to the motor 53. Since the effect of the motor is to drive the follow-up element 40 in the counterclockwise direction, as shown by the arrow 61, the follow-up mechanism will be driven by the motor counterclockwise following the motion of the vane and will stop, as later explained, when equilibrium is restored.

It will be understood that at some intermediate position of illumination, as shown in Figure 4, the amplified impulse from the phototube when applied to the motor will produce just enough torque to overcome the counter-torque, in this case applied by gravity to the follow-up mechanism. Therefore, when in Figure 2 the illumination of the phototube was increased, the amplified impulse from the phototube was accordingly increased and the torque increased to full torque, substantially in excess of the counter-torque applied by gravity or otherwise, thus permitting the follow-up motion which is described in Figure 2.

Let us now assume that the motion of the primary indicator and of the vane is clockwise, as shown in Figure 3. The effect is then to eclipse or cut off the beam 66, as shown at 72, so that substantially no light reaches the phototube. The phototube impulse will then accordingly be cut off, or dropped to a low threshold value, so that the amplified impulse will not produce sufficient torque in the motor to overcome the counter-torque applied by gravity or otherwise. Accordingly, the counter-torque will exceed the torque and cause the follow-up mechanism to move clockwise in the direction of the arrow 62 (Figure 3) which again tends to restore coincidence between the follow-up element and the primary indicator.

However the motion starts, whether as a clearing motion or an eclipsing motion with respect to the beam, the final equilibrium will be attained as indicated in Figure 4 when the beam is partially eclipsed, as shown at 73, in which the upper portion 74 of the beam is cut off and the lower portion 75 of the beam is cleared. In this condition the phototube impulse when amplified is just sufficient to produce a torque in the motor which overcomes the counter-torque, and therefore equilibrium will be maintained in this position so long as the primary indicator remains stationary.

Whenever the primary indicator again begins to move, the action of Figures 2 or 3 will be repeated depending upon direction of motion, with a view to restoring coincidence between the primary indicator and the follow-up element.

It will be understood, of course, that the conditions of complete clearing and complete eclipsing shown in Figures 2 and 3 are extreme conditions, which can only occur in the case of extremes of motion of the primary indicator in one or the other direction, and that actually in normal operation there will be momentarily minute motions of the primary indicator which will cause minute changes in illumination of the phototube element, with minute follow-up motion, but after the manner indicated in Figures 2 and 3.

It will thus be evident that the angular movement of the primary indicator can be reproduced perfectly by the angular movement of the follow-up element. The control is entirely by the degree of eclipsing of the light beam by the vane, or in other terms, the change in the quantity of light on the photoelement of the phototube, which tends to restore the initial illumination conditions and recreate equilibrium.

It will be evident that in this and a number of other forms of the invention, the amplified output of the phototube continuously urges the follow-up mechanism in one direction, but the question of whether or not motion in that direction occurs depends upon whether or not the counter-torque

is overcome by the amplified phototube impulse acting on the motor.

It will be evident that in Figures 2 to 4, the light beam deviates slightly from the radial direction, but may be regarded as being generally radial, one edge of the beam being truly radial.

In the form of Figure 5, the structure differs slightly from that of Figures 1 to 4. In this form the primary indicator 30 has been slightly modified to show an offset end 76 carrying the head 39.

To indicate conveniently that the primary indicator may be part of a water level system, I show at the end of the axis shaft 32 an arm 77 carrying a float 78, intended to be inside a vessel such as a boiler to indicate the liquid level therein. At some point such as 79, the motion of the float is transmitted by any suitable means such as that described in my copending application above referred to, or by a conventional stuffing box or rotating joint, through the wall of the boiler or through the vessel, not shown.

The vane construction has been slightly varied in this form to show an extension 36 on one side of the vane, which is attached to the pointer and avoids the necessity of using the rod at 36, as shown in Figure 1.

In this form of the invention the light beam is placed truly radially with respect to the coincident axes 32, 42 of the primary indicator and the follow-up element. Thus the center of the photoelement 50 of the phototube 44 is on the line of centers between the axis and the center of the light source. This presents the problem, where a very light, thin sheet metal vane of considerable axial length is used, as shown, of preventing the possibility that the beam will be divided at the center and light from both sides of the beam might reach the photoelement, thus confusing response. To prevent this possibility, a light cut-off surface 80 has been located at a convenient point on the vane, preferably at the axis, and extending transversely to the beam for a sufficient distance to cut off any rays which might pass to the phototube over the top of the vane in any operating position of the vane. Thus in this form, the upper portion of the phototube element 50 adjoining the edge 70 is substantially inactive and the device operates by variant response from the quantity of light reaching the lower portion of the phototube element. While this arrangement is operative, it is inefficient since it does not employ the phototube element to best advantage.

In the structure of Figure 5 the follow-up element 40 is incorporated with the segmental gear 56 as a single member 81, reducing the number of component parts.

In the previous form shown, the vane 35 was extended in a radial direction, but it will be evident that other vane contours and directions may be employed with or without change in the direction of the beam.

In Figure 6, the vane 35' is extended circumferentially with respect to the axis 32 of the primary indicator 30, being suitably mounted on the pointer at 82, and extending in segmental form from a top edge 83 to a bottom controlling edge 84. The counterweight 34 has been broken away in this form and in that of Figure 10. The light source 43 and the phototube 44 are preferably radially spaced as in the forms previously described, and are located one immediately radially beyond and the other immediately radially within the vane 35'.

Depending upon the operation of the primary indicator, the vane may be shortened or may require lengthening in respect to its circumferential extent, as it is obviously important that the characteristics of the device should not permit wide enough displacement between the primary indicator and the follow-up element, so that confusion could occur between the control edge 84 and the opposite edge 83 of the vane. In all of the forms shown, it is contemplated that the primary indicator and the follow-up device will have limited arcuate motion, but it will be understood, of course, that this is not essential and the principle may be applied with movement of a complete circumference or complete circumferences. However, where limited arcuate motion is employed, it will be convenient to extend the vane 35 over a substantial portion of the range of arcuate movement.

The operation will be essentially the same as in the other forms. Thus, if the primary indicator moves counterclockwise in Figure 7, the light beam from the light source to the phototube is completely clear and the amplified impulse from the phototube drives the motor 53 in a direction to turn the follow-up mechanism counterclockwise in the direction of the arrow 61 to restore equilibrium and coincidence between the primary indicator and the follow-up mechanism.

Likewise if the primary indicator moves clockwise, as shown in Figure 8, the vane 35' eclipses the beam, causing the amplified phototube impulse to drop off to practically zero, so that the counter-torque prevails over the torque of the motor 53 and the follow-up element 40 moves clockwise in Figure 8 in the direction of the arrow 62 to restore coincidence and equilibrium. The equilibrium condition, as shown in Figure 9, is that in which the beam is partially split by the controlling edge 84 of the vane, and in that condition the predetermined coincidence exists and the recorder or other device operated by the follow-up mechanism will agree with the primary indicator.

In the form of Figure 10, the vane 35^2 is positioned in a plane at right angles to the axis 32 of the primary indicator 30, and the follow-up element 40 is formed as an arm 85 transverse to the segmental gear 56. The light source 43 and the phototube 44 are located as close together as convenient on the arm 85, one on either side of the vane 35^2. The controlling edge of the vane in this case is at 84' and the operation is the same as that already described in the other forms.

In this form of the invention a spring counter-torque is provided at 86 on the axis shaft 42 of the follow-up element, in this case replacing the action of gravity used in the earlier forms.

As shown in Figure 11, I may, in some cases, use a twin phototube or two phototubes, preferably having two separate phototube cathode elements in one envelope, as shown at 87, 88, with the vane 35 located radially and centering at the center of the beam so that in equilibrium position light will be supplied to each element 87 and 88 from the light source, and in effect the energy imparted from the amplified impulse of one or the other photoelement will act as a counter-torque. In this form the motor 53' will be reversing, preferably a capacitor type induction motor. The devices of Figures 22 to 24 inclusive are suitable to operate this device.

It will be understood that in Figure 11 the operation is substantially the same as in the

other forms, but with the marked difference that when the vane moves in the direction to eclipse the portion of the beam reaching one photoelement, the amplified impulse from the other photoelement may remain unchanged if the control vane is accurately out of the path of the beam to the other element when the vane is centered or may be slightly increased if the movement of the control vane allows slightly more light to come to the photoelement not being eclipsed. Thus the torque mechanism or motor winding responding to the photoelement not being eclipsed will act as a substantially greater torque to move the follow-up element in the direction to follow the primary indicator.

Figures 12 to 17 inclusive illustrate a more complete embodiment of the invention based upon the form of Figures 1 to 4 inclusive, suitably consisting of a liquid level indicator 89 and a recorder 90 combined with follow-up mechanism of the type described.

The liquid level indicator may be of any suitable type, for example connected to a float as diagrammatically suggested in Figure 5, and having primary indicator 30 on a common axis 32 with the follow-up mechanism. The vane 35 is of the type shown in Figure 1. The head 39 of the pointer is, in the preferred embodiment, suitably enclosed by a cover 91 having a cover glass 92 provided with indications 93.

The follow-up element 40 includes an arm 41 mounting the light source and the phototube in the relation indicated in Figure 1, the phototube being on the opposite side of the axis from the light source and the vane controlling the beam passing from the light source to the phototube. The arm 41 is secured to the segmental gear 56 by a bracket 94 fastened at 95 to the gear and at 96 to the arm. The mounting of the phototube is aided by a clip 97 extending over the top of the phototube and secured to the arm as shown in Figure 16.

A rack 98 is movable up and down in guides 99 and 100, supported on the end 101 of the case 102 of the recorder 90, and the rack is intergeared at 103 with the segmental gear 56. The end of the rack is bent at 104 to form a flange 105 to prevent movement beyond the guides. At the upper end of the rack a reverse bend extension 106 over the guide 100 carries a pen arm 107 which is bent at 108 and extends through a slot 109 in the front 110 of the recorder, suitably extending across the face of a rotatable recording disk 111 carrying a graduated chart 112 of any conventional type. A pen is located at 107'. The recorder has a radial inner limiting pen position 113 corresponding with an "off" position of the device and a radial limiting outer-position 114, specially adapted for changing the chart, in which the pen arm 107, of suitable resilient metal, is raised from the surface of the chart 112 by encountering a pen lift cam 115 sloping from a minimum at 115' where it is first encountered to a maximum at 115^2, in the pen lift position. This structure is illustrated in Figure 13*a*.

It will be evident that an important feature of the invention is the ability to employ the power of the follow-up mechanism to move the recorder to the upper and lower limiting positions for the special purposes of indicating an "off" position, as when the power fails, and for moving to an upper limiting position for changing the chart.

As already explained, an important advantage of the device of this invention is that ample power is available in the follow-up mechanism to perform auxiliary functions, such as operating high-low alarms and level controllers, without drag on the primary indicator. To suggest this I show in Figure 13 electric switches 116 and 117 respectively for an electric high and a low level alarm and controller, of any well known type, suitably a push button with a hemispherical top, closed by the pen arm when it reaches the switch position, and otherwise open.

The recorder may be of conventional type in respect to other features, and is shown including a chart turning shaft 118, a chart rotating motor, suitably a timing motor, 119 having electrical connections 120 to a suitable power source. The interior of the recorder and the face are suitably illuminated by lamps 121 (the front 110 is desirably made of translucent or transparent material such as acrylic resin so that the illumination will be applied to the chart), connected to a power source at 122 and controlled by a switch 123. The amplifier and power connection, or electronic torque control unit 57 is desirably built into the recorder case, and provided with suitable connections to the motor 53 and the phototube and light beam source as already described. Switching means are shown at 124 for turning off and on the follow-up mechanism and the amplifier, and at 125 to permit adjustment for variation in line voltage where required.

In operation the device of Figures 12 to 17 performs substantially like that of Figures 1 to 4, the operation of the follow-up mechanism itself being identical with that of Figures 1 to 4 inclusive, and the motion of the follow-up mechanism being transmitted to the recorder by moving the rack 98, and with it the pen arm 107.

Although the recorder as shown uses a straight line motion provided by the rack, it will be evident of course that any other suitable recorder motion might be employed, as well known in the art.

Suitable circuit connections for the electronic torque control unit, the phototube, the light source and the motor are shown in Figure 18, in which a suitable alternating current source, preferably at 110 volts and 60 cycles is shown at 60 connected to a suitable amplifier 57 which is suitably connected to the phototube 54 by the leads (cable) 52, and to the motor 53' by the leads (cable) 59. The source 43 of illumination is suitably connected to 4.5 volts alternating current, and is preferably a 6 to 8 volt lamp (thus increasing the life of the lamp). The phototube is connected to the input of the amplifier 57 and the output of the amplifier is connected to a conventional motor 53, which may be operated by alternating or direct current. The amplifier 57 is designed to provide the necessary alternating or direct energizing current for the motor under the control of the phototube in accordance with well known practice.

Switches 60' are shown to disconnect the electric power and return the pen to "off" position, and a switch 44' is shown to short circuit the phototube and move the pen arm to the upper position in which the pen is off the chart, for chart changing.

Where an alternating current type motor is provided, an amplifier of modified character may be employed, as described and claimed in a copending application of Stephen V. Hart, Serial No. 693,792, filed August 29, 1946. While this amplifier is preferred, alternative systems are set forth below.

In Figure 19 I illustrate a suitable amplifier for performing this function when connected to

a D. C. motor 53', which amplifier may be that of United States Patent No. 2,054,836, granted September 22, 1936, to F. H. Shepard, for Light responsive device. In this construction a suitable source of alternating current, preferably at 60 cycles and 110 volts, is applied at 60 by a transformer 126 having a primary 127 and secondary 128 connected across a phototube 44 through a capacitor 129. The phototube 44 is connected between the cathode 130 and control grid 131 of an amplifier tube 132 from a series resistor 133 in series with the control grid. The two ends of the resistor 133 are connected to the cathode or ground by a resistor 134 and by a shunt capacitor 135 respectively.

The anode 136 of amplifier 132 terminates in connections 59 to the motor 53', representing the output of the amplifier. The connections 59 return to ground through an anode supply battery 137.

In operation of the device of Figure 19, the phototube rectifies the applied alternating current and controls the grid bias of the amplifier tube 132. The output current flowing through the motor 53' connected across the output terminals 59 is therefore proportional to the amount of light falling on the phototube as previously described.

In the preferred embodiment of the device as already described, the motor 53 will be an alternating current motor, rather than a direct current motor as shown at 53' in Figure 19. To accomplish this function I illustrate in Figure 20 a circuit substantially identical with that of Figure 19, but omitting the battery 137, employing additional connections at 138 to a source of alternating current, suitably at 110 volts and 60 cycles, and employing an A. C. motor 53^2. As well known in the art it will be understood that a full wave amplifier may be employed if desired.

In Figure 21 I illustrate a circuit similar to that of Figure 20, but designed to operate with a two-phase induction motor of the capacitor type, preferably a squirrel cage or drag cup motor, as shown at 53^2, and preferably used in Figures 1 to 10, inclusive.

The motor 53 has a rotor 139 and separate phase field windings 140 and 141, of which 141 is directly connected to the source of alternating current 60, suitably at 110 volts and 60 cycles through a capacitor 141', while the winding 140 is connected to the output from the amplifier 132, and shunted by a capacitor 140'. The amplifier circuit differs slightly from that of Figures 19 and 20 in that the resistor 133 and capacitor 135 have been omitted. I also illustrate in this form a suitable transformer 142 connected to the alternating current source for supplying the energy for the lamp 45 for the light source.

Any one of a variety of circuits may be employed with the twin photoelectric element form of Figure 11, and several are suggested for convenience. As shown in Figure 22 the photoelectric elements 87 and 88 are normally separate elements cooperating with separate anodes 143 and 144 in a sirgle envelope 145.

In the form shown the respective pairs of phototube elements are connected by leads 146 and 147 to twin amplifiers 57' and 57^2 having connections to suitable alternating current sources 60, suitably at 110 volts and 60 cycles. The outputs of the respective amplifiers pass through connections 148 and 149 to the respective opposed primaries 150 and 151 of a transformer 152, having a secondary 153 connected to a suitable alternating current motor 154, of any suitable reversing type responding to variant torque. If the capacitor type induction motor type is used, it will be evident that one field connection $154'$, shunted by a capacitor 154^4, will be made to the transformer secondary 153 and the other field connection 154^2 will be made directly to a source of alternating current 60, through a capacitor 154^3, normally part of the motor.

In operation it will be evident that in this form the direction of the motor and its operation will be determined by the comparative outputs of the two amplifiers 57' and 57^2, and this in turn is determined by the quantity of light received by the respective phototube elements 87 and 88.

In some cases it may be preferable to oppose the impulses mechanically, as by using two separate motors 155 and 156 opposed and having a common shaft 54 which is controlling the motion of the follow-up element of Figure 11.

If preferred, the two phototube units may themselves be opposed, as by connecting the respective phototube cathode elements 87 and 88 by leads 157 and 158 to the outside terminals of a resistance 159, and connecting the anodes together by leads 160 and 161 to the center 162 of the device. The resultant impulse across the resistor 159 is then carried by leads 163 to the input side of an amplifier 57, the output of which operates a motor 53^2, desirably a capacitor type induction motor as shown in Figure 22.

It will be evident that various other circuits may be used to accomplish the power amplification function.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the apparatus and process shown, and I, therefore, claim all such insofar as they fall within the reasonable spirit and scope of my claims.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement generally conforming to that of the primary indicator, means for projecting a beam of light from a single source which moves with the follow-up element, means on the primary indicator for variantly eclipsing the beam of light from the single source in accordance with the relative angular positions of the primary indicator and the follow-up element and phototube means for continuously angularly shifting the follow-up element as the primary indicator shifts angularly, and in response to the extent of eclipse of the beam from the single source.

2. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, means for projecting a beam of light which moves with the follow-up element, means on the primary indicator for cutting the beam of light in one relative angular position with respect to the follow-up element, for clearing the beam of light in another relative angular position and for partially cutting the beam in an intermediate relative angular position, a phototube responding to the quantity of light, if any, passing in the beam, a power source for the phototube, an amplifier for the output of the phototube, means for providing a counter-torque

on the follow-up element and a motor having a torque greater than the counter-torque, driving the follow-up element against the counter-torque in continuous response to the amplified output of the phototube.

3. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, means for projecting a beam of light which moves with the follow-up element, means for producing a counter-torque on the follow-up element, means for controlling the quantity of light passed by the beam in response to the decrease of coincidence between the primary indicator and the follow-up element and means for continuously urging the follow-up element against the counter-torque by a torque responsive to the quantity of light passing in the beam and capable of exceeding the counter-torque.

4. In an instrument, a primary indicator having angular movement about an axis, a follow-up element having angular movement about the same axis and adapted to follow that of the primary indicator, means for projecting a beam of light from a single source which moves with the follow-up element, means on the primary indicator for cutting the beam of light from the single source in one relative angular position with respect to the follow-up element, for clearing the beam of light from the single source in another relative angular position and for partially cutting the beam from the single source in an intermediate relative angular position, and phototube means for maintaining the primary indicator and the follow-up element in an equilibrium relation in which the beam from the single source is partially cut.

5. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, means for projecting a beam of light from a single source which moves with the follow-up element, a vane on the primary indicator for variantly eclipsing the beam of light from the single source in accordance with the relative angular positions of the primary indicator and the follow-up element, and phototube means for continuously restoring the relative position of the primary indicator and the follow-up element which corresponds with equilibrium of the beam of light from the single source with respect to the vane.

6. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, means for projecting a beam of light which moves with the follow-up element, a vane on the primary indicator for cutting the beam of light in one relative angular position with respect to the follow-up element, for clearing the beam of light in another relative angular position and for partially cutting the beam in an intermediate relative angular position, a phototube responding to the quantity of light, if any, passing the vane, a power source for the phototube, an amplifier for the output of the phototube, means for providing counter-torque on the follow-up mechanism, and a torque motor driving the follow-up element against the counter-torque in continuous response to the amplified output of the phototube and capable of developing torque exceeding the counter-torque.

7. In an instrument, a primary indicator including a light interfering means and adapted to turn around an axis, a follow-up element adapted to turn around the same axis, and photoelectric means including a source and a phototube mounted both on and moving with the follow-up element to return the follow-up element continuously to a balanced condition at a predetermined extent of interference by the light interfering means with the phototube as the primary indicator moves.

8. In an instrument, a primary indicator adapted to rotate around an axis, a follow-up element adapted to move preferably in coincidence with the primary indicator about the same axis, means for producing a return torque on the follow-up element of relatively low order, means for producing a light beam travelling with the follow-up element, means on the primary indicator for intercepting the light travelling with the follow-up element and means for continuously applying a torque opposite to the return torque and of a higher order on the follow-up element to keep the follow-up element in coincidence with the primary indicator including phototube means mounted on and carried by the follow-up element and responding to the light beam, the light to the phototube being intercepted by the primary indicator.

9. A reactionless light beam coupling comprising a rotatable primary indicator, a light intercepting vane carried by the primary indicator, a rotatable follow-up element, means mounted on the follow-up element for producing and receiving a light beam, and means for moving the follow-up element continuously to an equilibrium position in proportion to the quantity of light passing the vane.

10. A reactionless light beam coupling comprising a rotatable primary indicator having a light intercepting vane, a follow-up element adapted to rotate about the same axis as the primary indicator, means for producing a beam of light travelling with the follow-up element, means for urging the follow-up element by a torque in one direction in response to the quantity of light passing the vane, and means for continuously producing a counter-torque of substantially half the torque, the mechanism achieving an equilibrium position corresponding to passage of approximately half of the light of the beam.

11. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, means for projecting a beam of light from a single source in a single direct straight path which moves with the follow-up element, means on the primary indicator for cutting the beam of light from the single source along its single direct straight path in one relative angular position with respect to the follow-up element, for clearing the beam of light from the single source in another relative angular position and for controllably and partially cutting the beam from the single source in an intermediate relative angular position, and phototube means for continuously maintaining the primary indicator and the follow-up element in the relation in which the beam from the single source is partially cut and the primary indicator and the follow-up element are in equilibrium.

12. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, a light source mounted on and moving with the follow-up element and projecting a beam of light which moves with the

follow-up element, means on the primary indicator for cutting the beam of light in one relative angular position with respect to the follow-up element, for clearing the beam of light in another relative angular position and for partially cutting the beam in an intermediate equilibrium position, a phototube mounted on and moving with the follow-up element and responding to the quantity of light, if any, passing in the beam, a power source for the phototube, an amplifier for the output of the phototube, means for providing a counter-torque on the follow-up element and a torque motor capable of developing torque exceeding the counter-torque and driving the follow-up element against the counter-torque in continuous response to the amplified output of the phototube.

13. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, a recorder moved continuously in response to the movement of the follow-up element, means for projecting a beam of light which moves with the follow-up element, means on the primary indicator for variantly eclipsing the beam of light in accordance to the relative angular positions of the primary indicator and the follow-up element, and phototube means for continuously angularly shifting the follow-up element and thereby the recorder as the primary indicator shifts angularly, and in response to extent of eclipsing of the beam.

14. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, a recorder continuously moved in response to the movement of the follow-up element, means for projecting a beam of light which moves with the follow-up element, means on the primary indicator for cutting the beam of light in one relative angular position with respect to the follow-up element, for clearing the beam of light in another relative angular position, and for partially cutting the beam in an intermediate equilibrium position, a phototube responding to the quantity of light, if any, passing in the beam, a power source for the phototube, an amplifier for the output of the phototube, means for providing continuous counter-torque on the follow-up element, and a torque motor capable of developing torque exceeding the counter-torque and moving the follow-up element and the recorder continuously against the counter-torque in continuous response to the amplified output of the phototube.

15. In an instrument, a primary indicator having angular movement on an axis, a follow-up element having angular movement about the same axis and adapted to follow the movement of the primary indicator, a single light source mounted on and moving with the follow-up element for projecting a beam of light which moves with the follow-up element, a vane on the primary indicator for variantly eclipsing the beam of light from the single source in accordance with the relative angular positions of the primary indicator and the follow-up element, and phototube means, including a phototube mounted on the follow-up element beyond the vane and moving with the follow-up element, for continuously angularly shifting the follow-up element as the primary indicator shifts angularly, and in response to the extent of eclipse of the beam from the single source, the light source and phototube being respectively one nearer to and one farther from the axis of the follow-up element.

16. In an instrument, a primary indicator having angular movement about an axis, a follow-up element having angular movement about the same axis and adapted to follow the movement of the primary indicator, a light source mounted on and moving with the follow-up element for projecting a beam of light which moves with the follow-up element, a vane on the primary indicator for cutting the beam of light in one relative angular position with respect to the follow-up element, for clearing the beam of light in another relative angular position and for partially cutting the beam in an intermediate equilibrium position, a phototube mounted on and moving with the follow-up element beyond the vane and responding to the quantity of light, if any, passing in the beam, the light source and phototube being positioned respectively one nearer to and one farther from the axis, a power source for the phototube, an amplifier for the output of the phototube, means for providing a counter-torque on the follow-up element and a torque motor capable of developing torque which exceeds the counter-torque and driving the follow-up element against the counter-torque in continuous response to the amplified output of the phototube.

17. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement about the same axis as the primary indicator and adapted to follow the movement of the primary indicator, a light source mounted on and moving with the follow-up element for projecting a beam of light generally parallel to the radius and moving with the follow-up element, an elongated vane having substantial radial length on the primary indicator and moving into the path of the beam of light in one relative angular position with respect to the follow-up element, clearing the beam of light at another relative angular position and partially cutting the beam at an intermediate equilibrium position, a phototube mounted on and moving with the follow-up element beyond the vane and responding to the quantity of light, if any, passing in the beam, a power source for the phototube, an amplifier for the output of the phototube, means for providing counter-torque on the follow-up element and a torque motor capable of developing torque exceeding the counter-torque and driving the follow-up element against the counter-torque in continuous response to the amplified output of the phototube.

18. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement about the same axis as the primary indicator, and adapted to follow the movement of the primary indicator, a light source mounted on the follow-up element at a distance from the axis and projecting a beam of light generally toward the axis, a vane on the primary indicator nearer the axis than the light source for cutting the beam of light in one relative angular position with respect to the follow-up element, for clearing the beam of light in another relative angular position and for partially cutting the beam in an intermediate relative angular position, a phototube mounted on the follow-up element on the opposite side of the axis from the source and responding to the quantity of light, if any, which passes the vane, a power source for the phototube, an amplifier for the output of the phototube, means for providing counter-torque on the follow-up element, and a

motor capable of developing torque exceeding the counter-torque and driving the follow-up element against the counter-torque in continuous response to the amplified output of the phototube.

19. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement about the same axis as the primary indicator, and adapted to follow the movement of the primary indicator, a light source mounted on the follow-up element at a distance from the axis and projecting a beam of light generally toward the axis, a vane on the primary indicator nearer the axis than the light source for cutting the beam of light in one relative angular position with respect to the follow-up element, for clearing the beam of light in another relative angular position and for partially cutting the beam in an intermediate relative angular position, a phototube mounted on the follow-up element on the opposite side of the axis from the source and responding to the quantity of light, if any, which passes the vane, a phototube having a photo-sensitive element substantially out of the line of centers between the phototube and the axis, a power source for the phototube, an amplifier for the output of the phototube, means for providing counter-torque on the follow-up element, and a motor capable of developing torque exceeding the counter-torque and driving the follow-up element against the counter-torque in continuous response to the amplified output of the phototube.

20. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement generally conforming to that of the primary indicator, means for projecting a beam of light from a single source generally parallel to the radius and which moves with the follow-up element, a segmental vane on the primary indicator for variantly eclipsing the beam of light from the single source in accordance with the relative angular positions of the primary indicator and the follow-up element and phototube means responsive to light passed by the segmental vane for continuously angularly shifting the follow-up element as the primary indicator shifts angularly, and in response to the extent of eclipsing of the beam from the single source.

21. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, means for projecting a beam of light in a general direction parallel to the radius and which moves with the follow-up element, a segmental vane on the primary indicator for cutting the beam of light in one relative angular position with respect to the follow-up element, for clearing the beam of light in another relative angular position and for partially cutting the beam in an intermediate equilibrium position, a phototube responding to the quantity of light, if any, passed by the vane, a power source for the phototube, an amplifier for the output of the phototube, means for providing counter-torque on the follow-up element and a motor capable of developing torque exceeding the counter-torque and driving the follow-up element against the counter-torque in response to the amplified output of the phototube.

22. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, means for projecting a beam of light generally parallel to the axis and which moves with the follow-up element, a vane extending in a plane transverse to the axis of the primary indicator and mounted thereon for cutting the beam of light in one relative angular position with respect to the follow-up element, for clearing the beam of light in another relative angular position and for partially cutting the beam in an intermediate relative angular position, a phototube responding to the quantity of light, if any, passing the vane, a power source for the phototube, an amplifier for the output of the phototube, means for providing counter-torque on the follow-up element and a motor capable of developing torque exceeding the counter-torque and driving the follow-up element against the counter-torque in continuous response to the amplified output of the phototube.

23. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement generally conforming to that of the primary indicator, means including a single source for projecting a beam of light which moves with the follow-up element, means on the primary indicator for variantly eclipsing the beam of light in accordance with the relative angular positions of the primary indicator and the follow-up element, and phototube means including two phototube elements operating on the beam from the single source for continuously angularly shifting the follow-up element as the primary indicator shifts angularly and in response to the extent of eclipse of the beam with respect to either phototube element.

24. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement adapted to follow that of the primary indicator, means including a single source for projecting a beam of light which moves with the follow-up element, means on the primary indicator for cutting the beam of light in either direction, phototube means including two phototube elements operating on the beam from the single source responding to the quantity of light passed in the beam to the respective elements, a power source for the phototube means, amplifier means for the outputs of the phototube means and motor means driving the follow-up element in response to the relative amplified outputs of the phototube means.

25. In an instrument, a primary indicator having angular movement, a follow-up element having angular movement generally conforming to that of the primary indicator, photo-responsive means for driving the follow-up element in continuously balanced relation to the primary indicator, a recorder having a pen driven by the follow-up element and means cooperating with the photo-responsive means for moving the recorder to a limiting position and concurrently removing the pen from the record.

26. The process of controlling the following of an angularly movable primary indicator by an angularly movable follow-up element, which comprises projecting a beam of light from a single source which moves with the follow-up element, variantly eclipsing the beam of light from the single source in accordance with the relative angular relationship of following, and continuously progressing the follow-up element as the primary indicator shifts angularly, and in response to the extent of the eclipse of the beam from the single source.

27. The process of controlling the following of an angularly movable primary indicator by an angularly movable follow-up element, which com-

prises projecting a beam of light which moves with the follow-up element, variantly eclipsing the beam of light in accordance with the relative angular relationship of following, and continuously progressing the follow-up element as the primary indicator shifts angularly, and against a counter-torque, by a torque responsive to the extent of eclipse of the beam.

28. The process of controlling the following of an angularly movable primary indicator by an angularly movable follow-up element, which comprises projecting a beam of light which moves with the follow-up element, variantly eclipsing the beam of light in accordance with the relative angular relationship of following, and continuously progressing the follow-up element as the primary indicator shafts angularly, and against a counter-torque, by a torque responsive to an amplified photoelectric impulse from the quantity of light in the beam.

29. The process of controlling the following of an angularly movable primary indicator by an angularly movable follow-up element, which comprises projecting a beam of light from a single source which moves with the follow-up element, cutting the beam from the single source by the primary indicator in one relative angular relationship of following, passing the beam from the single source in another relative angular relationship and partially cutting the beam from the single source in an intermediate relative angular relationship, and continuously restoring the follow-up element to the relationship in which the beam is partially cut by an amplified photoelectric impulse responding to the quantity of light in the beam from the single source.

30. The process of controlling the following of an angularly movable primary indicator by an angularly movable follow-up element, which comprises pivoting the primary indicator and the follow-up element on the same axis, projecting a beam of light from a single source which moves with the follow-up element, variantly eclipsing the beam of light from the single source in accordance with the relative angular relationship of following, and continuously progressing the follow-up element as the primary indicator shifts angularly to restore the initial extent of the eclipsing of the beam from the single source.

31. The process of controlling the following of an angularly movable primary indicator by an angularly movable follow-up element, which comprises projecting a beam of light which moves with the follow-up element, variantly eclipsing the beam of light in accordance with the relative angular relationship, and continuously progressing the follow-up element as the primary indicator shifts angularly, against a counter-torque, by a torque responsive to the quantity of light passed in the beam, to restore equilibrium with respect to illumination conditions.

32. The process of controlling the following of an angularly movable primary indicator by an angularly movable follow-up element, which comprises projecting a beam of light which moves with the follow-up element, variantly eclipsing the beam of light in accordance with the relative angular relationship, and continuously progressing the follow-up element as the primary indicator shifts angularly against a counter-torque, by a torque responsive to an amplified photoelectric impulse from the quantity of light in the beam, to restore continuously the initial equilibrium conditions with respect to illumination.

33. The process of controlling the following of an angularly movable primary indicator by an angularly movable follow-up element, which comprises projecting a beam of light from a single source which beam moves with the follow-up element, variantly eclipsing the beam of light in accordance with the relative angular relationship, and continuously progressing the follow-up element as the primary indicator shifts angularly, by a torque responsive to amplified balanced photoelectric impulses from the quantity of light in the beam from the single source.

34. The process of maintaining angular positional relationship between a primary indicator having a vane and a follower having a single phototube mounted thereon, which comprises photoelectrically controlling the angular follower response entirely in accordance with change in the degree of shading by the vane upon the single phototube.

35. The process of manipulating a follower in response to a primary indicator moving about a common axis of rotation, which comprises modulating a light beam from a single source moving with the follower by the action of the primary indicator and controlling the motion of the follower photoelectrically to restore equilibrium at a predetermined extent of modulation of the beam from the single source.

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