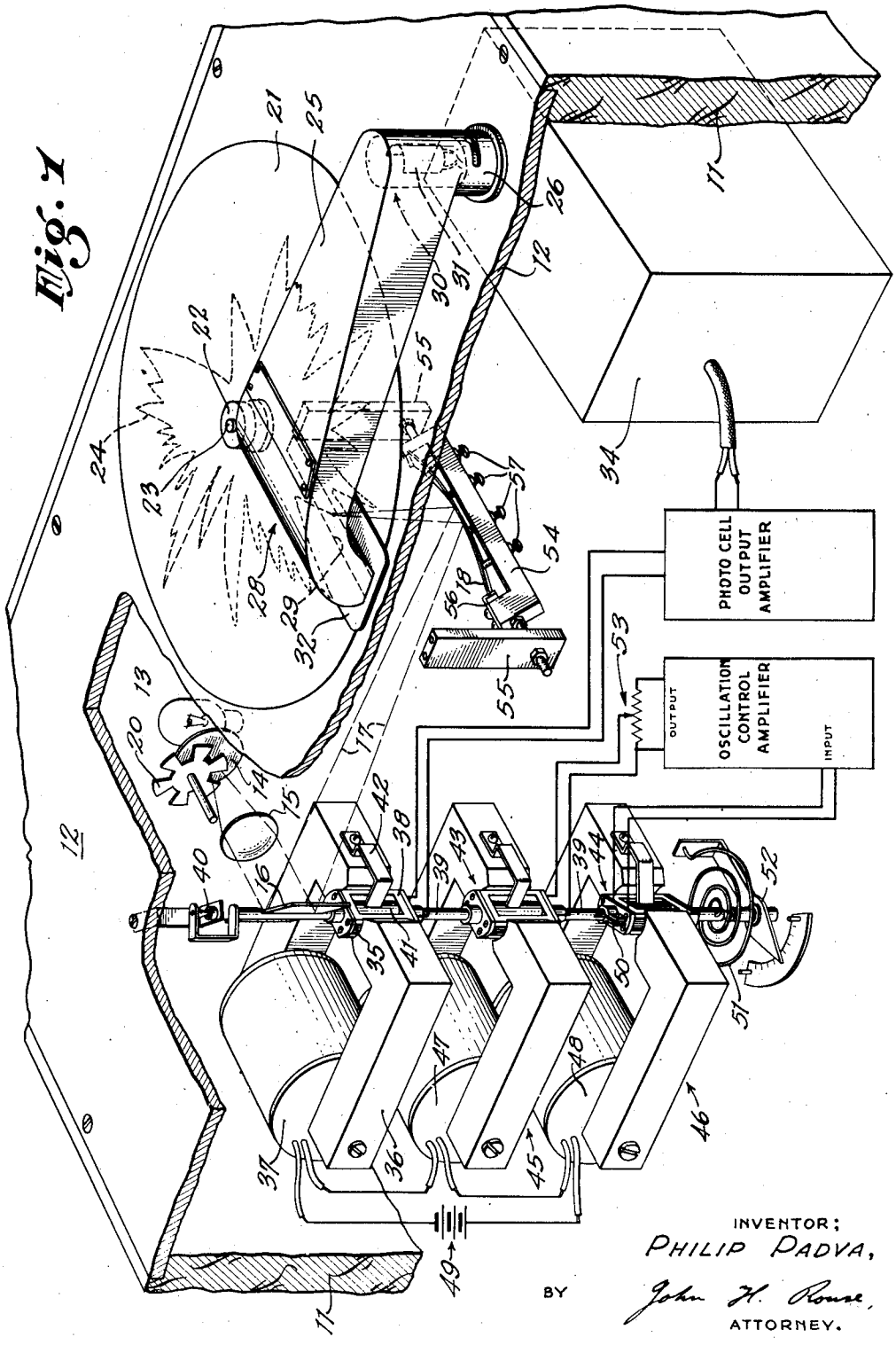
March 24, 1942. P. PADVA 2,277,502

LINE TRACKER

Filed Sept. 20, 1940 2 Sheets-Sheet 1

Fig. 1



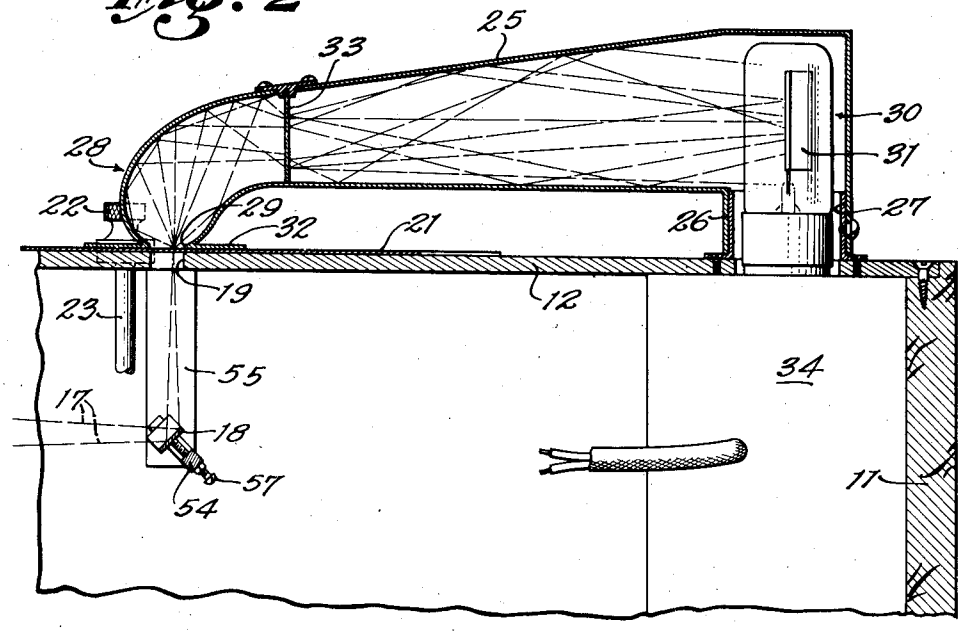
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LINE TRACKER

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Fig. 2



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Patented Mar. 24, 1942

2,277,502

UNITED STATES PATENT OFFICE

2,277,502

LINE TRACKER

Philip Padva, Los Angeles, Calif.

Application September 20, 1940, Serial No. 357,564

9 Claims. (Cl. 250—41.5)

My present invention relates to a system for automatically "tracking" or following, on a moving chart, a line such as that formed by a recording pen moved in response to changes in a condition, such as pressure, flow, temperature, or the like. The means which I preferably employ for following the line is a beam or pencil of light which is maintained in a predetermined position with respect to the line by photoelectric means. A system of the general character indicated is disclosed in U. S. Patent No. 2,121,211, issued June 21, 1938, in the names of Philip Padva and Lloyd J. Cannon; in general, the present invention being an improvement over that system.

An object of the present invention is to improve a photo-electric line-tracking system so that it can be operated effectively under ordinary conditions of general illumination and without the requirement for a dark-room.

In most recording instruments, the pen is mounted on the end of a pivoted arm and the line drawn by the pin (when the chart is stationary) is thus in the form of an arc. In some instruments, e. g., a drum recorder, the line may be in the form of a compound curve when the chart is stationary. It is therefore an object of my invention to provide means for so moving a beam of light that its path on a chart corresponds to a curve of predetermined simple, compound, or complex form.

Another object of my invention is the provision of a housing for a photoelectric cell, which housing includes means for diffusely passing light to the cell from a beam entering an elongated opening provided in the housing so that the cell is affected substantially uniformly regardless of the position of the beam with respect to the opening.

Other objects and advantages of the invention will be found in the description, the drawings, and the appended claims.

For complete understanding of the invention, reference may be had to the following detailed description and accompanying drawings, wherein:

Figure 1 is a partly-diagrammatic perspective view of a photoelectric line-tracking system embodying my invention; and

Figure 2 is a longitudinal sectional view of the cell housing 25, and its associated parts, shown in Fig. 1.

In the drawings, the numeral 11 indicates the side walls of a substantially lighttight cabinet having a top wall 12, the walls being shown broken away to disclose the arrangement of the parts within the cabinet. Mounted in the cabinet is a light-beam producing system which comprises an electric lamp 13, light from which passes through a restricted opening in an opaque disk 14 toward a lens 15 which concentrates and directs the light toward a reflector or mirror 16. From this mirror the light is reflected substantially horizontally, as indicated by the broken lines 17, toward the curved and inclined surface of a reflector 18, whence it passes substantially vertically through an elongated opening 19 in the top wall 12. A motor-driven chopper disk 20 may be interposed between the disk 14 and lens 15 for periodically interrupting the light beam so that its effect on a photoelectric cell can more readily be amplified.

Mounted on the top surface of the cabinet and overlying the opening 19 is a chart 21 of transparent or translucent material. The chart is rotated at a constant speed, such as one revolution per minute, by a motor (not shown), a nut 22 clamping the chart to the motor shaft 23. On the underside of the chart is a continuous opaque line 24 which represents variations in a condition with respect to time (or other factor), which have been recorded on the chart by a conventional recording instrument. In the example shown, the line was recorded by a pen which was moved in an arc in response to changes in the condition, as is indicated by the curvature of the abruptly peaked portions of the line. Mounted on the top of the cabinet is an elongated metallic housing 25 of general flattened funnel-shaped form, the smaller end of which is provided with a hollow cylindrical downwardly-extending portion 26, into which a tubular member 27, secured to the wall 12, extends. The larger end or nose 28 of the housing is downwardly arched so that it is in virtual contact with the chart and is provided with an elongated opening 29 corresponding approximately to the opening 19. By its mounting on the member 27, the housing may be swung forward when changing charts. Mounted in the smaller end of the housing is a photoelectric cell 30 having a cathode 31 directed toward the opposite end of the housing. The portion of the housing which touches the chart is provided with a horizontal flange or lip 32 which serves to prevent entrance of stray light around the opening 29.

The light beam reflected upward through the opening 19 by the reflector 18 is arranged to converge to its focal point at the underside of the chart. The light spot thus formed should be quite small—of the order of 0.010 inch in diameter when a chart line of average thickness is to be tracked. Such a spot is readily produced by the simple optical system shown, particularly when the size of the opening in disk 14 does not exceed that of the spot.

The nose 28 of the cell housing is generally curved in section and has a polished inner surface that diffusely reflects light entering the opening 29 toward the photoelectric cell, as is indicated in Fig. 2 by the broken lines, with

the result that the cell is substantially uniformly illuminated by light passing through the chart regardless of the position of the spot with respect to the length of the openings. Diffusion of the light is increased by a translucent screen 33, of ground glass or equivalent material, mounted in the housing and extending to the sides thereof. It will be noted that the shape of the housing nose is such that the light is substantially directed toward the photoelectric cell, despite its diffusion in passing through a translucent chart.

The photoelectric cell 30 is connected to a preamplifier contained in the cabinet 34, the output of the pre-amplifier being connected through a photocell output amplifier, indicated by the legend, to the movable coil 35 of an electromagnetic motor comprising a U-shaped core member 36 and an energizing or field coil 37 therefor. The coil 35 is wound on a frame 38, of insulating material, which is mounted for rotary movement between the poles of the core member on a shaft 39. This shaft is supported by a pivot bearing 40 and carries the mirror 16. A cylindrical center core 41, supported by a bracket 42 secured to an arm of the core member 36, aids the flow of magnetic field flux.

Mounted on lower portions of the shaft 39 are the coil assemblies 43 and 44 of two other electromagnetic devices 45 and 46, respectively. These devices are similar in construction to the motor described above. The field coils 37, 47 and 48 of the devices are connected to a common source 49 of direct current or rectified alternating current. The functions of the electromagnetic devices 45 and 46 will be described hereinafter.

The shaft 39 is preferably composed of separate sections, but for the sake of simplicity it will be considered as a single shaft. Connecting means 50 is provided on a lower portion of the shaft whereby the plane of the coil assembly 44 can be oriented with respect to the coils 43 and 35. Secured to the lower end of shaft 39 is a spiral spring 51 which serves to bias the shaft in a clockwise direction, as viewed from above, adjustment of the tension being effected by positioning the spring mounting member 52.

The spot of light formed by the beam on the under-surface of the chart 21 is partly obscured by the peripheral edge of the line 24. When the photoelectric cell is illuminated, the power produced by the amplified photoelectric current flowing in coil 35 tends to rotate the mirror in a direction such as to move the light spot toward the center of the chart. This movement is in opposition to the bias of spring 51. If the chart is rotated in an anticlockwise direction, as viewed from above, then the line will fall away from the spot, permitting more light to pass to the photoelectric cell. This increased light energy is manifest in increased amplifier output, and the coil 35 controlling the movement of mirror 16, is caused to turn in a direction that will place the spot of light in normal contact at the new portion of the chart line. As the chart continues to turn, the spot will reach a portion of the line which, instead of falling away from the spot, rises toward the periphery of the chart and tends to intrude upon the spot. The spot is then obscured to a greater extent, reducing the light energy falling upon the photoelectric cell 30, and the consequent lessened output of the amplifier permits the bias spring 51 to become more dominant, pulling the spot toward the periphery. The mean proportion of the area of the spot exposed or obscured can be controlled by balancing amplifier gain to spring bias. The action is, of course, not discontinuous as description analysis requires, but is constant and smooth. Throughout the entire range of travel from center to periphery, or vice versa, the spring 51, and the energy resident in coil 35 as controlled by the extent that the spot is obscured or exposed by the chart line, are in balance. The spot thus remains in its balanced position with respect to the line as the chart rotates.

However, such conditions only result when the balancing forces are relatively small and the chart is rotated slowly. If the forces are increased to a degree such as will effect rapid movement of the spot in either direction, sustained high-frequency inward and outward movement (or oscillation) of the spot will be set up. If one considers a light spot of 0.010 inch diameter and a chart line of 0.010 inch width, and the spot half obscured at its mean point of range of travel across the chart, it will be realized that a motion of 0.005 inch will entirely obscure the spot from, or reveal it to, the photoelectric cell, thus permitting relatively enormous forces to be set up which will cause the spot to cross the line to a considerable distance beyond and on both sides of the line. A detailed discussion of this phenomenon is given in my copending application, Serial No. 345,434, filed July 13, 1940, wherein the means which I employ for quelling the oscillation are fully described and claimed. It will suffice herein to state that these means are entirely separate from the electrical system of the "line tracker" described above, and comprise the electromagnetic devices 45 and 46, their associated movable coils 43 and 44, and the oscillation control amplifier, indicated by the legend, which interconnects these coils; the output of this amplifier being connected to the coil 43 through a potentiometer 53. The coils 35, 43 and 44 being each rigidly mounted on the shaft 39, upon movement of the shaft, initiated by the displacement of the spot with reference to the chart line, the coils 43 and 44 are moved, cutting the flux lines produced by the electromagnetic devices 45 and 46, respectively, and thus each generating an E. M. F. The E. M. F. of coil 43 is of no practical consequence, but the E. M. F. generated by coil 44 is of basic importance, for it forms the stimulus of the oscillation control amplifier, the output of which is coupled to the coil 43 so that the direction of the E. M. F. induced in coil 44 is preserved when coil 43 receives it from the amplifier. The coil 43 is so polarized in connection to the output of the oscillation control amplifier that its motor reaction in the field of assembly 45 is in opposition to the direction of movement which induces the E. M. F. in coil 44. Thus, high frequency oscillation of the moving system is effectively quelled; the normal tracking movement being substantially unaffected on account of the lower velocities involved, and the consequent immaterial E. M. F.'s produced.

To minimize coupling of the several coils, which may tend to cause erratic action of the system, the plane of the coil 44 may be oriented with respect to that of the other coils; by way of example, this coil being shown at about 30° to the other coils and the pole faces of its electromagnet correspondingly moved. However, the necessary degree of orientation is obviously dependent on various factors, such as the distance between the

coils, incidental field distortion, et cetera, and may best be determined by experiment.

As has been stated above, on the particular chart shown, the line was recorded by a pen which was moved in an arc in response to changes in the recorded condition. It is therefore essential that the light spot, in the movement of mirror **16**. should move in a path on the chart surface corresponding to this arc. This is accomplished by adjustment of the curvature of the reflector **18**. This reflector is supported at its ends by a member **54**, pivotally mounted in supporting brackets **55** secured to the wall **12**. By adjustment of end plate **56** and screws **57**, it will be seen that any desired curvature of the reflector strip may be produced. After the member **54** has been rotatably adjusted so that the reflected beam passes through the opening **19**, it is locked in position. The shape of the openings **19** and **29** may conveniently be rectangular as shown, but must then be of such width that the beam is not obscured along its curved path.

The system of my invention is obviously also applicable to the tracking of charts other than of the disk-type shown by way of illustration. For example, the recorded paper strip of a drum recorder could be arranged to be drawn across the light beam opening. Also, if the line to be followed is such as was formed by a pen moving in a rectilinear path, the surface of the reflector **18** may be plane. Further, any complex recording-instrument-pen motion may be simulated by corresponding modification of the reflector **18**. Means responsive to the movement of the light beam in tracking the chart line may be provided for integrating such movement but are not disclosed herein as they form no part of the present invention.

While I have herein shown and described a specific embodiment of my invention, I wish it to be understood that modifications may be made without departing from the spirit of the invention and that I intend therefore to be limited only by the scope of the appended claims.

I claim as my invention:

1. In a system for following a line on a moving chart, which line is formed by means moved in a predetermined basic path, and modified in response to changes in a condition: means for producing a concentrated beam of light, movable means for deflecting said beam in a plane, and a reflector positioned in the path of said beam for reflecting the beam toward said chart, said reflector being so shaped that the path of the beam on the chart corresponds to said path of said condition responsive means.

2. In a system for following a line on a moving chart, which line is formed by means pivoted to move in a curved path on the chart in response to changes in a condition: means for producing a concentrated beam of light, movable means for deflecting said beam in a plane, and a reflector positioned in the path of said beam for reflecting the beam onto said chart, said reflector being so curved that the path of the beam on the chart corresponds to said path of said condition responsive means.

3. In a system for photoelectrically tracking a line on a moving chart: means defining a substantially lighttight compartment having an elongated opening in a wall thereof, a chart of translucent material mounted for movement on the outside of said wall and overlying said opening, means in said compartment for projecting a beam of light through said opening onto said chart, an elongated lighttight housing mounted on the outside of said compartment and having an end portion overlying said chart provided with an opening registering with said first-named opening, the axis of said housing lying in a plane substantially parallel to the surface of said wall, a photoelectric cell mounted in the other end of said housing, and means in said housing for reflecting onto said photoelectric cell light passing from said beam through said chart and said openings.

4. A receptacle for a photoelectric cell comprising an elongated lighttight housing having a lateral opening adjacent one of its ends, the other end of the housing forming a space for the reception of a photoelectric cell, and means in said housing adjacent said lateral opening for diffusely reflecting light entering therethrough toward said other end.

5. A receptacle for a photoelectric cell comprising an elongated lighttight housing of flattened funnel-shaped form and having an elongated lateral opening adjacent the large end of the funnel, the smaller end of the funnel forming a space for the reception of a photoelectric cell, and means in said housing adjacent said lateral opening for diffusely reflecting light entering therethrough toward said smaller end.

6. A receptacle for a photoelectric cell comprising an elongated lighttight housing of flattened funnel-shaped form and having an elongated lateral opening adjacent the large end of the funnel, the smaller end of the funnel forming a space for the reception of a photoelectric cell, the inner surface of said housing adjacent said opening being so curved as to diffusely reflect light entering said opening toward said smaller end.

7. A receptacle for a photoelectric cell comprising an elongated lighttight housing of flattened funnel-shaped form and having an elongated lateral opening adjacent the large end of the funnel, the smaller end of the funnel forming a space for the reception of a photoelectric cell, the inner surface of said housing adjacent said opening being so curved as to diffusely reflect light entering said opening toward said smaller end, and a translucent screen in said housing intermediate the ends thereof.

8. In a system for photoelectrically following a line on a moving chart, which line is formed by means moved in a predetermined basic path, and modified in response to changes in a condition: means for producing a beam of light, movable means for deflecting said beam in a plane, a flexible member providing a surface positioned in the path of said beam for reflecting the same toward said chart, and means for adjustably bending said member so that the path of the beam on the chart corresponds to said path of said condition responsive means.

9. In a system for photoelectrically following a line on a moving chart, which line is formed by means pivoted to move in a curved path on the chart in response to changes in a condition: means for producing a beam of light, movable means for deflecting said beam in a plane, a flexible member providing a surface position in the path of said beam for reflecting the same toward said chart, and means for so bending said member that the resultant curvature of the path of the beam on the chart corresponds to that of said condition responsive means.

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