

Nov. 14, 1944.

J. V. DUNHAM

2,362,473

RECORDATION OF THE PATH OF MOVABLE BODIES

Filed Dec. 10, 1941

2 Sheets-Sheet 1

Fig. 3-

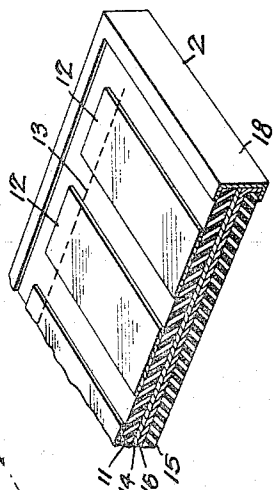


Fig. 4-

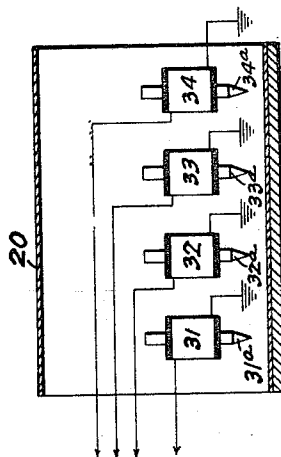
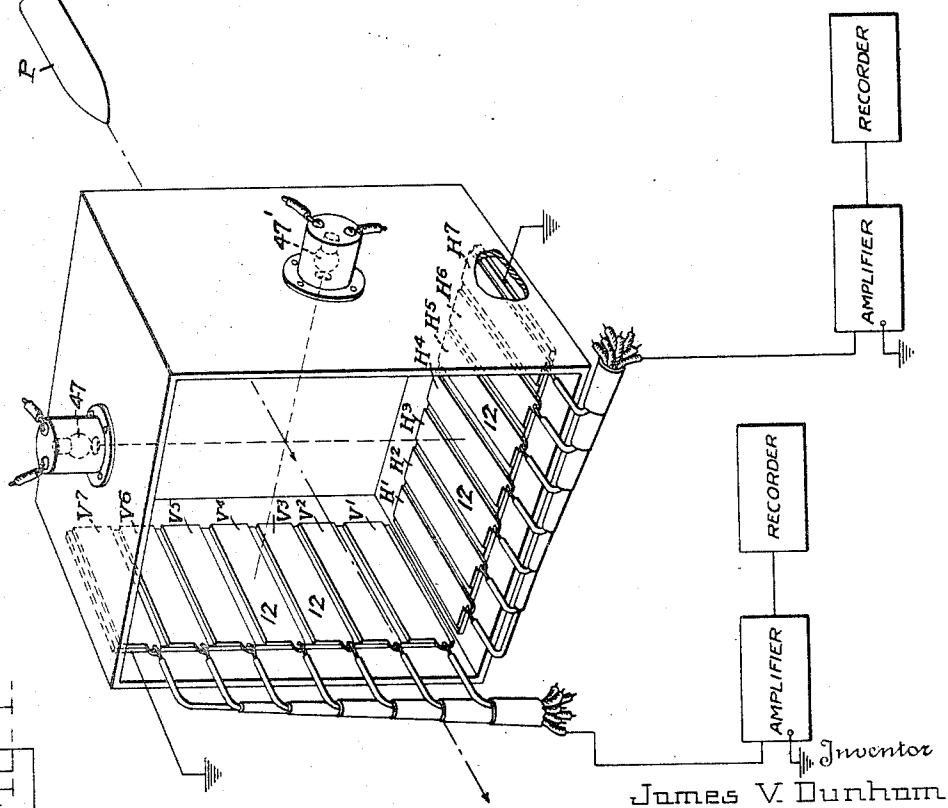


Fig. 1-



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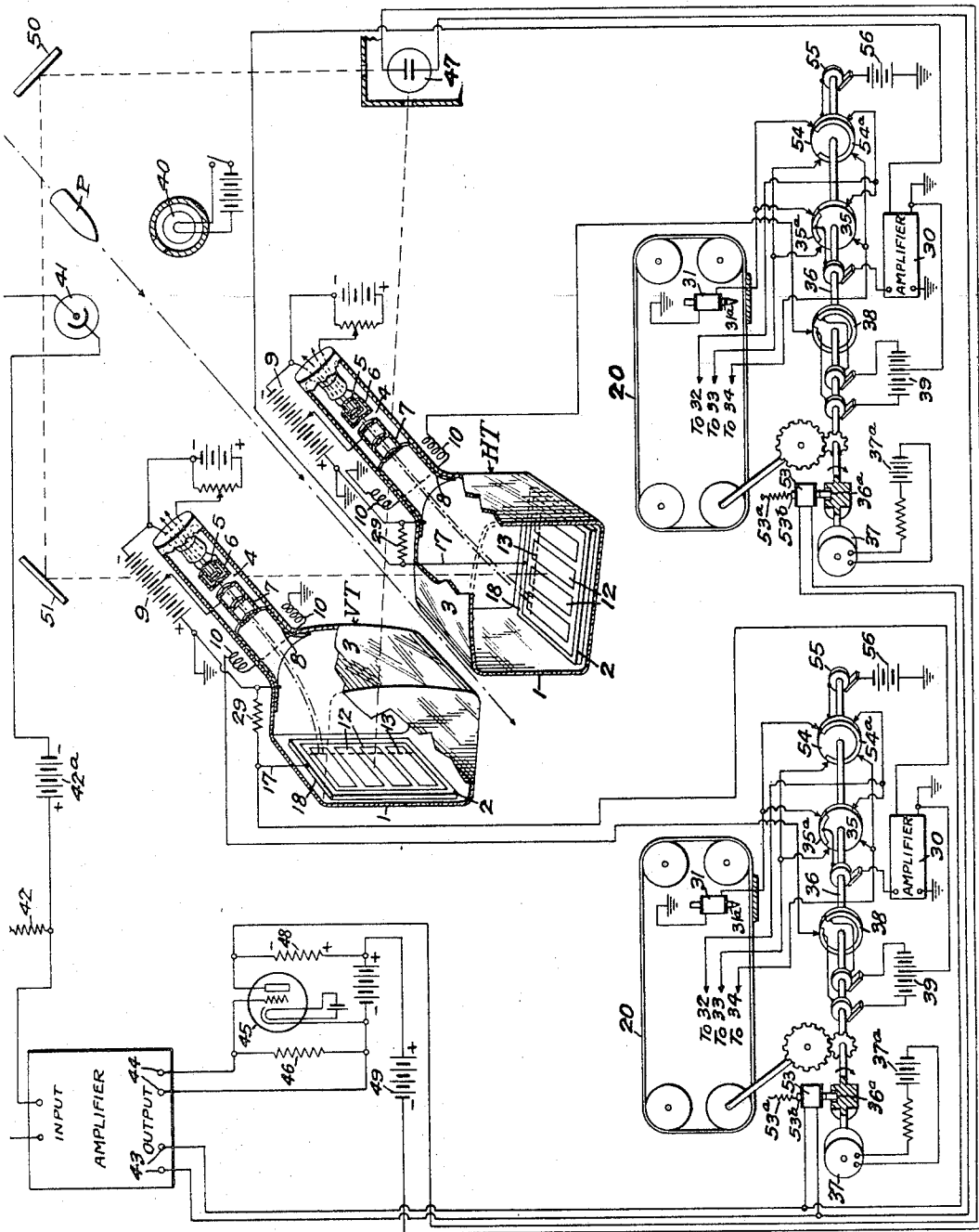


Fig. 2

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UNITED STATES PATENT OFFICE

2,362,473

RECORDATION OF THE PATH OF MOVABLE BODIES

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4 Claims. (Cl. 177—311)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

This invention relates to means for recording the path of movable bodies.

An object of this invention is to provide a self-marking target including light sensitive means.

Another object of this invention is to provide means for determining the accuracy of ammunition.

Another object of this invention is to provide means for determining the coordinates of a projectile in flight.

The present practice of determining the accuracy of ammunition includes firing the ammunition in groups of ten rounds 600 yards. After firing each group of ten rounds, the replaceable target material, usually paper, is measured so as to give the coordinates of the ten perforations and these measurements permit the calculation of the mean radius of the perforations from the center of the group. The method of making these measurements and interpreting the results is well known to those skilled in the art.

The present practice has the disadvantage that certain hazards to life and property are always present when firing over such long outdoor ranges. Sufficient land is not always available near the manufacturing plant. Errors due to wind and other weather conditions are introduced thus making it difficult to properly evaluate the results.

There is reason to believe that the coordinates of the projectile at 600 yards have already been determined by such factors as may reside in the ammunition or the weapon after the projectile has been in flight for less than 100 yards. However, it is not practical to fire at paper targets at 100 yards because the shot group is so small that proper interpretation is impossible. With the apparatus disclosed herein the coordinates of a projectile in flight may be ascertained at considerably shorter ranges than the customary 600 yards. The only limit on the shortness of the range is the requirement that the projectile shall have become stable at the chosen range, i. e., the projectile coordinates must be proportional to the coordinates at 600 yards. Satisfactory measurements at 100 yards may be obtained by using the optical method described below.

The specific nature of the invention as well as other objects and advantages thereof will clearly appear from a description of a preferred embodi-

ment as shown in the accompanying drawings in which:

Fig. 1 is a schematic view of the arrangement of the photosensitive elements shown in Fig. 2 and is helpful in describing the optical method for recording the coordinates of a projectile P in flight.

Fig. 2 discloses a practical embodiment of the invention residing in the optical method.

Fig. 3 is a perspective cross-sectional view of a portion of one of the photosensitive electrodes shown in Fig. 2.

Fig. 4 is a cross section of a portion of the apparatus shown in Fig. 2.

Referring to Fig. 1, the optical method is shown schematically as consisting of a light source 47 adapted to illuminate a horizontal plane and a light source 47' adapted to illuminate a vertical plane. Each light source 47, 47' illuminates a series of strips 12 having light sensitive surfaces which extend parallel to the projectile trajectory. The width of the strips 12 is dimensioned with due regard to the distance of the target from the muzzle and the projectile diameter. The length of the strips should preferably equal the projectile length. Each series of strips 12 is spaced from its light source 47, 47' an amount depending upon the expected dispersion of the projectile group.

Each light sensitive strip is connected through a corresponding tube amplifying circuit to a suitable and convenient recorder such as an annunciator box. A plunger type solenoid may be placed in the amplifier output circuit and the plunger may be associated with a recording tape so that markings are made on the tape as the current in the amplifier output circuit varies.

In Fig. 1 it is seen that a projectile P passing through the light beam will block off the light to some of the sensitive strips 12; the particular ones which are blocked off will depend upon the relative deviation of the projectile from the muzzle-target line. Accordingly, the current changes through those particular strips are amplified and recorded.

The light sensitive strips shown schematically in Fig. 1 may be substituted by the light sensitive elements in the type of tube shown in U. S. Patent 2,247,684 Hickok issued July 1, 1941. The arrangement disclosed in Fig. 2 incorporates tubes described in the above Hickok patent and that arrangement of elements furnishes a practical working of the arrangement disclosed schematically in Fig. 1.

In order to obtain a record for accuracy measurements from the data obtained in the manner above, graph paper having a number of horizontal and vertical lines corresponding to the number of light sensitive strips is used. With the apparatus placed at 100 yards from the muzzle, the line spacing of the graph paper would be greater by a factor of 6, than it would be at 600 yards.

For example, assuming the projectile to block the light falling on horizontal strips Nos. 3, 4, and 5 and vertical strips Nos. 5, 6, and 7 then the group of recorders would register H-345 and V-567. The shot would be transferred to the graph paper and be designated by a point at the intersection of horizontal line 4 and vertical line 6. If the recorder registered H-4, 5 and V6, 7, the shot would be transferred to the graph paper at the point having the coordinates 4.5, 6.5. After marking a "target" of ten rounds it would be ready for the usual measurements.

Referring to Fig. 2, two tubes VT and HT of the type described in the above Hickok patent are disposed with the photoelectric strips 12 of the tubes in the same relationship to each other as in Fig. 1, i. e., one series of strips 12 is perpendicular to the other and the strips extend in a direction parallel to the expected projectile flight. The strips have the dimensions recited preferably for those in Fig. 1 and it is obvious that more strips than those shown in Fig. 2 may be used with advantage.

Tubes VT and HT are of substantially the same structure described in the above mentioned Hickok Patent 2,247,684. Tube VT and its associated apparatus will be described but it is understood that the apparatus associated with tube HT is similar and is therefore given the same reference numerals. Tube VT comprises a highly evacuated glass envelope enclosing a conventional type electron gun and a flat target or mosaic electrode 2 symmetrically positioned in the envelope so that its front surface may be scanned by a beam of electrons from the electron gun and also may have projected upon it shadows due to the passage of projectiles. Since the shadows are produced by light from objects outside the tube, a portion of the tube such as the transparent window 3 is made optically uniform so that shadows may be projected upon the mosaic electrode 2 with a minimum of distortion.

The electron gun assembly 4 comprises an electron emitting cathode 5 from which an electron stream may be drawn, a control electrode 6 to control the average electron intensity connected to the usual biasing battery, and a first anode 7 maintained positive with respect to the cathode 5. The electron stream leaving the first anode 7 is accelerated, and concentrated into an electron scanning beam focused on the front surface of the mosaic electrode 2 by a second anode 8 which is preferably a conducting coating on the surface of the bulb 1 near and in the neck of the bulb but removed from that portion through which is projected the optical shadow. The first anode 7 and the second anode 8 are maintained at the desired positive potentials, such as 300 and 1000 volts respectively with respect to the cathode 5 by a battery 9. Conventional electromagnetic deflection coils 10 are used to sweep the beam in one direction only across the target or mosaic electrode 2. In the arrangement shown in Fig. 2 the deflection coils are so arranged as to sweep the beams along the line designated as 13.

The mosaic electrode may have the structure

disclosed in Fig. 2 of Hickok patent which is reproduced here as Fig. 3. The mosaic electrode comprises a sheet of insulating material such as a sheet of mica 11 having on one side, that is the front surface, a discontinuous photosensitive structure of line formation and on the opposite side or rear surface a continuous coating of electrically conducting material. The discontinuous photosensitive structure comprises a number of closely spaced but mutually insulated and electrically photosensitized metallic conductors 12, each of which extends across the mica to the opposite edge. The number of photosensitized metallic conductors depends upon the dispersion of the ammunition since preferably the strip width is equal to the width of the projectile. The mosaic electrode is positioned in the tube in such a manner that it may have shadows of the projectile projected on its front surfaces, and also so positioned that it may be scanned by the electron beam from the electron gun which scans or sweeps across the photosensitized surface such as along a path represented by the dashed line 13.

In making the mosaic electrode, a sheet of mica 11 is selected having a uniform thickness of approximately .002" thus obtaining a sheet of insulation sufficiently thin and of sufficiently uniform insulating properties over its exposed surface without sacrificing mechanical strength or other desired properties. The front side of the sheet of mica 11 has deposited thereon a metal such as silver which may be highly photosensitized or otherwise applied to the sheet of mica as narrow continuous rectilinear strips or conductors 12 which extend from one edge of the sheet of mica to the other edge and are of low electrical resistance throughout their length. The rectilinear conductors may be applied as in the above mentioned Hickok patent or by a process somewhat similar to that disclosed by Tedham et al., in their U. S. Patent No. 2,077,442. A process for oxidizing and sensitizing the conductors is taught in the U. S. Patents 2,062,122 and 2,065,570 respectively of S. F. Essig.

A uniform coating of metal such as platinum or other conducting material which serves as a signal plate 14 for the mosaic electrode 2 is deposited on the rear side of the sheet of mica 11. In order to strengthen the thin mica sheet 11, a relatively thick backing sheet 15 also preferably of mica and of the same shape and area as the sheet 11 is provided. On the side of the backing sheet facing the signal plate 14 of conducting material, a conductive coating 16 is provided also preferably of metal such as platinum in good electrical contact with the platinum coating 14 to assure minimum electrical resistance between various points on the coating 14 and the external circuit which is connected through the lead 17 to a frame or clip member 18 which grips the two edges of the mica and which is in electrical contact with the signal plate through the coating 16.

Referring to Fig. 2, each projectile P whose coordinates are to be recorded interrupts a light beam from a constantly lit source 40 to the photoelectric cell 41 thus causing a diminution in current flow through it in accordance with well recognized principles. Cell 41 is energized from source 42a through resistor 42. This diminution in photoelectric current causes a decreased potential drop across resistor 42 and a correspondingly lower output voltage across the two pair of amplifier output terminals 43, 44. The output terminals 44 are connected in the

grid circuit of tube 45 by means of resistor 46. With uninterrupted light from source 40 falling on photoelectric cell 41 the source of illumination 47 which is adapted to produce a flash of light and which might be a glow discharge tube, is, for all practical purposes, extinguished because the voltage drop across resistor 48 in the output circuit of tube 45 is high enough and in such a direction as to oppose the effect of fixed voltage supply 49 on light source 47 but as the voltage across terminals 44 is lowered the voltage drop across tube output resistor 48 decreases and the source 47 is effectively energized so that it emits light copiously; the source 47 emits light when the projectile P interrupts a light beam between source 40 and photoelectric cell 41.

Also, a drop in voltage across terminals 43 will cause the recording mechanism to function.

Light from source 47 is projected upon the mosaic electrodes of tubes VT and HT by a direct path and by means of mirrors 50 and 51 each time the light to cell 41 is interrupted by a projectile P. Light from source 47 causes each sensitized strip of tubes VT and HT to lose electrons and thus acquire a positive charge in an amount depending upon the degree to which they are illuminated; those strips blocked off due to the presence of projectile P will of course lose a minimum amount of electrons and accordingly have a charge different than the others. Electric currents representative of the electrostatic charge on each of the conductors 12 generate signals across an output impedance 29, connected between the lead 17 and ground, in a time sequence determined by the rate of scanning the conductors 12 by the electron beam. The signals are applied to an amplifier 30 of the conventional type and thence to a distributing circuit to actuate the recording apparatus.

More particularly, the output of amplifier 30 is connected sequentially to a plurality of current solenoids shown at 31-34 through a single segment commutator 35 mounted on a shaft 36 which is driven by motor 37. The number of solenoids 31-34 correspond to the number of strips 12 on the mosaic electrode. Also mounted on motor shaft 36 and therefore operated synchronously with commutator 35 is a second commutator 38 having means to provide a linear resistance characteristic around its periphery. The ends of the resistance on the commutator 38 are connected to a potential source such as the battery 39 through the conventional slip rings shown and the contactor sliding on the commutator 38 is connected to one end of the serially-connected deflection coils 10, the opposite end of which is grounded. In order to complete the circuit a source of potential such as battery 39 is provided which is connected to the slip rings and thence to the resistance commutator 38, the midpoint of the battery 39 being grounded. The resistance characteristic of the commutator 38 and the potential supplied by the battery 39 are so chosen that for one complete revolution of the commutator 38 the electron beam from the electron gun is magnetically deflected across the conductors 12 of the mosaic electrode 2 and is returned to its starting point whereupon the deflection is repeated by further rotation of the commutator 38. The motor 37 also preferably drives the perforable tape 20 through a suitable gear reduction mechanism.

The tape 20 is perforated by a sharp point on solenoid plunger 31a when the current through the solenoid 31 is reduced below a certain value;

plunger 31a falls due to gravity. In order to maintain the plunger 31a in raised position when no current to solenoid 31 flows via element 35, the auxiliary shunt circuit including elements 54, 55, 56 is used. It will be seen from the drawings that the metal commutator bars 35a, 54a are disposed in such relative angular relationship that a closed electrical circuit for the solenoid 31 always exists for all positions of the shaft 36. As the shaft 36 revolves, the solenoid 31 is energized by charge pulses through the amplifier 30 and/or by the current from the parallel connected voltage source 56. The voltage source 56 is of such a capacity as to maintain the solenoid plunger 31a in raised position due solely to current flow from source 56 through slip ring 55 and commutator 54. The plunger 31a will drop and cause a perforation of tape 20 if the energizing current, which is due to the neutralization of a corresponding strip 12, is below a certain value which corresponds to the charge produced by lighting the strip completely. That is, when those strips are discharged which had a portion of the projectile shadow cast thereupon, a perforation of tape 20 will be made by that corresponding plunger 31a-34a. The total angular displacement of the commutator bars 35a, 54a is more than 360°; and the bars 35a, 54a are disposed relative to one another so that a closed electrical circuit for the solenoids always exists. Upon rotation of shaft 36, it is quite possible that the solenoids 31-34 will be energized through amplifier 30 in accordance with the charge neutralizing currents as well as a current from source 56 for a short time interval, but these currents are additive and maintain the plungers 31a-34a in raised position.

Shaft 36 is driven by the motor 37 which is constantly energized from source 37a so that shaft 36 will rotate when magnetic plunger 53b is drawn up out of the shaft hole 36a by the action of spring 53a when the current through solenoid 53 is diminished due to a diminution in light to the photo cell 41. Shaft 36 will make one revolution for each projectile P which blocks off the current to photocell 41 because solenoid 53 will draw its plunger 53b into shaft hole 36a when the plunger and plunger hole become aligned again. It is obvious that the two shafts 36 may be mechanically interconnected and may be driven by a common motor and thus may be prevented from rotating by using only one magnet 53.

The contacts on commutator 54 are approximately at equal angular distances from one another but this relation is distorted somewhat in such a manner whereby they are all in contact with bar 54a when the shaft 36 is in its locked position (Fig. 2); when the shaft 36 is locked no perforations are made on the tape 20 due to current flow from source 56 through the solenoids 31-34.

In operation, a projectile P fired from a gun, in its path to the recording targets VT and HT, will block off the light to the photocell 41 from source 40, and the corresponding diminution in photoelectric current will cause the source 47 to radiate a flash of light and will cause magnet 53 to be sufficiently deenergized to allow the recording shaft 36 to rotate. The source 47 radiates light only for a short period of time corresponding to the time the projectile P is in a position to block off that light to one or more of the photosensitive strips 12. The photosensitive strips 12 have charges developed therein in an

amount depending upon the amount of light falling upon them. These charges are neutralized by the electron beam having the path 13 once per revolution of shaft 36. The current produced by sequentially neutralizing the strips 12 flows through resistor 29, is amplified and synchronously applied to current solenoids 31-34; relays 31-34 are operated in accordance with the charge on corresponding strips 12, i. e., a strip 12 is provided for each relay of the type 31-34. Only one revolution of the shaft 36 is allowed for each projectile because after each diminution of current in photocell 41 the current through solenoid 53 again reaches its highest value and pulls plunger 53b downward in abutting relation to the shaft 36, and when shaft hole 36a makes one revolution and becomes aligned with the plunger 53b it drops into hole 36a against the action of spring 53a. A perforation is made on tape 20 if the current through any one of the relays 31-34 is below a predetermined value. These perforations correspond to particular positions of projectile P with respect to the tubes VT and HT and thus allow a determination of the position of the projectile P when it passes those tubes.

In order that the light source 47 flash at the exact instant the projectile P passes the tubes VT and HT it may be feasible to space the photocell 41 a distance from tubes VT, HT or to place a time delay circuit such as a resistor-capacitor network in the leads to amplifier 45; both means may be used simultaneously.

I claim:

1. Apparatus for determining the position of a body moving in space comprising two sets of photosensitive strips disposed so that the strips of each set lie parallel to each other in a common plane and the plane of one set is perpendicular to the plane of the other set, means for projecting an image of said moving body on the plane of each set of strips, the path of said images being substantially parallel to said strips, means for maintaining the strips of both sets insulated from one another and in spaced relationship, and separate electrical indicating means associated with the strips of both sets.

2. Apparatus for determining the position of a body moving in space comprising two sets of parallel photosensitive strips disposed so that the strips of each set lie parallel to each other in a common plane and the plane of one set is substantially perpendicular to the plane of the other set, means for projecting an image of said mov-

ing body on the plane of each set of strips, the path of said images being substantially parallel to said strips, means for maintaining the strips of both sets insulated from one another and in spaced relationship, said strips of each set having a width and spaced so that said image of the body is cast upon at least one of the strips, and separate electrical indicating means associated with the strips of both sets.

3. An apparatus for determining the position of a body moving in a space comprising two sets of photosensitive elements each mounted within the envelope of a vacuum tube having means to generate an electron beam, said sets of elements being disposed so that the elements of each set lie parallel to each other in a common plane and the plane of one set is perpendicular to the plane of the other set, capacitive means associated with said photosensitive elements whereby said elements may acquire a charge in proportion to the light incident thereon, means to scan said electron beam over said elements to discharge the elements, means for projecting an image of said moving body on the plane of each set of elements, the path of said image being substantially parallel to said elements, and indicating means responsive to the change in value of stored charge produced on each of said elements over which images pass.

4. An apparatus for determining the position of a body moving in space comprising two sets of photosensitive elements each mounted within the envelope of a vacuum tube having means to generate an electron beam, said sets of elements being disposed so that the elements of each set lie parallel to each other in a common plane and the plane of one set is perpendicular to the plane of the other set, capacitive means associated with said photosensitive elements whereby said elements may acquire a charge in proportion to the light incident thereon, means to scan said electron beam over said elements to discharge the elements, means for projecting a shadow of said moving body on the plane of each set of elements, the path of said shadows being substantially parallel to said elements, said elements of each set having a width and spaced so that each of said shadows of the body is cast respectively upon at least one of the elements of said sets, and indicating means responsive to the change in value of stored charge produced on each of said photosensitive elements over which said shadows pass.

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