April 6, 1948. L. HAMMOND 2,439,294

STEERING CONTROL APPARATUS

Filed Nov. 27, 1943 7 Sheets-Sheet 1

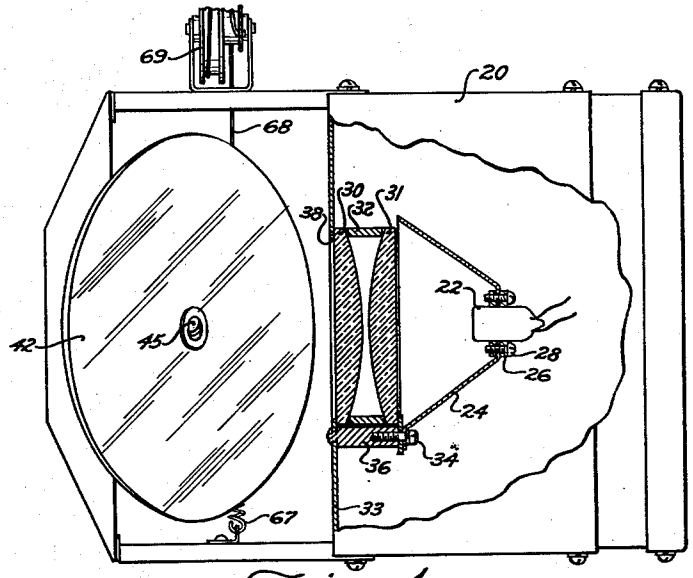


Fig. 1

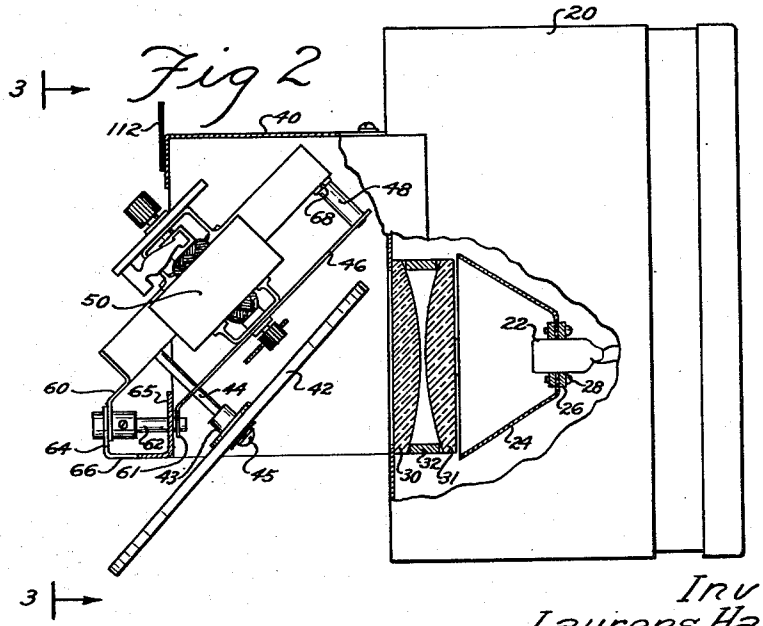


Fig 2

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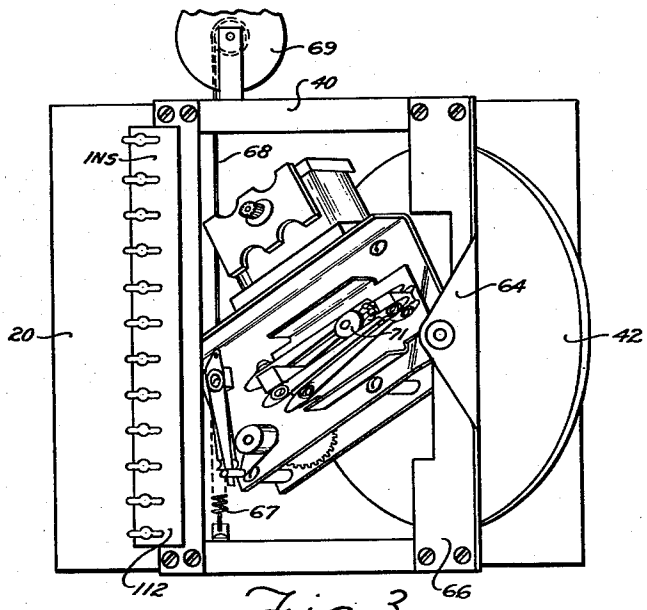


Fig. 3

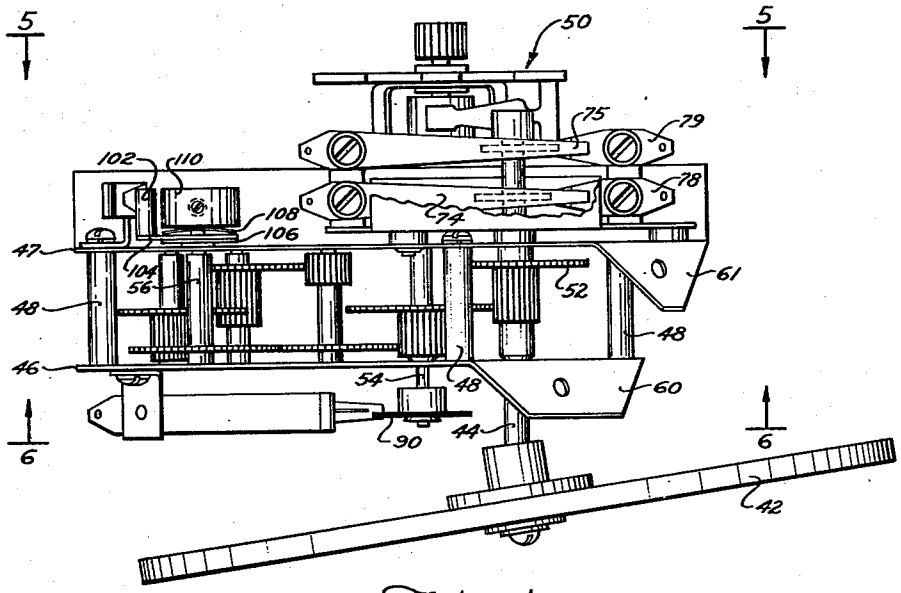


Fig. 4

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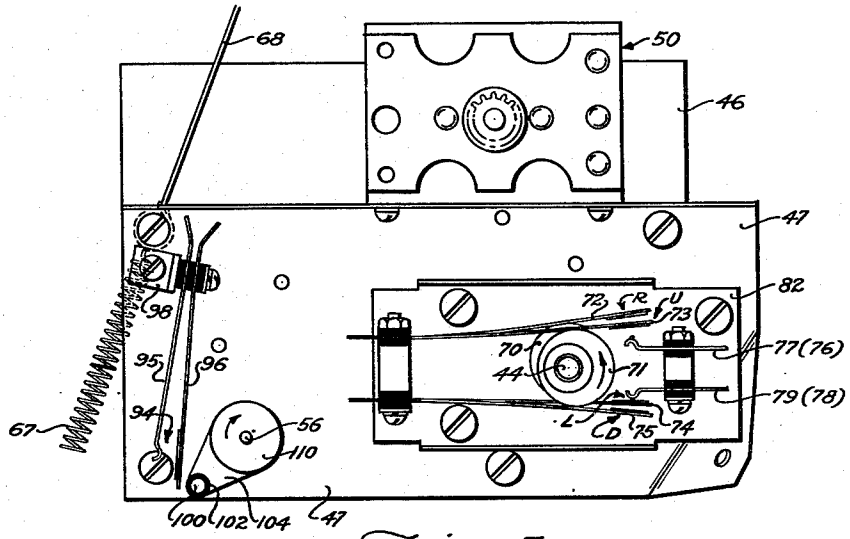


Fig. 5

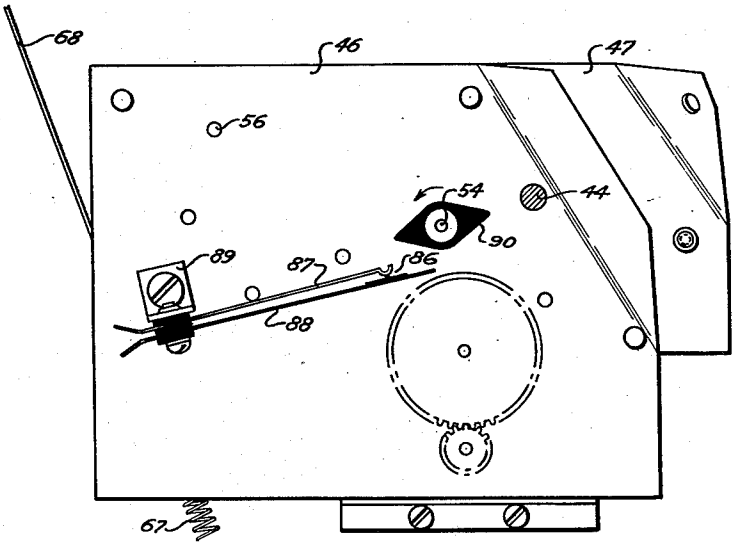


Fig. 6

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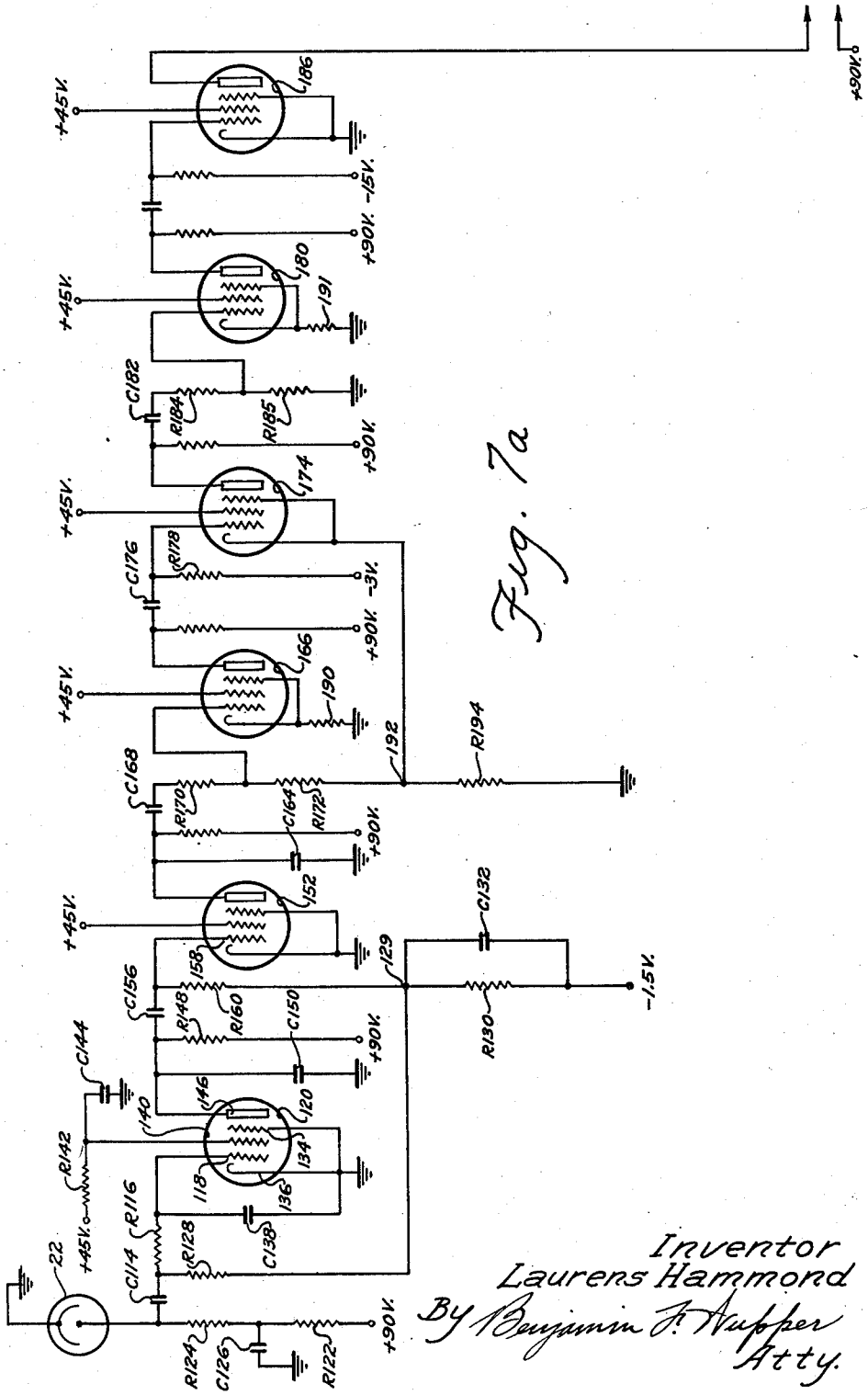


Fig. 7a

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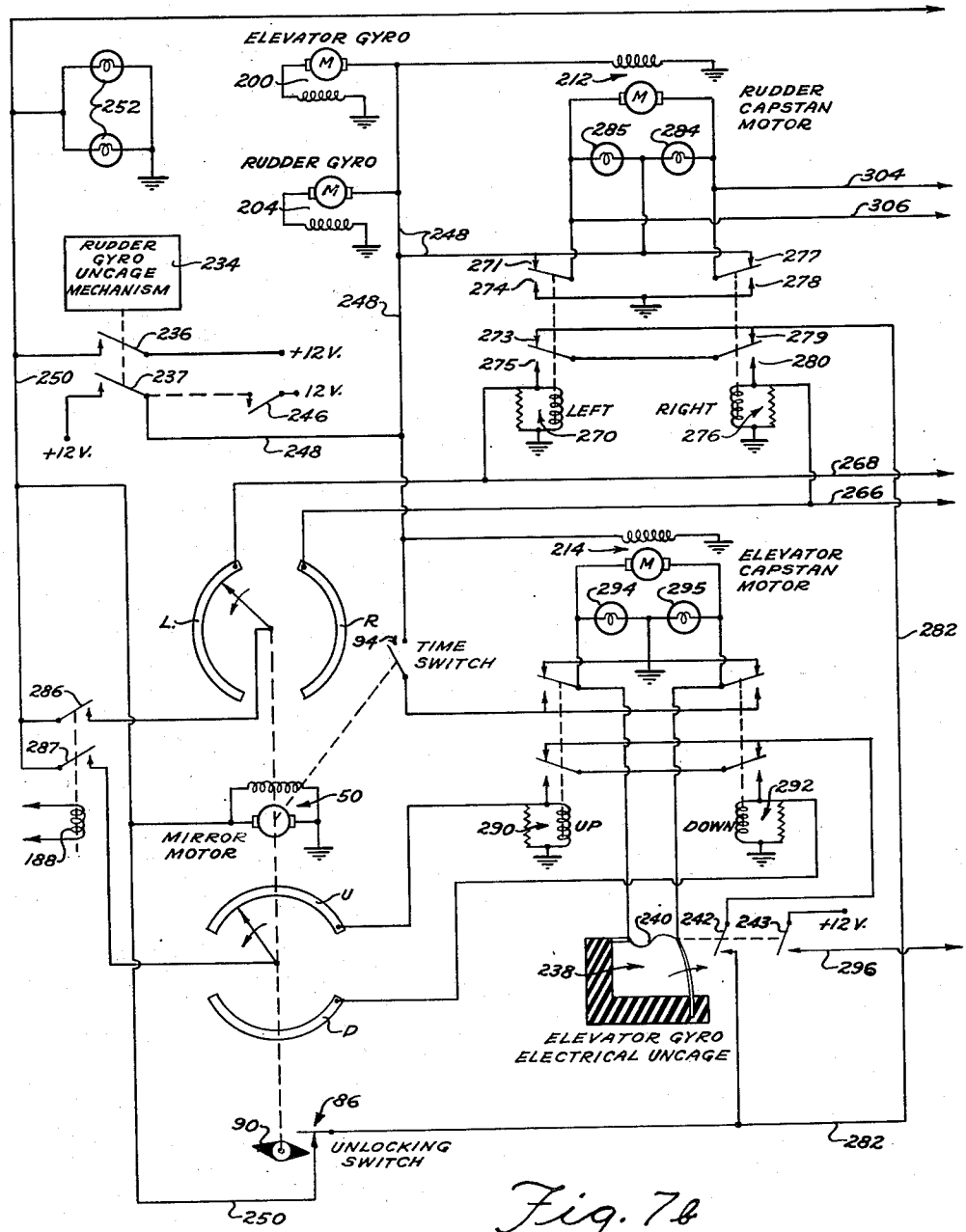


Fig. 7b

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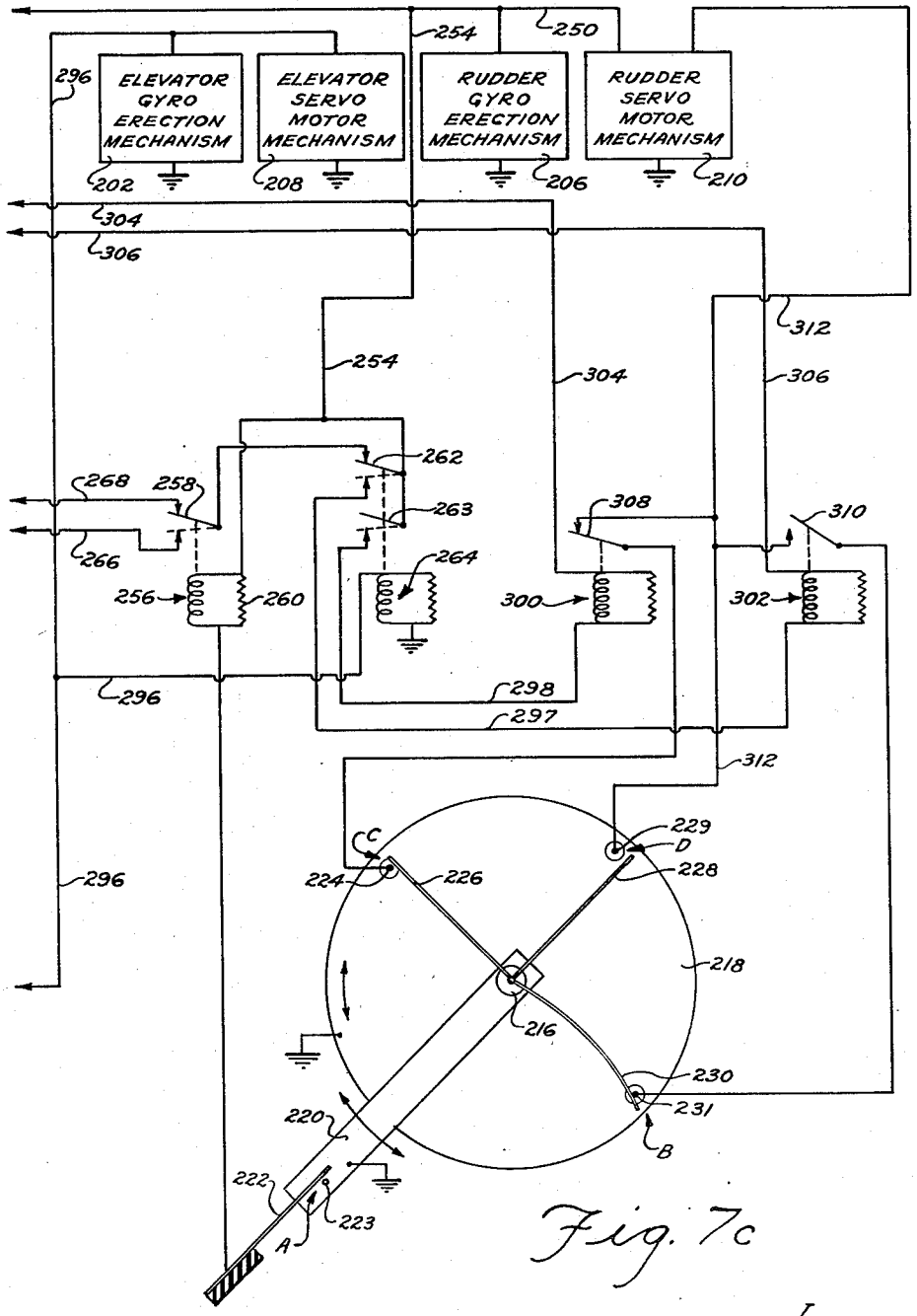


Fig. 7c

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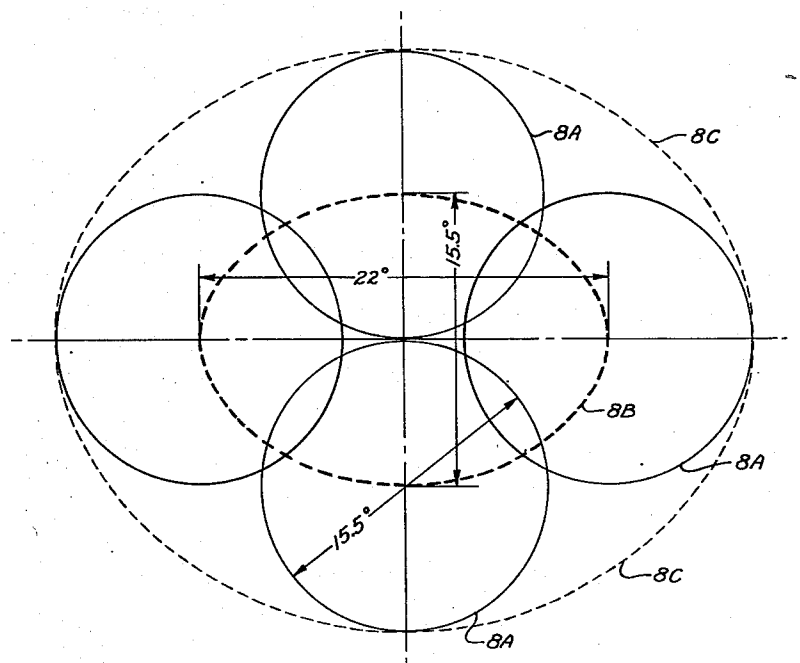


Fig. 8

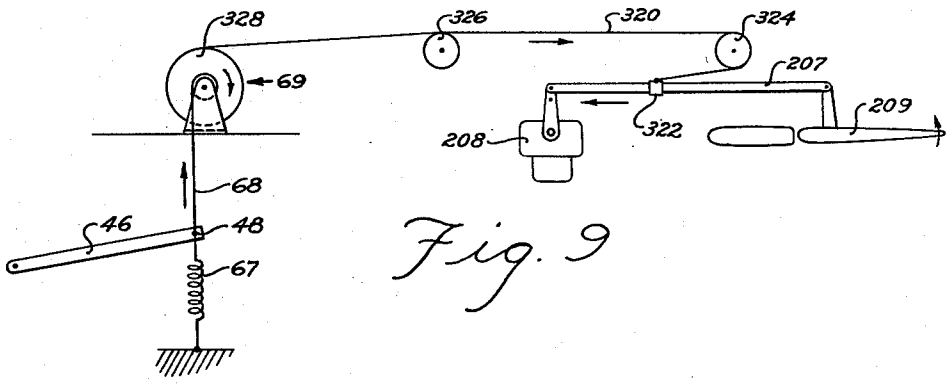


Fig. 9

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2,439,294

UNITED STATES PATENT OFFICE

2,439,294

STEERING CONTROL APPARATUS

Laurens Hammond, Chicago, Ill., assignor to Hammond Instrument Company, Chicago, Ill., a corporation of Delaware

Application November 27, 1943, Serial No. 511,917

22 Claims. (Cl. 244—77)

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My invention relates generally to steering control apparatus and more particularly to improvements in apparatus for automatically steering a vehicle toward a radiation source.

In various types of military equipment and apparatus it is desirable to have incorporated means for automatically steering the apparatus toward a target radiating (or reflecting) energy of intensity differing from that of the surrounding field, and it is the primary object of my invention to provide an improved equipment for this purpose.

A further object is to provide an improved optical scanning apparatus.

A further object is to provide an improved amplifying system.

A further object is to provide an improved gain control apparatus in an amplifying system so as to render the latter responsive to a wide range of amplitude in the input signal, while maintaining an output signal of relatively constant amplitude, and in which the changes in gain are effected at a rate slow with respect to the rate at which the amplifier normally receives independent signal impulses.

A further object is to provide an improved scanning mechanism equipped with a commutating mechanism for segregating signals received during the scanning of different portions of the field.

A further object is to provide an improved control means for automatically steering an airplane, glider, or other vehicle.

Other objects will appear from the following descriptions, reference being had to the accompanying drawings in which:

Figure 1 is a front elevational view of the mirror showing a portion of the optical system in vertical section;

Figure 2 is a plan view of the apparatus shown in Fig. 1 with portions of the mirror casing broken away to show its driving mechanism;

Figure 3 is a side elevational view of the mirror and its driving mechanism taken on the line 3—3 of Fig. 2;

Figure 4 is a bottom plan view of the mirror driving mechanism shown on an enlarged scale;

Figure 5 is a rear elevational view of the mirror driving assembly taken on the line 5—5 of Fig. 4;

Figure 6 is a vertical sectional view taken on the line 6—6 of Fig. 4, being substantially a view of the mirror driving mechanism with the mirror removed;

Figures 7*a*, 7*b* and 7*c* together constitute a wiring diagram of the apparatus, Fig. 7*a* showing principally the photocell and amplifier, while 7*b* and 7*c* show principally the control and steering apparatus;

Figure 8 is a diagram indicating the field of view scanned by the lookout; and

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Figure 9 is a schematic diagram showing the connection between the elevator and the lookout device for changing the inclination of the latter with changes in elevator position.

General Description

To facilitate an understanding of the detailed description which is to follow, it is preceded by this general description of a preferred embodiment of the invention.

The invention is disclosed as a means for automatically steering a pilotless glider toward a source of light, the light source being considered as representative of any other source of electromagnetic radiation, whether it be the source at which the radiation is generated or an object by which such radiation is reflected. The source of radiation will hereinafter be referred to as the target.

The glider carries a lookout device which is responsive to the radiation from the target and is adapted to control the positions of the aerodynamic control surfaces of the glider. The latter may consist of one or more rudders and an elevator, although in some instances the glider may also be provided with ailerons. In the latter case the ailerons may be suitably linked to the rudder controls.

The lookout device comprises a nutatory plane mirror set at an angle of approximately 45° with respect to the longitudinal axis of the glider. Light from the target striking the mirror is reflected to a condensing lens system and is concentrated upon the active element of a phototube.

The phototube is coupled to a multi-stage cascaded amplifier which includes a plurality of automatic gain control stages, whereby the gain of the amplifier is progressively reduced as the signal impulses increase in amplitude and vice versa. These reductions in gain have a time constant of substantial duration. Thus, in general, all except the highest amplitude impulse provided by the phototube during a single scanning cycle will be blocked by the amplifier.

This changing amplitude sensitivity of the amplifier is important for the following reason. When the glider is remote from the target, the amount of light energy received by the phototube is necessarily very small and, even though the target is a light source of considerable intensity, there may be relatively low intensity sources of light other than the target within the field of view scanned by the lookout. When the glider is remote from the target, these low intensity sources would not produce significant signals in the output of the phototube. However, as the glider approaches the target, the absolute amount of light received by the phototube from these low intensity sources might be greater than was received from the target when the glider was

remote therefrom, and therefore the light from these low intensity sources would provide significant signal impulses in the output of the phototube, and, if the gain of the amplifier were not reduced as the glider approached the target, signal impulses, as a result of scanning these low intensity light sources, as well as those resultant from scanning the target, would appear in the output of the amplifier and would obviously introduce an element of uncertainty.

Thus the provision of an amplifier, in which the gain is decreased in response to an increase in the amplitude of the input signal, assures that the amplifier will provide an output impulse only at the instant that the lookout device is scanning the target and will completely block input signal impulses of amplitude substantially less than those due to the target.

The glider is equipped with a gyropilot apparatus which comprises a rudder gyro maintaining fixed orientation in space and operating through a servomotor and follow-up mechanism to control the position of the rudder. This gyropilot apparatus operates not only to correct for course deviations due to the trim of the glider, but, in addition, this follow-up mechanism is arranged for the introduction of course changing factors under the control of the lookout so as automatically to steer the glider in azimuth toward the target.

The gyropilot apparatus also includes an elevator gyro which provides a horizontal reference axis for the means by which the elevator is controlled. This elevator gyro also has associated therewith control means responsive to signal impulses from the lookout device so as to steer the glider, in elevation, toward the target.

In the preferred form of the invention, there is provided means for changing the vertical angle between the optical axis of the lookout and the longitudinal axis of the glider in response to changes in the position of the elevator, and thus to make compensation for changes in lift, and hence in flight path, resultant from changes in the angle of attack as the elevator position is changed.

Lookout device

The lookout device as shown in Figs. 1 to 6 comprises a casing **20**, preferably of sheet metal, in which is suitably mounted a photoelectric tube **22**. The phototube **22** is secured to a conical shield **24** by means of a compressible elastic gasket **26** which is clamped against the central portion of the shield by screws **28**. The inner surface of the shield **24** has a dull black finish to prevent random light rays from reaching the phototube **22**. The condensing lens system comprises lenses **30**, **31** separated by an annular band **32**, the lenses being clamped to the forward wall **33** of the casing **20** by a plurality of screws **34** threaded into studs **36** which are riveted to the wall **33**. The wall **33** has a window opening **38** for admitting light to the lens system.

A mirror and mirror driving mechanism are mounted within a housing **40** which is suitably secured to the casing **20**. This mechanism comprises a flat circular mirror **42** which is secured to a hub **43** by a clamping screw **45**, the face of the hub **43** being at an angle of 84.5° with respect to the axis of a mirror shaft **44** to which it is secured. This lack of perpendicularity of the shaft **44** and the face of the mirror **42** is illustrated in an exaggerated manner in Fig. 4, it being understood that the extent to which the plane of the mirror departs from perpendicularity with the shaft **44** may be any suitable angle depending upon the included angle of the conical field of view desired. As the result of this mounting of the mirror, rotation of the shaft **44** will cause nutational motion of the mirror.

The shaft **44** lies in a substantially horizontal plane and at an angle of 45° with respect to the optical axis of the lenses **30**, **31**, and is mounted for rotation in a pair of frame plates **46**, **47** which are secured in spaced relation by a plurality of spacer studs **48**. An electric motor **50** is suitably mounted on the frame plate **47** and is adapted to drive the mirror through a speed reducing gear train which includes a gear **52** driven at a speed of approximately 2 R. P. S. and secured to the mirror shaft **44**. The gear train driven by the motor **50** also includes rotating shafts **54**, **56**, the shaft **54** being driven at approximately .5 R. P. S. while the shaft **56** may be driven at a speed of approximately .12 R. P. M. The frame plates **46**, **47** are provided with sidewardly bent ears **60** and **61** respectively which are perforated to receive a pintle **62**, the latter being secured in ears **64**, **65** which are formed on a mounting strip **66** secured to the mirror housing **40**. The frame plates **46**, **47** are thus mounted for pivotal movement about the axis of the pintle **62**.

As best shown in Fig. 3 and as diagrammatically shown in Fig. 9, a spring **67** has one end anchored to the housing **40** and its other end secured to the stud **48**. A flexible stranded wire **68** has one end secured to the stud **48** and its other end attached to the smaller drum of a stepped pully **69** suitably mounted on the housing **40**. The pulley **69** is rotated by means of a connection to the elevator as will be hereinafter described.

The mirror supporting frame carries a number of switches which are operated at different speeds by the mirror driving gear train. Secured to the mirror drive shaft **44** are a pair of cams **70** and **71** which are circular in shape and mounted eccentrically on the shaft **44** in 90 degree phase relation. These cams **70**, **71** operate resilient switch arms **72**, **74** and **73**, **75** respectively. Switch arms **72** to **75** cooperate respectively with fixed contact members **76**, **77**, **78** and **79** respectively. For convenience of reference hereinafter, these switches are termed phase switches and are conventionally illustrated in Fig. 7*b*. The switch formed by the contacts **72**, **76** will hereinafter be referred to as the R-switch, that formed by the contacts **73**, **77** the U-switch, contacts **74**, **78** the L-switch, and contacts **75**, **79** the D-switch, the letters representing the control effected upon closure of the switches, namely, right, up, left and down. The contacts for these switches are suitably secured in insulated relation upon a phase switch plate **82** attached to the rear frame plate **47**.

The arrangement of the cams, and of the switches operated thereby, is such that the switches L and R operate in 180° phase relation and will each be closed during 145° of rotation of the shaft **44**, while the switches U and D are likewise operated in 180° phase relation and will each be closed during 130° of rotation of this shaft.

An unlock switch **86**, comprising a pair of switch arms **87** and **88**, is suitably secured by an angle bracket **89** to the frame plate **46**, the switch arm **88** being adapted to be engaged by a diamond-shaped cam **90** of insulating material fixed to the shaft **54**. Since the shaft **54** rotates at

.5 R. P. S. the switch 86 is momentarily opened by the cam 90 once per second.

A time switch 94, comprising switch arms 95 and 96 which are suitably secured to the rear frame plate 47 by a bracket 98, is adapted to be operated by a pin 100 partially enclosed in an insulating sleeve 102 and projecting outwardly from an arm 104. The arm 104, as best shown in Fig. 4 is frictionally connected to the shaft 56, being pressed by a spring washer 108 against a disc 106 fixed to the shaft 56. The washer 108 is held in place by a collar 110 secured to the shaft 56. The angular position of the arm 104 may be initially adjusted manually so that the insulated pin 100 thereof will contact the switch arm 96 and close the switch 94 a predetermined time interval after the motor 50 has commenced operation.

For the sake of clarity the wires connecting the various switches and the wires to the motor are not illustrated in Figs. 1 to 6 but it will be understood that the necessary flexible connecting wires are provided and are secured to suitable soldering lugs on a terminal strip 112 mounted on the mirror housing 40.

Photoelectric and amplifying system

As shown diagrammatically in Fig. 7*a* the phototube 22 (which may be of the Cetron CE–22 type) has its cathode connected to ground and its anode connected through a blocking condenser C114 and resistor R116 to the grid 118 of a preamplifier pentode 120. In order to have the connections between the grid 118 and the anode of the phototube 22 physically short, the tube 120 is preferably mounted within the casing 20. The casing 20 may also contain the remaining tubes of the amplifier. The operating potential for the phototube 22 is supplied from a suitable source, indicated as a terminal +90 v., through a filter network comprising resistors R122 and R124, and condenser C126.

Grid bias is supplied to the grid 118 from a suitable potential source indicated as −1.5 v. through a resistor R128, a junction terminal 129, and a resistor R130, the latter resistor being shunted by a condenser C132. The suppressor grid 134 and cathode 136 of the preamplifier pentode 120 are connected to ground and a condenser C138 is connected between the grid 118 and ground, this condenser, together with the resistor R116, operating in a manner to suppress radio frequency interference. The screen grid 140 is connected to a suitable source of direct current potential, indicated as +45 v., through a filter network comprising a resistor R142 and a condenser C144. The plate 146 of the pentode 120 is connected to a source of plate potential indicated as +90 v. through a load resistor R148, and is connected to ground through a filter condenser C150 having a value such that it acts to suppress high frequencies which may be introduced by microphonic effects in the pentode 120.

The output of the pentode 120 is coupled to the input of a pentode 152 which forms part of the first of two stages of automatic gain control, this coupling being through a blocking condenser C156 connecting the plate 146 with the grid 158 of the pentode 152. The cathode and suppressor grid of the pentode 152 are connected to ground while the screen grid is connected to a suitable operating potential indicated as +45 v. The grid 158 is connected to the bias potential junction point 129 through grid leak resistor R160. The time constant of the mesh comprising the condenser C156 and grid leak resistor R160 may be in the order of .6 second. The pentode 152 and its associated circuit elements form the first stage of automatic gain control, the operation of which will be described in greater detail hereinafter. The resistors R160 and R128 and the network R130, C132 form an inverse feed back circuit for stabilizing the operation of the preamplifier pentode 120.

The output of the pentode 152 is provided with a filter condenser C164, which has a function corresponding to that of the condenser C150, and is coupled to the input of a phase inverting and amplifying pentode 166 through a blocking condenser C168 and a voltage dividing network comprising resistors R170 and R172. A second automatic gain control stage includes a pentode 174 suitably coupled to the output of the pentode 166 by means of a blocking condenser C176 and resistor R178, the latter being connected to a bias potential source indicated as −3 v. The latter condenser and resistor form a mesh having a time constant in the order of .6 second and have a function corresponding to that of the mesh comprising the condenser C156 and resistor R160 connected to the grid 158. The output of the pentode 174 is coupled to a second phase inverting and amplifying pentode 180 through blocking condenser C182 and a voltage divider network consisting of resistors R184 and R185. The output of the pentode 180 is suitably coupled to the input of a power amplifier pentode 186, in the plate circuit of which there is a winding of a relay 188 (Fig. 7*b*).

The electrodes of the pentodes 166, 174, 180 and 186 are connected in a conventional manner to suitable fixed direct current potential sources, the pentodes 166 and 180 being provided with self-bias cathode resistors 190 and 191 and the cathode of pentode 174 being connected to a junction point 192 which is connected to ground through a resistor R194. A negative feed back circuit is thus provided between the cathode circuit of pentode 174 and the grid circuit of pentode 166 for the purpose of stabilizing the operation of the pentode 166.

The constants of the circuit elements of the amplifying and automatic gain control system shown in Fig. 7*a* may, in general, be conventional and may vary considerably without materially affecting the operation. The following values have been found to be satisfactory and may be considered as illustrative, it being understood that the invention is not limited to these particular constants.

R116—4 megohms	R191—7,500 ohms
R122—10 megohms	R194—200 ohms
R124—50 megohms	C114—.02 mfd.
R128—50 megohms	C126—.2 mfd.
R130—2 megohms	C132—.15 mfd.
R148—50,000 ohms	C138—.002 mfd.
R160—4 megohms	C144—.3 mfd.
R170—1 megohm	C150—.3 mfd.
R172—120,000 ohms	C156—.15 mfd.
R178—4 megohms	C164—.3 mfd.
R184—1 megohm	C168—.3 mfd.
R185—60,000 ohms	C176—.15 mfd.
R190—4,000 ohms	C182—.3 mfd.

The tube types usable in this amplifier are: 120 and 152—6J7; 166, 174 and 180—6SJ7; 186—6K6GT.

For convenience the principles of operation of the amplifier of Fig. 7*a* will be described at this

point. When the mirror 142 scans a field containing an area from which the intensity of light radiation is greater than that of the remainder of the field scanned, the phototube 22 will, upon each revolution of the mirror, produce a signal impulse which is amplified by the preamplifier pentode 120. It will be understood that the absolute amplitude of this signal may in actual practice vary throughout an extremely wide range, depending upon the nature of the source of radiation and the distance of the apparatus from the source. The amplifier is designed to discriminate against all but the highest amplitude signal generated in the phototube 22 during each revolution of the mirror. This is because in the customary use of the apparatus it is desirable that in the final output of the amplifier only such signals generated by the phototube 22 shall appear as correspond to those produced as the mirror scans the brightest source of light within the field. Since this brightest source may produce a very low amplitude signal when the apparatus is very distant from the source as compared with the signal when the apparatus is close to the source, and since a second and less bright source of radiation within the field may, when the apparatus is close to the source, produce a signal of absolute amplitude much greater than that produced by the highest intensity source when the apparatus is at a great distance therefrom, it is essential to decrease the overall gain of the amplifier progressively as the signal strength increases. The two stages of automatic gain control comprising the pentodes 152 and 174 and associated circuit elements are for the purpose of progressively decreasing the overall gain of the amplifier as the maximum amplitude signal during each revolution of the mirror increases in amplitude.

A positive signal of suitable amplitude appearing on the grid 158 will cause grid current to flow in the pentode 152 at the expense of the charge on condenser C156, the resistance of the grid leak R160 being too great to allow sufficient current to flow from the bias junction point 129. A negative potential will therefore appear on the grid 158, its value depending upon the amplitude of the signal.

Since the time constant of the mesh comprising condenser C156 and resistor R160 is in the order of .6 second and in the usual operation of the apparatus the signal impulses due to scanning the brightest light source in the scanned field will be of a frequency of 2 C. P. S., the grid bias will not decrease to its 1.5 volt value between impulses but will be "pumped up" (in a manner analogous to pumping air into a very leaky tire) by the successive signal impulses so that the bias will increase as the amplitude of the signal impulses increases. Any failure of the target light source will permit the bias to decrease until the amplifier becomes responsive to the light source next in brightness, but assuming that the target light source remains the brightest in the field of view of the lookout the amplifier will automatically maintain the grid bias on the automatic gain control pentodes 152 and 174 so that only the signal impulses resultant from scanning the target will not be blocked. Since the two automatic gain control pentodes are coupled in cascade, the range of gain control effected thereby is geometrically increased.

The signal in the output of the automatic gain control pentode 152 is not of the correct phase directly to drive the second stage of automatic gain control, and the phase inverting and amplifying pentode 166 is therefore used as a coupling between the gain control stages. Likewise the output of the second automatic gain control pentode 174 must be reversed in phase by pentode 180 to operate the power amplifying pentode 186 in order that the relay 188 may be energized at the instant that a light source is being scanned by the lookout. Since the additional gain provided by the phase inverter pentodes 166 and 180 is greater than required for the reliable operation of the relay 188, the overall gain of the amplifier is reduced by means of the voltage dividers provided by the resistors R170, R172 and R184, R185.

The amplifier is similar to that disclosed and claimed in my copending application, Serial No. 511,916, filed November 27, 1943.

From the foregoing it will be clear that the relay 188 will be energized at least once during each revolution of the mirror 142, at the particular instant that the mirror is scanning an area from which the light radiation is greater than that from any other corresponding area within the field, providing there is an area within the field of view from which the radiation differs sufficiently in intensity from that of the field to exceed the sensitivity threshold of the apparatus as a whole.

Steering control apparatus and circuits

The invention is illustrated as applied to control the steering of a pilotless glider. This glider will be provided with the usual aerodynamic control surfaces such as the rudder and elevator and will have two gyros for stabilizing flight. These gyro mechanisms may be of the type disclosed in my copending applications, Serial Nos. 463,642, which has matured into Patent No. 2,408,929, and 463,643, filed on October 28, 1942.

The elevator gyro is herein shown as a gyro motor 200 (Fig. 7b) which has an elevator gyro erection mechanism 202 (Fig. 7c) and maintains an elevational reference axis, and a rudder gyro motor 204 which, together with its erecting mechanism 206 and associated parts, maintains an azimuthal reference axis. The elevator gyro is arranged, in the manner disclosed in my aforesaid applications, to control an elevator servomotor mechanism 208 (Figs. 7c and 9) which is connected by a link 207 to the elevator 209 of the glider. Similarly the rudder gyro controls the operation of a rudder servomotor mechanism 210 which is mechanically linked to the rudder of the glider.

There is provided a rudder capstan motor 212 (Fig. 7b) which, in a manner similar to that described in my aforesaid application, Serial No. 463,642, and conjointly with the rudder gyro mechanism, controls the rudder servo mechanism 210. Similarly an elevator capstan motor 214 in part controls the operation of the elevator servo mechanism 208.

In Fig. 7c there is illustrated a plan view of a portion of the rudder gyro mechanism comprising a vertical gimbal shaft 216 which, through the operation of the gyro, maintains a fixed orientation in space.

Pivotally mounted with reference to the shaft 216 is a follow-up pulley 218. An arm 220, secured to the gimbal shaft 216 and thereby grounded, carries a contact pin 223 which cooperates with a spring contact 222 to form a switch A. A contact pin 224 carried by the follow-up pulley 218, but suitably insulated there-

from, cooperates with a grounded contact arm 226 fixed to the gimbal shaft 216, these contacts providing a switch C. Similarly contact arms 228 and 230 fixed to the shaft 216 and cooperable respectively with insulated contact pins 229 and 231 carried by the pulley 218 form switches D and B. The contact members forming the switches B, C and D are in such angular relation that upon clockwise rotation of the pulley 218 with respect to the gimbal shaft 216, the switches will close in the order: B, C, D, at 6° intervals. Upon counter-clockwise rotation of the pulley 218 with respect to the gimbal shaft 216 the switches will open in the order: D, C, B, at 6° intervals. In Fig. 7c the follow-up pulley 218 is shown in an intermediate position at which the switch D is fully opened, the switch C is about to open, and additional clockwise movement of the pulley 218 of approximately 6° is required before switch B will open. The switch arm 222 is illustrated as being fixed to the case or frame of the gyro apparatus and the switch A therefore closes whenever the glider is directed to the left of a predetermined course and is opened whenever the glider is directed to the right of such predetermined course as disclosed in greater detail in my aforesaid application Serial No. 463,642. The functions of the switches A, B, C and D will be described in greater detail hereinafter.

A rudder gyro uncage mechanism 234 (Fig. 7b) is adapted to be operated upon starting the glider upon its free flight course. This mechanism may consist of any means suited to the particular installation and is adapted to close switches 236 and 237 at the time that such release takes place. As will hereinafter appear, an elevator gyro electrical uncage mechanism 238 is operated upon the melting of a fuse wire 240 to uncage the elevator gyro and also to close switches 242 and 243.

Prior to release of the glider for free flight, and to condition it for operation, a switch 246 (Fig. 7b) is closed. This switch connects a conductor 248 to the ungrounded terminal of a source of power such as a storage battery on the airplane carrying the glider. The supply of current to the conductor 248 energizes the elevator and rudder gyro motors 200 and 204 and also, for purposes of convenience, the fields of the rudder and elevator capstan motors 212, 214.

When the glider is released from the supporting airplane the rudder gyro uncage mechanism 234 operates to uncage the rudder gyro and thus establish as a reference orientation, the direction of flight at the instant of release, and also to close switches 236 and 237. In addition, the connection of the conductor 248 with the switch 246 is broken at the instant of release. The closure of the switch 237 connects the conductor 248 to the +12 v. terminal of a source of current, such as a storage battery, carried by the glider.

Closure of the switch 236 connects a conductor 250 to the +12 v. terminal of a glider-carried battery and thus energizes the rudder gyro erecting mechanism 206 (Fig. 7c) and the rudder servo mechanism 210. The conductor 250 also supplies current to a pair of incandescent lamps 252 (Fig. 7b), which may be positioned on the glider so as to be visible from the airplane and from the ground when the apparatus is being used in practice maneuvers. Current is also supplied through the conductor 250 to the mirror driving motor 50 which, as previously described, also operates the L, R, U and D switches as well as the unlocking switch 86 and time switch 94.

The previously mentioned switch A (Fig. 7c) is for the purpose of making correction for irregularities in the trim of the glider, which irregularities would otherwise tend to cause the glider to veer to the left or right of the course on which it is launched. When the rudder gyro uncage mechanism 234 operates to close the switch 236, a circuit is completed from the conductor 250 through a conductor 254 (Fig. 7c) through the winding of a relay 256 to the fixed flexible contact arm 222 of the switch A.

At the instant the glider is launched the switch A may be either closed or opened, but, if closed, is upon the verge of opening upon the slightest veering of the glider to the right of the initial course, and, if open, is on the verge of being closed upon the slightest veering of the glider to the left of its initial course. When the switch A is closed, the circuit through the winding of relay 256 is completed, energizing the latter to move its switch 258 from its full line to its dotted line position. (To prevent excessive sparking at the contacts by which the circuits through various relay windings are completed, it is preferable to provide an anti-spark resistor 260 in parallel with each of the windings.) When the switch 258 is in its dotted line position, the circuit from the conductor 254 through normally closed switch 262 of a relay 264 is completed to supply the +12 v. operating potential to a conductor 266. When the switch A opens, relay 256 is deenergized and the switch 258 is resiliently returned to its full line position, thereby supplying the +12 v. operating potential to a conductor 268.

Thus conductors 266, 268 are alternately connected to the +12 v. source upon closing and opening of the switch A. The conductor 268 is connected to the winding of a "left" relay 270 while the conductor 266 is connected to a winding of a "right" relay 276, the other terminal of each of these relay windings being connected to ground. The relay 270 upon energization opens switches 271 and 273 and closes switches 274 and 275. Similarly the relay 276 upon energization opens switches 277 and 279 and closes switches 278 and 280. By virtue of the double throw construction of the switch 258 the relays 270 and 276 will not be simultaneously energized.

Assuming that the relay 270 is energized, the switch 274 will be closed to connect one terminal of the armature of motor 212 to ground, while the switch 277 will remain closed thereby connecting the other terminal of the motor armature to the conductor 248 which is at the +12 v. operating potential. At the same time, closure of the switch 275 results in the establishing of the holding circuit for the relay 270, this circuit being traced as follows: from ground, through the winding of relay 270, switch 275, switch 279, conductor 282, normally closed unlocking switch 86, conductor 250, and switch 236 to the +12 v. terminal of the battery. The capstan motor 212 will thereby be energized to operate in a direction to cause the glider steering apparatus to make compensation for lack of trim, in the manner more fully disclosed in my aforesaid application, Serial No. 463,642. Similarly, upon energization of the relay 276, the rudder capstan motor 212 will be energized to cause it to rotate in the opposite direction. Such energization of the relay 276, by opening the switch 279, breaks the holding circuit for the previously energized relay 270 and, by closure of the switch 280, establishes a locking circuit for relay 276.

For practice maneuvers it may be convenient to provide signal lamps 284, 285 which, it will be clear from the diagram, are alternately energized and thus are capable of indicating the direction in which the capstan motor 212 is operating. The mechanical arrangement of the capstan motor and mechanism operated thereby is such that, when the relay 270 is energized, it will cause steering of the glider toward the left, and, when the relay 276 is energized, it will cause steering of the glider to the right. Such steering under the control of one of these relays normally continues until the other relay is energized, because of the locking circuits of these relays, and thus the signal lights 284, 285, will, by their illumination, indicate in which direction the glider is being steered.

When the optical and electrical system of the apparatus detects a light source and thus causes energization of the relay 188, switches 286 and 287 are closed to connect one of the contacts of each of the phase switches L, R, U and D to the 12 v. conductor 250. If the signal energizing the relay 188 occurs while the mirror 42 is scanning the left hand portion of the field, that is while the switch L is closed, the relay 270 will be energized, with the result that the glider will be steered toward the left, while if the relay 188 is energized while the switch R is closed, the relay 276 will be energized to cause the glider to be steered toward the right. Similarly, reception of an appropriate light signal when the switch U is closed will cause energization of an "up" relay 290, while if such signal is received when the switch D is closed a "down" relay 292 will be energized. The relays 290 and 292 operate switches similar to those operated by the relays 270 and 276 to control the direction of rotation of the armature of the elevator capstan motor 214. It will be noted, however, that the operating potential for this motor is supplied through the time switch 94 and that the operating potential for the locking circuit for these relays is supplied through the switch 242. Thus upon the reception of a significant signal while the U-switch is closed (assuming the time switch 94 is closed) the glider will be steered upwardly, and, similarly, if the signal is received while the D-switch is closed, the glider will be steered downwardly. Since it is undesirable to have the glider commence steering upwardly until it is well away from the launching airplane, the time switch will be set so as to remain open for a short length of time, to enable the glider to assume a stabilized course and to prevent possible erratic flight which might cause collision with the airplane For practice purposes, signal lamps 294, 295 may be connected in the energizing circuit for the motor 214 to provide an indication of the up or down steering of the glider.

Upon the first time that either of the relays 290 or 292 is energized after the time switch 94 is closed, a circuit through the fuse wire 240 will be completed, whereupon through resilient means, the elevator gyro electrical uncage mechanism 238 will be operated, and also the switches 242 and 243 will be closed. The closure of the switch 242 supplies a locking potential for the locking circuits of relays 290 and 292 while the closure of switch 242 provides an operating potential for the elevator gyro erection mechanism 202 (Fig. 7c) and servo mechanism 208, through a conductor 296. The elevator steering apparatus of the glider will thus be rendered fully operative.

Closure of the switch 243, upon melting of the fuse wire 240, also results in supplying of 12 volt energizing potential which energizes relay 264 through the conductor 296, causing the switches 262 and 263 thereof to move from full line to dotted line positions. Such operation of the switch 262 breaks the circuit to the movable pole of switch 258 and thus renders ineffective the trim correcting mechanism which is under the control of the switch A. Moving the switches 262, 263 to their dotted line positions connects the 12 volt conductor 254 to conductors 297 and 298 respectively, thus conditioning relays 300 and 302 for energization. Relay 300 is energized upon completion of a circuit through a conductor 304 to ground whenever the relay 276 is energized. Similarly, the circuit through the relay 302 is completed through a conductor 306 to ground whenever the relay 270 is energized. The energization of the relay 300 opens a normally closed switch 308 while energization of the relay 302 closes a switch 310.

A conductor 312 is connected to a relay forming a part of the rudder servomotor mechanism 210 and wired in such way as to reverse the rudder servomotor when the conductor 312 is grounded. In the normal position of the follow-up pulley 218 shown in Fig. 7c a circuit is completed from conductor 312 through relay switch 308 to the insulated pin 224 of switch C and through the switch arm 226 to ground. At this time the rudder servo relay will be energized and the rudder servomotor will operate in such direction as to turn the pulley 218 in a counter-clockwise direction. Upon opening of the switch C produced by this counter-clockwise rotation of pulley 218, the rudder servo relay will be released and the direction of rotation of the rudder servomotor will be reversed. The pulley 218 will now turn in a clockwise direction, closing switch C and completing a cycle of oscillation of the rudder servo mechanism.

When the lookout device receives a significant signal, for example, while the R switch is closed, the right relay 276 will be energized and thus through closure of switch 278 connect conductor 304 to ground. The grounding of this conductor will result in energization of relay 300, thereby opening switch 308 which, it will be recalled, is in series with switch C. Thus the rudder servo relay will be released and the pulley 218 will turn in a clockwise direction until the rudder servo relay circuit is completed to ground through switch D, the insulated pin 229 being connected directly to conductor 312. Thereafter, as long as relay 300 remains energized, oscillation of the rudder servo motor mechanism will continue under the control of switch D.

It will be understood that the follow-up pulley 218 moves clockwise when the rudder servomotor mechanism swings the rudder counter-clockwise and vice versa. Therefore, a 6° clockwise motion of the pulley 218 results in a motion of the rudder in such direction as to tend to turn the glider to the right.

If, on the other hand, a signal from the lookout device is received through the L-switch and operates left relay 270, conductor 306 will be connected to ground through switch 274, and relay 302 will be energized. The resultant closure of switch 310 will complete a circuit from the conductor 312 to insulated pin 231 of switch B and through switch arm 230 to ground. The rudder servomotor relay will now remain energized until the pulley 218 has moved counter-clockwise to a position at which switch B opens. Thereafter,

as long as relay 302 remains energized, oscillation of the rudder servomotor mechanism will be under the control of switch B. Thus a 6° counter-clockwise shift of pulley 218 resulting from the energization of relay 302 will cause the rudder of the glider to be turned in such a direction as to turn the glider to the left.

It will be understood that a "left" signal, energizing relay 270, will produce a slow leftward turning of the glider due to operation of the rudder capstan motor 212 in one direction, while a "right" signal, energizing the right relay 276 will cause the glider to turn gradually to the right due to the operation of the rudder capstan motor 212 in the opposite direction. The sudden shift of the rudder to right or left produced by shifting the rudder servo relay control from switch C to switch B, or from switch C to switch D, as described above, provides a means for securing more rapid response of the glider to right or left signals received from the lookout mechanism.

Referring to Fig. 9, it will be noted that the rudder operating link 207 has one end of a control wire 320 secured thereto by a clamp 322. The wire 320 passes around a direction reversing pulley 324 and a guide pulley 326 and has its other end secured to the large diameter drum 328 of the stepped pulley 69. By virtue of this connection the lookout mirror supporting frame is tilted up and down as the elevator 209 is swung up and down by the servomotor 208, the angular displacement of the lookout mirror frame being proportional to, but less than, the displacement of elevator by a ratio in the order of 1:2 or 1:3. By virtue of this operating connection compensation is made for the effect upon the flight path (the path of the center of gravity of the glider) of changes in lift resultant from changes in attitude as the elevator is displaced.

Operation

The diagram of Fig. 8 shows the area scanned by the lookout device in a plane normal to the axis of the generally conical beam of light which may activate the phototube 22. In this diagram the circles 8A represent instantaneous areas scanned. These circles have a diameter of approximately 15.5° and have their centers along a curve 8B which is shown as an ellipse, although in a mathematical sense it is not an ellipse but a curve in which successive points from right to left are on ellipses of progressively decreasing major axes.

However, for practical purposes, the curve 8B may be considered to be an ellipse, which in the particular apparatus disclosed, has a major axis of 22° and minor axis of 15.5°. Since the areas of the circles 8A, representing the instantaneous fields of view of the lookout, are 15.5° in diameter, the total field scanned, bounded by the curve 8C, is substantially an ellipse having a major axis of 37.5° and a minor axis of 31°. The actual area of a horizontal plane which is scanned will be substantially an ellipse with its major axis along the direction of the projection of the flight path and of length differing from that of the minor axis by a factor depending upon the angle of inclination of the optical axis of the lookout.

It will be recalled that the cams 70, 71 (Fig. 5) operate to close the R and L switches at 180° intervals and that these switches remain closed throughout 145° of angular displacement of the mirror. Similarly the U and D-switches close alternately in 180° phase relation and remain

closed during 130° of rotation of the mirror shaft. From these facts it might be assumed that significant signals from the phototube would be effective to energize the relays 270, 276, 290 and 292 only while the mirror is scanning corresponding sectors of total scanned elliptical area. This is not the case, however, because of the angular width of the instantaneous areas scanned (15.5°), and because of some lag in the opening of the relay 188, and possibly to delayed operation in other parts of the apparatus. It has been found that, if the target lies substantially anywhere in the scanned area to the right of the vertical center line, the right relay 276 will be energized and, if in the area to the left thereof, the left relay 270 will be energized. Similarly, the appearance of the target above or below the horizontal center line of the scanned area will result in the energization of relay 290 or relay 292 respectively. Thus, nearly invariably, the sighting of the target by the lookout device will result in the energization of two of the relays, one of each of the pairs, 270, 276 and 290, 292.

In tactical use of the apparatus the glider is secured to the airplane by suitable bomb release mechanism and upon sighting a suitable target the switch 246 (Fig. 7b) will be closed, thereby energizing the elevator and rudder gyro motors. When the airplane has then maneuvered to a suitable elevation and distance relative to the target, and the airplane is in steady flight toward the target, the glider is released.

At the instant of release the rudder gyro uncage mechanism 234 (which may be any simple type of spring-operated mechanism which is freed upon the release of the glider) operates to close switches 236 and 237. Closure of the switch 236 supplies energizing current to the rudder gyro erection mechanism 206 and to the rudder servomotor mechanism 210. The rudder gyro is therefore maintained erected and furnishes a reference axis in azimuth by maintaining its vertical gimbal shaft 216 oriented in space. Since the arm 220 is fixed to the shaft 216 and since the switch contact arm 222 of the switch A is fixed relative to the glider, deviation of the glider to the left of the gyro-determined course will cause switch A to close and thereby complete the circuit through relay 256 and cause switch 258 to move to dotted line position and thereby energize the right relay 276. As previously described, the relay 276 energizes rudder capstan motor 212 to rotate in a direction to cause steering of the glider to the right. When the glider is steered to the right sufficiently, the switch A will open, deenergizing relay 256 and permitting switch 258 to move to its full line position and thus to energize relay 270 and break the holding circuit for relay 276. This will cause reversal of the direction of rotation of the rudder capstan motor 212, and cause the rudder of the glider to swing toward the left (counter-clockwise). During this initial period of flight of the glider the mirror motor 50 is energized but the time switch 94 is open, so that energization of the elevator capstan motor 214 could not take place.

If a signal impulse occurs, due to the sighting of a target by the lookout device, the relay 188 would of course be energized and close the switches 286, 287 for an instant, but even if either the L or R-switch were closed at such instant it would not have any appreciable effect because the control effected by the relay switch 258 is dominant over that effected by the closure of the switch 286.

This initial period of wholly gyro-controlled flight will be of sufficient duration to assure that there will be no danger of collision of the glider with the airplane from which it was released and will usually be terminated shortly after the closure of the time switch 94.

The glider will continue on its initial course, even after the time switch 94 is closed, until a signal impulse energizes the relay 188 at a time when either the U or the D switch is closed. When this occurs the fuse wire 240 is placed in circuit and melts, closing switches 242 and 243 and uncaging the elevator gyro. Thereafter the steering and control apparatus of the glider is in fully operative condition. This is because the closure of the switch 243 results in energization of the elevator gyro erection mechanism 202 and the elevator servomotor mechanism 208, and also the energization of the relay 264. Energization of the relay 264 through the shifting of the switch 262 cuts off the supply of current to the switch 258 so that the operation of the relay 256 under the control of switch A no longer has any effect. Energization of the relay 264 also, through closure of switches 262 and 263, connects one terminal of each of the windings of relays 300 and 302 to the +12 v. source, so that these relays may be energized when their other terminals are connected to ground.

Let us assume that immediately after the fuse wire 240 has been melted, the lookout device "sees" a target in the upper right or first quadrant of the field 80 (Fig. 8). The relay 188 will thus be energized while both the R and U-switches are closed, and will therefore energize both the right relay 276 and the up relay 290. Energization of the relay 276 will result in energizing the rudder capstan motor 212 in a direction to cause turning of the plane to the right. Such turning, effected by the capstan motor, is at a relatively slow rate. To effect a more rapid rate of turn the energization of the relay 276 also connects conductor 304 to ground (through closure of the switch 278) and thereby completes the circuit to energize relay 300, opening the switch 308. Opening the switch 308 renders the switch C ineffective to control the rudder servo mechanism 210. Instead, this control is now effected by the operation of the switch D. When the switch D is open the rudder servomotor mechanism 210 operates in a direction to steer the glider to the right, and when this switch is closed this mechanism operates to steer the glider to the left. Thus, under the assumed conditions, the glider will be steered to the right at a relatively rapid rate due to the operation of the rudder servomotor mechanism, and will also be steered to the right because the rudder capstan motor will also be operating to rotate the follow-up pulley 218, but the effect of the latter will be small relative to the effect of the former.

Under the conditions last assumed, the relay 290 was energized with the relay 276. The relay 290 will result in energization of the elevator capstan motor 214 in a direction to raise the elevator and thereby decrease the angle of glide. As a result of the energization of both of the relays 276 and 290, the glider's course will be changed upward and toward the right and it will therefore become headed more nearly in the direction of the target.

Unlocking switch 86 is opened once per second so that the conditions described above do not prevail for a long period of time, for immediately upon unlocking of the relay 276 (under the assumed conditions) the relay 300 will be deenergized and control of the rudder servomotor mechanism 210 will revert to the switch C.

Carrying forward the assumed conditions let it be supposed that the changing of the course of the glider upward and to the right, as above described, results in heading the glider so far upward and to the right that the target appears in the lower left hand quadrant. Under these circumstances, the D and L-switches will be closed when a signal impulse due to scanning the target energizes the relay 188, and therefore the down relay 292 and the left relay 270 will be closed. This will result in energizing the elevator capstan motor 214 in a direction to lower the elevator and increasing the angle of glide, and also in energizing the rudder capstan motor 212 for rotation in a direction such as to cause slow leftward steering of the glider. In addition, by closure of the switch 274, the circuit through relay 302 will be completed. Closure of the switch 310 of this relay results in passing the rapid steering control of the glider to the switch B. When, under these circumstances, the switch B is closed, the rudder servomotor mechanism 210 is energized in a manner to steer the glider to the left at a relatively rapid rate of turn and, conversely, when this switch is open, the rudder is being turned toward the right, although it is still to the left of its central, or feathered, position. From the foregoing it will appear that the switches D and B, operating through the rudder servo mechanism 210, are effective to change the course of the glider in azimuth toward the target in response to signal impulses received from the lookout device, so that the course of the glider is continuously being corrected in azimuth and in elevation toward a course intersecting the target.

When the lookout device provides a signal impulse energizing the relay 188 during the time that the U-switch is closed, the up relay 290 is energized to cause the elevator capstan motor 214 to operate in a direction to raise the elevator and, as a result, decrease the angle of glide. When the elevator is swung upwardly, the angle of attack of the glider is changed with resultant change in lift and probable slight change in speed. As a result the projection of the true flight path on a vertical plane would not be in line with the target, and, depending upon the distance from the target and the elevation of the point at which the glider was released, the glider might overshoot or undershoot the target. To improve materially the operation of the apparatus in a manner to compensate for this possible cause of error, the optical axis of the lookout device is shifted in elevation simultaneously with the change in elevator position, but through a lesser angle. The means for accomplishing this, it will be recalled, is shown in Fig. 9, from which it will appear that as the elevator 209 swings upwardly, the mirror supporting frame is inclined further with reference to the horizontal, and as the elevator 209 is swung downwardly, the mirror frame is swung upwardly through a lesser angle. The action is such as to tend to make the lookout device "keep its eye on" the target. By proper selection of the ratio between the diameters of the drums constituting the pulley 69, for any particular design of glider, compensation may be made for the fact that the flight path is not exactly in line with the longitudinal axis of the glider in a vertical plane.

Corrections in the direction of flight continue

in response to signals from the lookout device in the manner described, at intervals of approximately one-half second as long as the lookout "sees" a target so that eventually the glider will strike the target.

The parts of the apparatus will usually be used but once so that wear on bearings and the like is not an appreciable factor in the design of the apparatus. Throughout the description of the apparatus various parts and functions have been given quantitative values. It will be understood that these values are merely exemplary and that they are subject to substantial variation, especially if compensatory changes are made in other parts of the apparatus. It is therefore intended that such values are in general not to be construed as limiting the scope of the invention. Furthermore, many parts of the invention disclosed may be utilized in other assemblies. For example, parts of the amplifier and the controls could be used in an apparatus in which there were means to detect other forms of radiation generated or reflected by the target, such as high frequency radio waves, infra-red or heat rays, acoustic vibrations, especialy in the supersonic range, and similar forms of radiation. Many of the parts of the apparatus are subject to considerable modification and variation and I therefore desire, by the following claims, to include within the scope of my invention all such variations and modifications by which substantially the results of the invention may be obtained through the use of substantially the same or equivalent means.

I claim:

1. In a lookout device, the combination of a radiation responsive element, a rotating shaft having its axis at an angle of approximately 45° with respect to the axis of radiation effective upon said element, a radiation reflector secured to said shaft with its reflecting surface at an angle in the order of 85° relative to the axis of said shaft, and motor means for rotating said shaft to cause nutatory movement of said reflector.

2. In a lookout device, the combination of a radiation responsive element, a rotating shaft having its axis at an angle to the axis of radiation effective upon said element, a radiation reflector secured to said shaft with its reflecting surface departing from perpendicularity with the shaft by a small angle, and means for rotating said shaft and reflector about the axis of said shaft thereby to cause nutatery motion of said reflector.

3. In a lookout device, the combination of a radiation responsive element, a radiation condensing system for concentrating radiation upon said element, a radiation reflector having its reflecting surface at an angle of approximately 45° relative to the axis of said radiation condensing system, and means for imparting nutational movement to said reflector, whereby said reflector will scan a generally elliptical field and reflect radiation therefrom to said radiation condensing system.

4. In a radiation responsive control apparatus, the combination of a photoelectric cell, a lens system for condensing light rays upon said cell, the optical axis of said lens system being substantially perpendicular to the axis of a beam of light from a source to which said cell is to be responsive, a plane mirror, and means for imparting nutational motion to said mirror through a relatively small angle, the mean angle of said mirror being approximately 45° with respect to the optical axis of said lens system and with respect to the beam of light from said source, said mirror being located adjacent said lens system so as to reflect light from said source to said lens system and cell.

5. In a lookout device, the combination of a phototube, a lens system therefor, a frame pivotally mounted on a horizontal axis, a rotatable shaft carried by said frame and having its axis at an angle of substantially 45° with respect to the optical axis of said lens system, a mirror secured to said shaft with the plane of its reflecting surface at an angle in the order of 85° with respect to the axis of the shaft, and means for swinging said frame about its pivot.

6. In a pilotless glider having direction of flight controlling means incuding a rudder and an elevator, servo-motors for operating said elevator and rudder respectively, a lookout apparatus responsive to radiation from a distant source and having means to scan cyclically a field including said source, said apparatus having a field of view forwardly in substantial line with the longitudinal axis of the glider, means responsive to signals from said apparatus to control the operation of said servo-motors, and means operated by the elevator servo-motor to direct the field of view of said apparatus downwardly as said servo-motor operates in a direction to raise the elevator.

7. In a target seeking glider, the combination of a scanning mechanism having means responsive to the radiation from the target and producing an electrical signal impulse at the instant of scanning the target, a gyro-pilot apparatus for maintaining the glider on a given course, a plurality of switches operated in synchronism with said scanning mechanism once during each scanning cycle thereof, a plurality of relays, locking circuits for said relays, circuits for energizing said relays upon the production of a signal impulse by said scanning mechanism, the particular relay energized by such signal impulse being determined by the operation of said switches, means to open said locking circuits at least once during each scanning cycle, and means operated by said relays effective to change the course on which the glider is maintained by said gyro-pilot apparatus.

8. In a target seeking glider having aerodynamic control surfaces including an elevator and a rudder, automatic gyro-pilot apparatus for controlling the positioning of said rudder and elevator and including separate means for operating said rudder and elevator, a lookout device for detecting radiation from a source, means controlled by signal impulses from said device resultant from the latter scanning a source of radiation differing materially in intensity from that of its surrounding field to effect adustments of said gyro-pilot apparatus to change the direction of flight of the glider toward the direction of the target, a time switch for controlling the energization of the elevator operating means, and means to close said switch a predetermined interval after said glider has commenced free flight.

9. In an apparatus for controlling the flight of an air craft equipped with an elevator and a rudder, the combination of an elevator gyro, a rudder gyro, a lookout device responsive to radiation from a distant source, said lookout device including a rotary scanning mechanism, four switches U, D, L, R operated by said rotary scanning mechanism in synchronism therewith, said switches being operated during the time that said lookout device is scanning the upper, lower, left, and right halves respectively of the area scanned, a relay associated with each of said switches and arranged to be operated upon the generation of a

significant signal by said lookout device while its associated switch is operated, and means conjointly under the control of said relays and said gyros for operating the elevator and rudder of the aircraft.

10. In a pilotless glider adapted to be released from an aircraft and having aerodynamic control surfaces including an elevator and a rudder, automatic gyro-pilot apparatus for controlling the positioning of said rudder and elevator, said apparatus including separate operating means for said rudder and for said elevator, means rendering said rudder operating means operative immediately upon release of the glider, a time switch for controlling the energization of the elevator operating means, and means to operate said switch to energize said elevator operating means a predetermined interval after the glider has been released.

11. In an apparatus for steering a pilotless rudder-equipped vehicle, the combination of a compass device having a part maintaining fixed orientation in space, a follow-up element associated with said part, a rudder operating servo-motor operatively connected to said follow-up element, a capstan motor operatively connected to said follow-up element so that the latter is conjointly positioned by said motors, means responsive to the heading of the vehicle relative to said compass part to determine the direction of operation of said capstan motor, means operative upon relative movement of said follow-up element and said part in one direction from a determined relative position of said element and part to cause forward operation of said servo-motor and to cause reverse operation of said servo-motor upon relative movement of said element and part in the other direction, and means for effectively changing the predetermined relative position of said element and part at which said means for controlling the direction of operation of said servo-motor becomes effective.

12. The combination set forth in claim 11 in which the last named means comprises a plurality of switches operating at different predetermined relative angular positions of said element and said part, and in which there is provided means for rendering one of said switches effective to control the operation of said servo-motor.

13. The combination set forth in claim 11 in which said last named means includes a plurality of switches, each arranged to open and close when said element and said part are in a predetermined position angularly spaced from the positions at which another of the switches opens and closes, in which there is incorporated means providing electrical signals indicative of the direction in which the course of the vehicle is to be changed, and in which there are means responsive to said signals to render one of said switches effective to control the direction of operation of said servo-motor.

14. In a steering control apparatus, the combination of a part maintaining fixed orientation in space, a follow-up element associated with said part, a plurality of switches, B, C, and D operable by relative movement of said part and said element, said switch C opening and closing when said element and part move relatively through a small angle when said element and part are in one predetermined relative position, and said switches B and D operating similarly when said element and part are in other predetermined relative positions angularly spaced respectively from said first predetermined position, steering means, a reversible servo-motor for operating said steering means and operatively connected with said follow-up element, circuit means for controlling the direction of operation of said servo-motor, and means for rendering one of said switches effective in said circuit means to control the direction of rotation of said servo-motor.

15. In an apparatus of the class described, the combination of a gyro-pilot apparatus, electrical means for energizing said apparatus, a scanning mechanism, a relay operated by said mechanism upon scanning the most intense source of radiation in the field scanned, steering means responsive to said gyro-pilot apparatus, and means controlled by said relay for effectively changing the setting of said gyro-pilot apparatus upon a course differing from its original course by an angle determined by the position of the intense radiation source in the scanned field.

16. In a steering control apparatus, the combination of a compass controlled part having its position determined by the orientation in space of the apparatus, a follow-up element associated with said part, a plurality of switches, B, C, and D operable by relative movement of said part and said element, said switch C opening and closing when said element and part move relatively through a small distance when said element and part are in one predetermined relative position, and said switches B and D operating similarly when said element and part are in other predetermined relative positions spaced respectively from said first predetermined position, steering means, a reversible servo-motor for operating said steering means and operatively connected with said follow-up element, multiple circuit means for controlling the direction of operation of said servo-motor, and means for rendering one of said switches effective in said circuit means to control the direction of rotation of said servo-motor.

17. The combination set forth in claim 16 in which said switches are respectively rendered effective by the operation of relays.

18. The combination set forth in claim 16 in which each of said switches includes a yielding member permitting said switches to remain closed during substantial range of relative movement of said part and said element.

19. In a steering apparatus for a pilotless glider adapted to be released from an aircraft in flight, the combination of automatic gyro-pilot apparatus for steering the glider, means operable upon release of the glider to render said apparatus effective to steer the glider on the course it had at the instant of release, a lookout apparatus carried by the glider responsive to radiation from a distant target, means controlled by said lookout apparatus to change the course on which the glider is steered by said gyro-pilot apparatus, and means operated a predetermined time interval after the glider has been released from the aircraft to render said lookout apparatus controlled means fully effective to determine the course of the glider.

20. In a steering apparatus for an aircraft having a rudder and an elevator, a rudder servo-motor connected to the rudder for controlling the position thereof, an elevator servo-motor connected to the elevator for controlling the position thereof, a rudder gyro having a part maintaining fixed orientation, an elevator gyro having a member maintaining a fixed position relative to the horizon, a lookout apparatus including rotary scanning means and means responsive to radiation from a distant source operative to provide an electrical signal impulse at the instant of

scanning said source, rudder steering control means operable conjointly with said rudder gyro to control the direction of rotation of said rudder servo-motor, elevator steering control means operable conjointly with said elevator gyro to control the direction of rotation of said elevator servo-motor, and switching means operating in synchronism with said rotary scanning means to switch signal impulses from said lookout apparatus to said rudder and elevator steering control means, said switching means being effective to switch signal impulses occurring during the scanning of the right and left halves of the field scanned respectively to different portions of the rudder steering control means, and to switch signals occurring during the scanning of the upper and lower halves of the scanned field respectively to different portions of said elevator steering control means, whereby each signal impulse produced by said lookout apparatus will be effective to control the direction of flight of the aircraft in both the horizontal and vertical planes.

21. In a steering apparatus for a pilotless glider, the combination of a rudder servo-motor mechanism, a part maintaining fixed orientation in a horizontal plane, a follow-up member mounted for rotation about the axis of said part, a plurality of flexible resilient switch contact arms carried by said part, a plurality of contacts carried by said follow-up member cooperable respectively with said contact arms, said contacts being spaced different angular distances from their respective contact arms, a plurality of control circuits for determining the direction of operation of said rudder servo-motor mechanism, each of said circuits including one of said contacts and its associated contact arm, and means for rendering one of said circuits effective to control said rudder servo-motor mechanism in response to opening and closing of the switch formed by the resilient contact arm and its contact.

22. In a gyro-pilot apparatus the combination of a directional gyro having a part maintaining fixed horizontal orientation in space, a plurality of resilient contact arms carried by said part, a follow-up pulley, and a plurality of contacts respectively engageable with said contact arms, said contacts being spaced different angular distances from their respective contact arms, a rudder servo-motor mechanism, a plurality of circuits for controlling the operation of said rudder servo-motor mechanism, each of said circuits including one of said contacts and its associated contact arm, and means for rendering one of said circuits effective for controlling said servo-motor mechanism.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,818,708	Hammond	Aug. 11, 1931
1,896,805	Sperry et al.	Feb. 7, 1933
2,015,670	Hammond, Jr.	Oct. 1, 1935
2,243,132	Soller	May 27, 1941
2,339,011	Gurney	Jan. 11, 1944

FOREIGN PATENTS

Number	Country	Date
352,035	Great Britain	June 22, 1931
354,768	Italy	Dec. 7, 1937
546,488	Great Britain	July 16, 1942

OTHER REFERENCES

Figure 12, page 182, of "Aeronautical Engineering," AER-54-21.