250-203.R 56 CROSS REFERENCE EXAMINER

Nov. 26, 1963 T. W. CHEW 3,112,399

DEVICE FOR AUTOMATIC HOMING OF MOVABLE OBJECTS

Original Filed Aug. 11, 1945 3 Sheets-Sheet 1

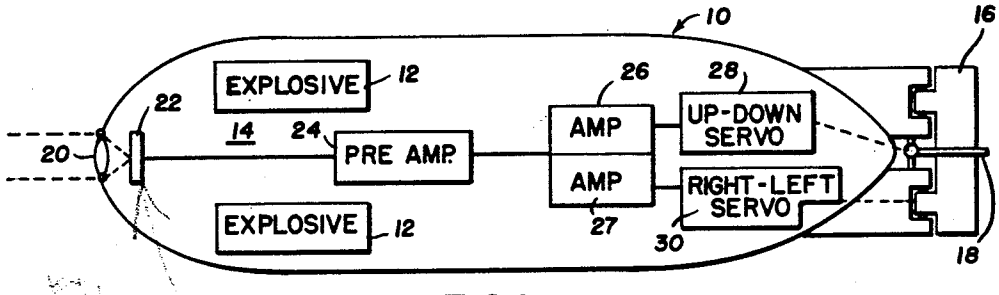


FIG. 1.

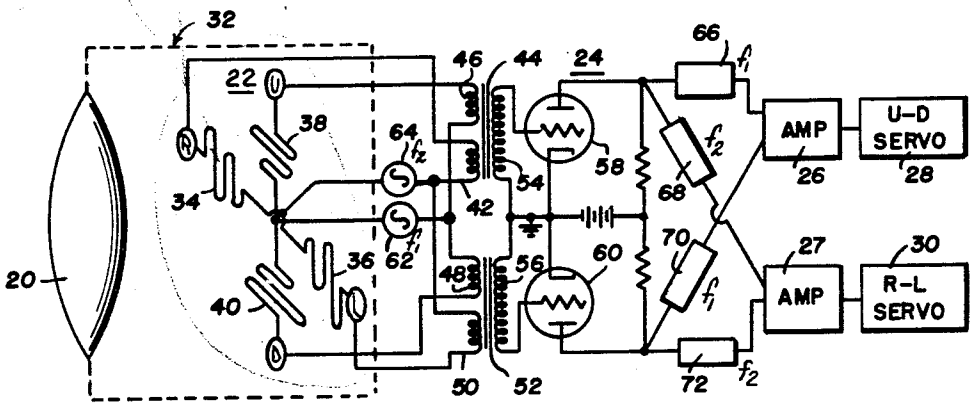


FIG. 2.

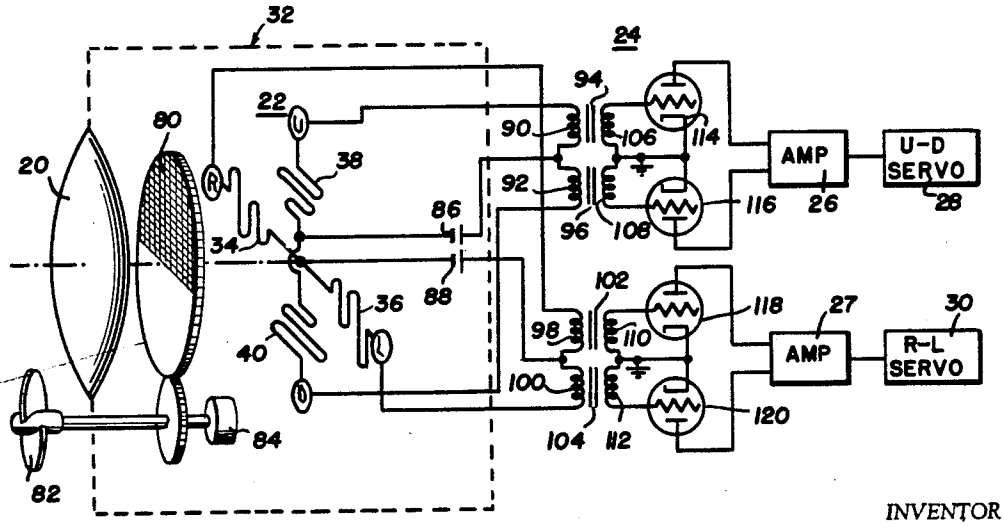


FIG. 4.

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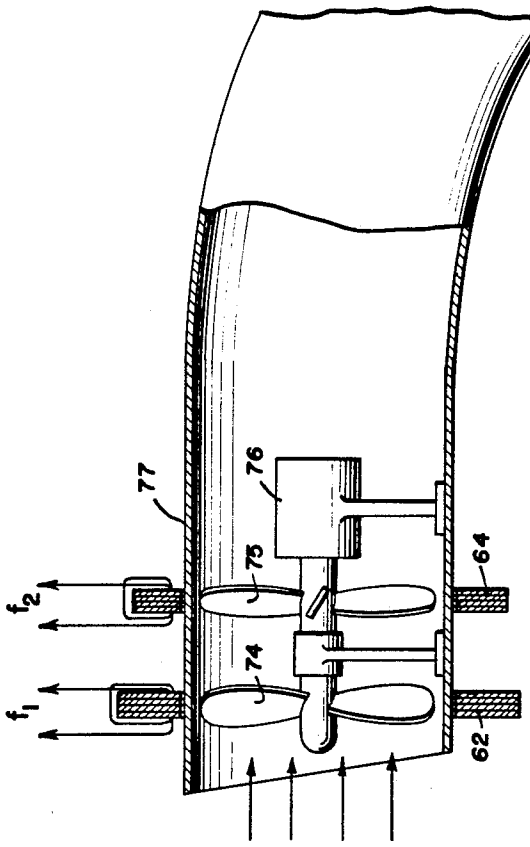


FIG. 3B.

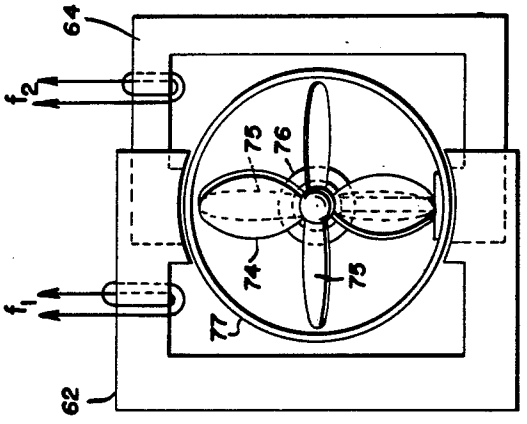


FIG. 3A.

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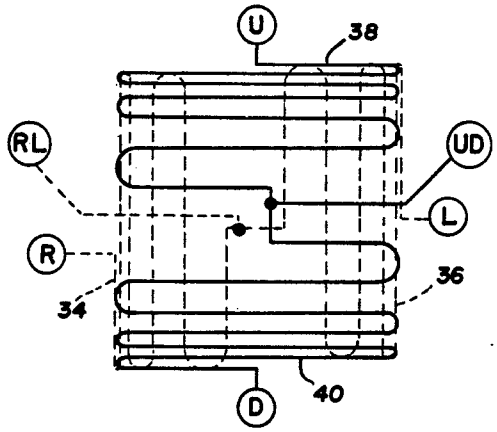


FIG. 5.

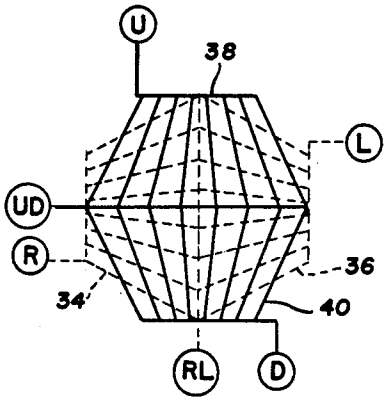


FIG. 6.

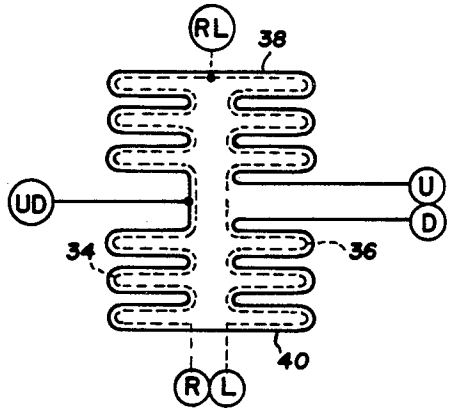


FIG. 7.

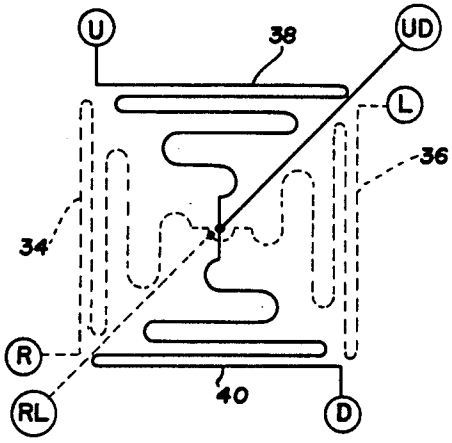


FIG. 8.

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United States Patent Office 3,112,399 Patented Nov. 26, 1963

3,112,399
DEVICE FOR AUTOMATIC HOMING OF MOVABLE OBJECTS

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Original application Aug. 11, 1945, Ser. No. 610,382. Divided and this application Feb. 14, 1951, Ser. No. 210,901

7 Claims. (Cl. 250—83.3)

(Granted under Title 35, U.S. Code (1952), sec. 266)

My invention relates to a homing missile responsive to target radiation. More specifically my invention relates to means to adjust the course of travel of an aerial bomb toward a target emitting radiation.

In the usual practice of bombing from aircraft the pilot maintains a steady course while the bombardier aligns the target in the bomb sight and at the prescribed state of alignment releases the bombs. The accuracy of this method of bombing depends upon the skill of the pilot and bombardier and upon favorable conditions of wind and visibility. Once the bombs are released, there is no way of compensating for errors in judgment of the pilot or bombardier or for unpredicted variations in air currents which may cause the bomb to miss the target.

Recently, methods have been devised to control by means of a radio wave the path of a bomb during its fall to the target. This enables an operator to correct an error in the initial aim of the missile. The effectiveness of this method of correcting initial errors in aim depends upon the reliable performance of the radio control equipment and upon the prompt and skilled reaction of the operator in transmitting the course correction required. To assist the operator in such correction missiles have been equipped with television conversion and transmitting equipment. Radio control and intelligence-relaying equipment frequently fail to function adequately either as a result of equipment failure or as a result of unfavorable radio wave propagation. In addition, the enemy may apply countermeasures in the form of "jamming" or interfering radio signals. Systems have also been devised for causing aerial bombs to home continuously and automatically while falling upon certain kinds of targets. These systems have the advantage of largely eliminating the element of human error in judgment and of eliminating the possibility of failure of radio control or intelligence-relaying equipment since these equipments are not used. It is only necessary to achieve moderate accuracy of initial aim of this type of bomb in order that the target shall be within the field of view of the automatic homing system. However, the automatic homing systems heretofore devised and known have relatively complex scanning mechanisms and signal-utilizing electric circuits. Some have vacuum tube circuits requiring delicate and critical adjustments to be maintained in flight. In all cases a smaller, lighter and more reliable functioning equipment is desirable in order to increase the exposive load and the certainty of hitting the target.

Ideally, if the axis of flight of a missile is maintained in continuous alignment with a target proceeding at a lesser rate than itself, the missile will eventually strike the target in spite of evasive maneuvers on the part of the target. It should be noted, however, that this is true for practical applications only where the velocity of the missile is several times that of the target and where the means contained in the missile for maintaining its alignment of axis of flight with the target is accurate and quick of response.

One of the means of maintaining this alignment or homing course is to incorporate in the missile a viewing device having its field of view coaxial with the line of flight utilizing for corrective effect the position of a target image with respect to the four quadrants about the center

of the field of view. By this method the center of the field of view becomes the origin while the remainder of the field of view may be defined in positive and negative values of "X" and "Y" coordinates or axes. Any deviations from the homing course may be represented in terms of four variations of positive or negative values of image displacements from the origin along the "X" and "Y" axes in the field of view. It remains to devise a means of converting these values into electrical and mechanical forms responsive in such a manner that the missile's course is altered and the target image returned to the origin.

My invention is characterized by the fact that simple means are provided for viewing the target and for producing the necessary aerodynamic correction to maintain the homing course.

My invention is further characterized by the fact that the signal provided by the target is substantially constantly effective to alter the course of the missile.

My invention is still further characterized by the fact that the image of the target in the viewing device is effective to cause simultaneous correction of the direction of flight of the missile in two mutually perpendicular planes.

In accordance with one aspect of my invention a configuration of temperature-sensitive resistive material having a high coeffecient of resistance is used to produce simultaneous correction in two planes.

In accordance with other aspects of my device, a temperature sensitive resistance element is used which produces a corrective signal which is an increasing function of the displacement of the target image from the optical axis.

Further, in accordance with my invention, I provide a temperature-sensitive cell, the elements of which are excited by alternating potentials at different frequencies.

In accordance with one aspect of my invention, a temperature-sensitive resistance element may be used continually to view a target without the intervention of mechanical chopping means.

One of the objects of my invention is to provide a superior automatic homing system suitable for aerial bombs.

Another object is to provide an automatic homing system which largely eliminates the element of human error in judgment.

Another object is to provide a homing system independent of radio-control or intelligence-relaying systems.

Another object is to provide a homing system which cannot be "jammed" by enemy radio counter measures.

Another object is to provide a more reliable automatic homing system by virtue of its having a simple target-responsive device and relatively simple signal-utilizing electric circuits which do not depend upon maintenance of delicate or critical adjustments during flight.

Referring to the drawing:

FIG. 1 is a block diagram showing the relative location of the various components in a homing missile constructed in accordance with my teachings.

FIG. 2 is a simplified circuit diagram showing temperature-sensitive resistance elements excited by two different frequencies together with the associated amplifying, filtering and servo devices;

FIG. 3*a* shows the driving of the exciting alternators by means of a wind-driven propeller;

FIG. 3*b* is a vertical sectional view of the device of FIG. 3*a*.

FIG. 4 shows the use of a mechanical chopping device used in conjunction with temperature-sensitive elements constructed in accordance with my design.

FIG. 5 shows a means of constructing a temperature-sensitive element utilizing series-connected resistance elements.

FIG. 6 shows the use of parallel-connected temperature-sensitive elements.

FIG. 7 shows the use of series-connected resistance elements in adjacent non-overlapping relation.

FIG. 8 shows a resistance element construction usable with the remainder of my device but of less inherently satisfactory design.

FIG. 1 shows an outline and block diagram of a homing missile in which the housing **10** includes the explosive load **12** and the homing equipment referred to generally by the numeral **14**. At the rear of the missile there are provided horizontal control surfaces **16** and vertical control surfaces **18**. At the nose of the missile is placed the optical system indicated generally by the numeral **20** passing radiation to a temperature or radiation-sensitive cell **22**. The output from the temperature-sensitive cell is fed into a preamplifier **24**, into power amplifiers **26** and **27** and thence to the servo operators controlling the control surfaces. One servo mechanism **28** is provided for controlling the surface **18** while another set of servo equipment **30** is used for controlling surface **16**.

FIG. 2 shows a simplified circuit diagram showing the main features of my device. A lens **20** or other suitable optical system focuses radiation on the temperature-sensitive cell **22**. The optical system and the temperature-sensitive cell are preferably mounted in an optical head **32**. The temperature-sensitive cell **22** is preferably centered with respect to the axis of the optical system. In the preferred embodiment of my device the temperature-sensitive cell **22** consists of four elements which will be designated for the sake of convenience as the "right" element **34**, the "left" element **36**, the "up" element **38** and the "down" element **40**. The "right" element is fed into a winding **42** of an input transformer **44** and the "up" element **38** is fed into a second primary winding **46** of this transformer. The "down" and "left" elements are similarly fed into windings **48** and **50** respectively of transformer **52**. The secondary winding **54** of transformer **44** is fed into the grid circuit of one side of a double channel preamplifier **24**. The secondary winding **56** of transformer **52** is fed into the other channel of the preamplifier **24**. I have shown vacuum tubes **58** and **60** as illustrative of the two channels of the amplifier **24**.

Resistance elements **38** and **40** are fed by a source **62** of alternating potential at frequency F_1 while the resistance elements **34** and **36** are excited by means of an alternating source **64**, at a frequency which we shall designate as F_2. At the output of the preamplifier **24**, filter **66** allows passage of a signal of frequency F_1 to power amplifier **26**. Another filter **68** allows passage of a signal at frequency F_2 from tube **58** to the power amplifier **27**. In like manner filter **70** allows a signal of frequency F_1 to be passed to power amplifier **26** and a filter **72** passes a signal at a frequency F_2 to power amplifier **27**.

For the sake of diagrammatic simplicity the resistance elements **34**, **36**, **38** and **40** have been shown as non-overlapping. However, in the preferred form of my device the resistance elements are considerably widened so that resistance element **34** extends upwardly to cover half the area occupied by element **38** and downwardly to cover half the area occupied by element **40**. In like manner, resistance element **36** is arranged to cover half the area occupied by elements **38** and **40** respectively. This type of structure will be more fully explained in connection with the explanation associated with FIGURES 5, 6, and 7. The resistance elements may consist of any material having a large temperature coefficient of resistance at the designed operating temperature. An example of such a material is columbium nitride cooled to approximately 15 degrees Kelvin. While no means has been shown for cooling the temperature-sensitive cell **22**, it will be obvious to one skilled in the art that cooling means such as liquid air may be used in the optical head or associated with the cell **22** itself.

In the embodiment of my device shown in FIG. 2, the radiation-sensitive elements are excited in diametrical pairs by alternating current sources **62** and **64** which differ in frequency. Since the power requirements are extremely low, the exciting current may be produced by electronic oscillators. For maximum simplicity, however, I prefer to obtain alternating current from a pair of generators driven by propeller means located in the slip stream of the missile. In FIGS. 3*a* and 3*b*, I have shown one design of alternators. The alternating voltage is obtained from the windings associated with the armatures **62** and **64** respectively. Cooperating with such armatures are propellers **74** and **75** which are constructed, at least partially, of magnetic material. In order to cause the frequency of the output to be maintained at a substantially constant value, a governor **76** of any well-known type may be provided. Since it will be necessary for the governor to absorb energy, I prefer to place the governor in the slip stream for maximum cooling effect. If desired the propellers may be mounted in a duct **77**. It will appear to one skilled in the art that a small constant speed direct current motor may also be used to drive the alternators.

The operation of the device thus far disclosed is as follows: If a source of radiation, for example, a ship or power plant, is located in the optical axis and aligned with the missile, its projected image will fall on the optical axis at the center of the temperature-sensitive cell **22**. Under such conditions, the current flowing through resistance element **34** will be the same as that flowing through resistance element **36**. Accordingly, the signal produced at the secondaries **54** and **56** of transformers **44** and **52** respectively, will be equal. Thus the output of tube **58** fed through filter **68** will equal the output of tube **60** fed through filter **72**. Included in the amplifier **27** is provided a circuit of any one of many types known to one skilled in the art which is responsive to the difference between the signal received from filter **68** and that received from filter **72**. Since under centered target conditions these signals are equal and the input of the amplifier **27** therefore balanced, no signal will be transferred from the amplifier **27** to the servo device **30**. It may likewise be shown that with the target vertically centered between temperature-sensitive elements **38** and **40**, the signal at a frequency F_1 will be balanced at the input of the power amplifier **26** and no motion of the servo device **28** will result to change the vertical direction of motion of the missile.

Normally, the image of the target will not be exactly aligned with the missile and the image of the target will be displaced from the optical axis. In order that the operation of the device may be more fully understood under these conditions we shall assume that the relative motion between the missile and the target has caused the image of the missile to fall in the "up-right" quadrant on elements **34** and **38**. The effect of the image on these two elements may be discussed separately. In the case of the image falling on element **34**, the temperature of the element **34** will be raised and its resistance accordingly changed. This will cause an unbalance of the signal at a frequency F_2 at the transformer secondaries **54** and **56**. Such unbalance will cause a different magnitude of signal to arrive at amplifier **27** through filter **68** as compared to the signal arriving at this amplifier through the filter **72**. Such unbalance causes motion of the servo device **30** tending to move the missile to the right or to the left as required to center the target between temperature responsive elements **34** and **36**. By the same reasoning it may be determined that the unbalance between the temperature sensitive elements **38** and **40** caused by the image of the target on element **38** causes a different magnitude of signals to arrive at amplifier **26** through filter **66** as compared to that passed through filter **70**. This unbalance causes motion of the servo device **28** in such a direction as to center the image of the target between temperature-responsive elements **38** and **40**.

In FIG. 4, I have shown another embodiment of my

homing missile in which the exciting cell voltage is obtained from a direct current source and the pulsating output signal is obtained through the use of a mechanical chopper. As in the previous embodiment, the optical system is represented by the lens **20**. Intercepting the optical path is the chopper **80** which may consist of a disc, half of which is transparent and half of which has been covered with an opaque substance. The chopper may be driven by any convenient means, as for example by the wind-driven propeller **82**, the velocity of which may be kept practically constant by means of a governor **84**. Temperature sensitive elements **38** and **40** obtain D.C. potential from a D.C. current source **86**, while elements **34** and **36** obtain their D.C. supply from source **88**. Source **86** is connected to one side of the primaries **90** and **92** associated with transformers **94** and **96** respectively; likewise, source **88** is connected to windings **98** and **100** of transformers **102** and **104** respectively. Secondary windings **106** and **108**, **110** and **112** are respectively connected to the preamplifier tubes **114**, **116**, **118** and **120**. Amplifier means **26** and **27** are provided which are similar to the means provided in connection with the previous embodiment. Servo equipment **28** and **30** may be the same as that discussed in connection with FIG. 2.

In FIG. 4, as in the case of the device of FIGURE 2, movement of the target image from the central position, for example, in such a direction as to fall upon temperature sensitive elements **34** and **38** will be accompanied by an unbalance of the system. This occurs as follows: a change of the resistance of the element **34** as compared to the element **36** will cause unlike currents to flow through primary windings **98** and **100** of the transformers **102** and **104**. These currents will, of course, be pulsating due to the chopping action of the chopper disc **80**. As the result of the unbalance, plate current will be unbalanced in tubes **118** and **120**. The magnitude and direction of the unbalance will be interpreted by amplifier **27** and operation of the servo device **30** will be produced. In like manner, unbalance between temperature-sensitive elements **38** and **40** will result in motion of the servo device **28**. The motion of each of the servo devices will be in such a direction as to restore the image of the target to the centered position, in other words, to align the missile and the target.

The chopper disc **80** is preferably of such a size as to completely cover any one of the temperature sensitive elements **34**, **36**, **38**, or **40**. With this arrangement the pulses of plate current of two associated preamplifier tubes will be out of phase and it will be necessary for the comparison means included in the amplifier to compare two signals out of phase by 180 degrees. If desired, the size of the chopper disc may be increased so that radiation is simultaneously removed and simultaneously applied to diametrically-opposed temperature-sensitive elements. In this way, the current pulses originating in such diametrically opposed elements will be in phase and somewhat simpler comparison means may be used.

As stated above, many designs of means responsive to the difference between the two input signals applied to the input of amplifier **26** or amplifier **27** will appear to one skilled in the art. One way in which such difference may be utilized is by feeding the amplified signals to be compared into two coaxial magnetic coils connected in bucking relation. Any difference between the current flow in one of the coils as compared to the other would be evidenced by motion of a spring-centered solenoid engaging both of the coils, according to well known differential current relay techniques, generally illustrated in Hammond 1,387,850.

It should be noted that in both of the embodiments discussed above means are provided for causing the signal appearing in the circuit of the sensitive elements to be of a cyclicly-varying nature, even where radiation of a constant value is being received. This enables the use of A.C. amplifiers which are inherently more stable and more practical to use than D.C. amplifiers.

FIG. 5 shows the preferred embodiment of cell construction in which temperature-sensitive elements **34**, **36**, **38** and **40** are connected in diametrical pairs with the resistance material in the form of a single filament. For diagrammatic simplicity elements **34** and **36** are shown dotted. In order that the displacement of the target from the central position toward the periphery may cause an increased signal as the radial displacement is increased, I prefer to increase the density of the resistance elements in a progressive manner with increasing radius. This may be done by causing the loops of resistance material to be more closely spaced at points away from the center or may be caused by changing the resistance of the filamentary material along its length. In this manner, the signal produced by a target image may be increased proportionately with the distance from the center of the cell if so desired.

FIG. 6 shows an arrangement of resistive material in which the strands of the resistive material are in parallel rather than in series relation.

In FIG. 7 is shown an arrangement which has the advantage that the resistance elements need not be placed in superposed relation but may be placed in a complementary interfitting relation to simplify the cell structure. By so doing, it is possible to eliminate a layer of insulating material which would otherwise have to be used between two elements occupying the same area, and thereby to simplify cell construction.

In FIG. 8 is shown a quadrant type cell with nonoverlapping elements which may be used with either the embodiment shown in FIG. 2 or that shown in FIG. 4 While the cell as shown in FIG. 8 may be somewhat easier to construct, it suffers from the disadvantage that simultaneous correction of the direction of motion in both planes is not as readily produced. For example, if a target should lie considerably in the "up" direction and only slightly to the left horizontal correction would not be initiated until vertical correction was practically accomplished.

It will be seen that all forms of this invention have inherent characteristics which contribute to the objectives of simplicity and reliability. Since neither mechanical nor electronic means (but rather optical effects incident to variation of the bomb's axis of flight with respect to the target) is employed to obtain a corrective signal, neither accuracy nor reliability of homing action is dependent upon such critical operations as synchronizing, wave-shaping, pulse-clipping, phasing and the like. The system is not critical of the carrier wave form. The amplifier tube may operate upon the straight portion of the grid voltage-plate current curve allowing wide tolerances of tube characteristics. The incoming radiation comprising the target image is utilized continuously and therefore more efficiently in a "storage" type of radiation device such as that described above, in contrast to other systems which utilize the radiation over only a small portion of a scanning cycle.

The area of the target image will vary inversely as the square of the distance from the target. Since the differential in carrier amplitude caused by displacement of the target image from the origin is proportional not only to the magnitude of radiation differential above or below the background but also to the area occupied by the target image, course correction can be proportionately greater as the target is approached. Thus, last-minute evasive action by the target will be met with increased force of homing action.

Thus, it will be seen that I have produced a homing device which is both simple and novel in construction and operation and which overcomes serious disadvantages inherent in previous devices of this nature. While only the aerial bomb application of this invention has been discussed, it is to be understood that it may also be applied

to other vehicles and for other uses in both peace and war. While I have shown and described but a limited number of forms which my invention may take, it will appear to those skilled in the art that various changes and modifications may be made without departing from the spirit and scope of my invention as set forth in the appended claims.

The invention described herein may be made or used by or for the Government of the United States for governmental purposes without the payment to me of any royalties thereon or therefor.

The present application is a division of application Ser. No. 610,382, filed August 11, 1945.

I claim:

1. A radiation-responsive device comprising an optical system having an optical axis, said optical system operating to transmit and focus a light beam along said axis from a remote radiation source, a light-responsive means comprising a patterned array of adjacently positioned filamentary conductors, said array being in a plane transverse to said axis, each conductor of said array providing a length arranged relative to said axis, whereby as said light beam deviates from said axis, the resistance of the conductor will be varied proportional thereto.

2. In a radiation homing device, an optical system including an optical axis and a focal plane, a radiation-responsive resistance consisting of adjacent filamentary conductors, said conductors more closely spaced at a point radially removed from said optical axis than in the region of said optical axis whereby the signal produced by said radiation-responsive resistor is greater with a radiation image remote from said axis than with said radiation image in the region of said axis.

3. A radiation-responsive cell consisting of an upper half, a lower half, a right half and a left haft, radiation-responsive elements occupying each of said areas in overlapping relation whereby radiation falling at a point on said cell may effect two of said elements simultaneously.

4. A radiation-responsive cell having a center, an upper filamentary conductor originating in the region of said center and disposed in zigzag formation to occupy the surface of the cell above said center, a lower filamentary conductor similarly occupying an area on said cell below said center, a right filamentary conductor similarly disposed on said cell occupying the area on said cell to the right of said center, a left filamentary conductor similarly disposed on said cell occupying the area to the left of said center, said right conductor occupying a portion of the space occupied by said upper and lower conductors whereby an incident radiation image falling on said cell is enabled simultaneously to affect the resistance of two of said conductors.

5. A heat sensitive cell of the type claimed in claim 4, the convolutions of said zigzag pattern lying more closely adjacent each other at a point remote from said center than in the region of said center whereby a radiation image produces a greater signal as the deflection of said image from said center of said cell is increased.

6. A heat sensitive planar cell having horizontal and vertical conductors respectively intersecting at the center of said cell, a plurality of filamentary conductors on the surface of said cell attached at spaced points on said horizontal conductor and proceeding respectively upwardly and downwardly from said horizontal conductor in converging relation, said converging filamentary conductors electrically interconnected at points on said cell remote from said horizontal conductor, filamentary conductors located in the plane of said cell and attached to spaced points on said vertical conductor, said filamentary conductors extending in converging relation respectively to the right and to the left of said vertical conductor said converging conductors being electrically interconnected at points remote from said vertical conductor.

7. A radiation-sensitive planar cell comprising an upper filamentary conductor occupying the area of said cell above said center, a lower filamentary conductor occupying the area of said cell below said center, a right filamentary conductor occupying the area of said cell to the right of said center, a left filamentary conductor occupying the area of said cell to the left of said center, said filamentary conductors arranged on the plane of said cell in zigzag relation to form convolutions, said conductors in interleaved nonoverlapping relationship whereby a heat image falling on said cell at a point removed from said center is effective to change the conduction characteristics of two conductor elements simultaneously.

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