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3,306,556

AUTOMATIC GUIDANCE SYSTEM

Filed June 23, 1961

2 Sheets-Sheet 1

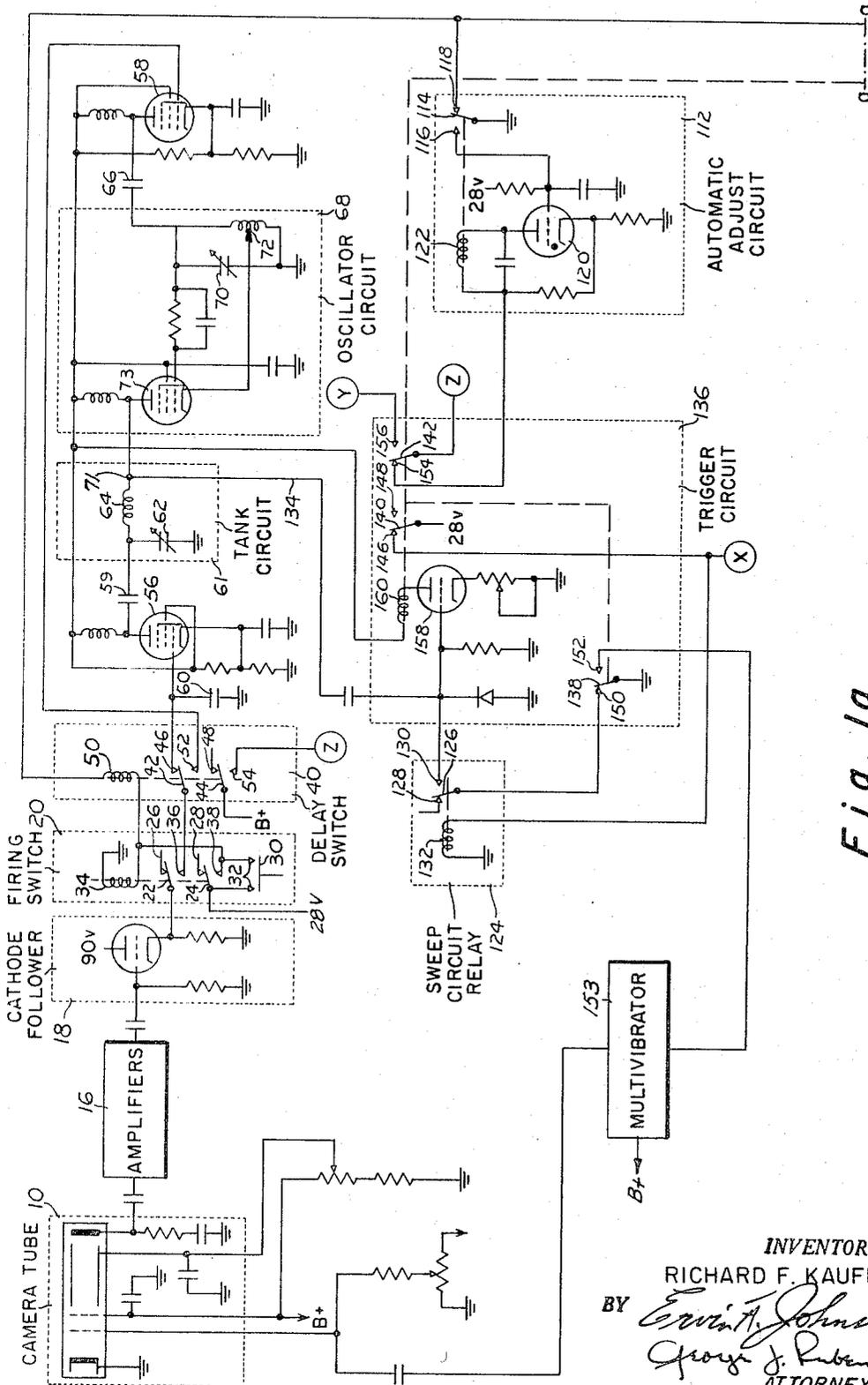


Fig. 1a

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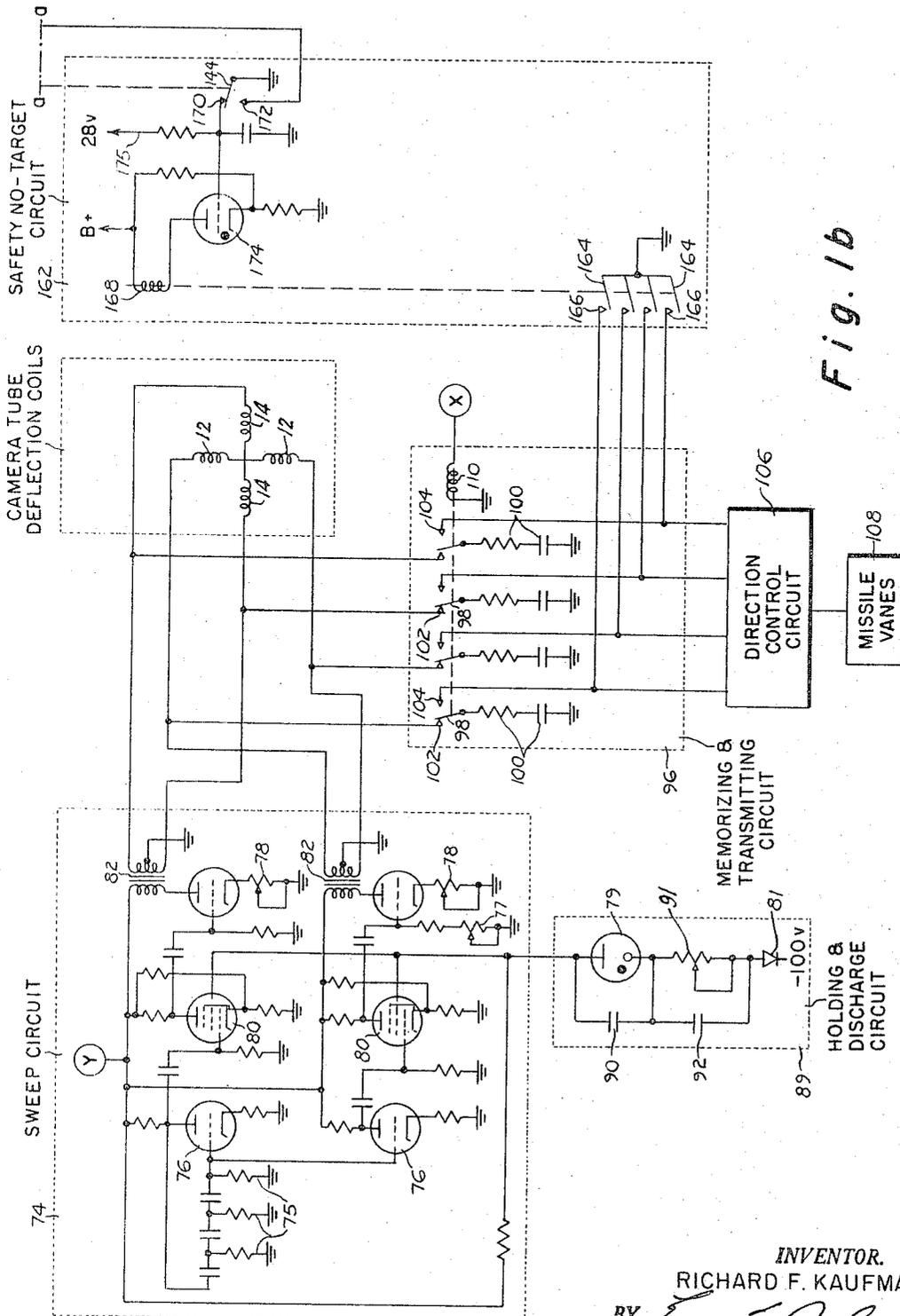


Fig. 1b

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3,306,556

**AUTOMATIC GUIDANCE SYSTEM**

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11 Claims. (Cl. 244—3.17)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of royalties thereon or therefor.

The present invention relates to an automatic guidance system and more particularly to a guidance system which will home a vehicle on a target by distinguishing the light characteristics of the target in contrast to its surroundings.

In the past, a pilot whose mission it was to deliver an air-to-ground missile was required to fly the missile all the way to the target since the missile had no homing feature. The disadvantage of this procedure is that it subjects the pilot to continual ground fire at or near the target and, further, the pilot will tend to neglect the control of his own aircraft in his attempt to deliver the missile to the target. This danger becomes even more pronounced as aircraft reach high-performance characteristics. Further, the prior-art air-to-ground missile firings do not allow pilot to make multiple firings, whereas, with the present invention the pilot is enabled to fire a plurality of missiles with one run.

The present invention has overcome the disadvantages of prior-art missiles by providing a practical automatic guidance system which can be employed with a missile to home on a desired target. The guidance system employs a light-differentiating device such as a vidicon tube which is mounted in the nose of a proposed missile. The electron beam within the tube is aligned so as to coincide with the axis of the missile. This electron beam strikes an image plate on the face of the tube and thus establishes the target light intensities immediately as the missile is fired toward the target. When the missile gets off target course during its flight the beam is able to distinguish a change of light intensity on the image plate in the area immediately surrounding the target. This change of light intensity originates a spiral search sweep by the beam in an effort to again establish the original target intensity. As the beam sees the target at its original intensity, it looks at this point, providing a reference position from target to missile. This reference position information is fed to the control section to provide course guidance. A continual correction signal is generated to afford smooth return to on-course position. As the missile approaches the target the constant rise in light intensity of the target is provided for by an attenuator circuit. Search, acquisition and lock occur in a matter of a few milli-seconds or less so hunting, which would cause missile oscillation, cannot easily occur.

An object of the present invention is to provide an automatic video guidance system.

Another object is to provide an improved automatic video guidance system for use in air-to-surface missiles.

A further object is to provide an automatic video guidance system which will home a vehicle on a target even though the light intensity of the target varies due to the relative positioning of the vehicle with respect to the target.

Still another object is to provide a device which will process on-target and off-target indications from a target-sensing device so as to produce guidance commands for homing a vehicle on the target.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the

accompanying drawings in which like reference numerals designate like parts throughout the figures thereof and wherein:

FIG. 1a shows a schematic diagram of a portion of the guidance system; and

FIG. 1b shows a schematic diagram of the remainder of the guidance system.

Referring now to the drawings wherein like reference numerals designate like and corresponding parts throughout the several views there is shown in FIG. 1a a camera tube 10 such as a vidicon or other cathode-ray tube having two pair of deflection coils 12 and 14, one pair being for a vertical deflection of the camera tube's bean and the other pair being for a horizontal deflection thereof. The camera tube has a signal output which is proportional to the light intensity viewed by the tube, this signal output being amplified by a series of video amplifiers 16. After amplification, the signal output of the camera tube is fed via a cathode follower 18 to a manually operated firing circuit 20. The switch 20 has an armature 22 which receives the signal from the cathode follower 18 and an armature 24 which is biased at 28 volts. The armature 22 is spring-biased against an off contact 26 and the armature 24 is spring-biased against an off contact 28. Upon closing a manual arm 30 so as to connect contacts 32 with one another, the voltage on the armature 24 is fed to an electromagnet 34, this electromagnet driving the armature 22 and armature 24 to connect with the contacts 36 and 38, respectively. After closing the arm 30 the electromagnet 34 holds the armatures 22 and 24 against the on contacts 36 and 38, respectively. In the on-position the switch 20 sends the output signal of the camera tube to a delay switch 40.

The delay switch 40 has an armature 42 which receives the output signal from the camera tube and an armature 44 which is biased at a predetermined voltage. The armatures 42 and 44 are spring-biased against delay contacts 46 and 48, respectively. Upon the closing of the firing switch 20 the bias on the armature 24 thereof is fed to an electromagnet 50 having a 50 millisecond delay, this electromagnet upon being energized driving, after the 50 millisecond period, the armatures 42 and 44 so as to connect with the contacts 52 and 54, respectively.

Immediately after closing the firing switch 20 the output signal of the camera tube is fed via the contact 46 to the grid of a first reactance tube 56 after the 50 millisecond delay the electromagnet 50 drives the armature 42 to the contact 52 so that the signal output of the camera tube is then fed to the grid of a second reactance tube 58. A biasing capacitor 60 is connected in parallel with the grid of the first reactance tube 56 so as to store the output signal of the camera tube during the delay period, this capacitor after the delay period setting the output signal at a potential difference above ground. Accordingly, an original output signal from the camera tube is memorized by the biasing capacitor 60 during the delay period and is then impressed upon the reactance tube 56 after the delay period. The output signal of the reactance tube 56 is sent via a capacitor 59 to a tank circuit 61, the tank circuit having an adjustable capacitor 62 and a coil 64. A signal output of the second reactance tube 58 is sent via a capacitor 66 to an electron-coupled oscillator 68, this oscillator having a variable capacitor 70 and an adjustable inductor 72.

The oscillator 68 is adjusted for a static condition of 10 mc. This electron-coupled oscillator utilizes the tank circuit 61 as the output tuned circuit. Frequency of the oscillator is varied by the change in capacitance of reactance tube 58 when it conducts. It will be noted that this tube is in parallel with variable capacitor 70 which controls grid flow in a tube 73. The output of the oscillator 68 is fed to the tank 61 where it is compared at a

point 71 with the signal output of the first reactance tube 56. The tank 61 and the oscillator 68 are both tuned substantially to the same frequency so that when the signal output of the first reactance tube 56 is equal to the output of the second reactance tube 58 the tank will have no output. However, if the signals from the reactance tubes 56 and 58 are not equal, the oscillator 68 will have a change in frequency giving an unbalanced condition in the tank circuit 61 causing this tank circuit to have an output. Accordingly, assuming that the camera tube 10 was aligned directly upon a target and an original output signal therefrom (representing the light intensity of the target) will upon the closing of the firing switch be fed to the first reactance tube 56, all subsequent signals after the delay period will be sent to the second reactance tube 58. When the original signal and the subsequent signals are equal the tank circuit will produce an on-target indication by having no output and when the original signal and the subsequent signals are not equal the tank circuit will produce an off-target indication by having an output.

A spiral sweep circuit 74 is connected to each pair of the deflection coils 12 and 14 in the camera tube 10 so as to cause the beam within the camera tube to conduct a spiral sweep when the sweep circuit is actuated. The sweep circuit 74 consists of two sine-wave generators operating 90° out of phase to produce a circle. The sine-wave frequency is set at 300 cycles by a series of capacitors and resistors 75 which control the generation of sine waves on the grid of tubes 76 and are further amplified through two subsequent stages. Phase shifting to a 90° separation between the two sine-wave generators is accomplished with a variable resistor 77. To round out the circle, amplitude of the signal is controlled by variable cathode resistors 78. A gas tube 79 determines the size of the circle by applying voltage direct to the suppressor grids of tubes 80. A spiral sweep is accomplished by steady increase in voltage of the tube 79 until discharge, at which time the circle collapses. To keep the gas tube 79 from leaking voltage and to operate at high potential, a diode 81 is biased below ground with direction of current flow toward the tube 79 only. Transformers 82 isolate the sweep circuit from the remainder of the system.

A holding and discharge circuit 89 is connected to sweep circuit 74, this holding and discharge circuit having a pair of capacitors 90 and 92 in conjunction with variable resistor 91 to adjust the sawtooth wave pattern and firing sequence across gas tube 79. This circuit is accurately explained under sawtooth circuits on pages 35 and 36 of "Handbook of Electronic Circuits" (HEC-1) by Howard W. Sams. During an on-target phase the gas tube 79 is not conducting. During an off-target phase B+ is applied to Y and the spiral sweep commences on the camera tube. As an on-target phase again appears, B+ is removed from Y and the potential across gas tube 79 is lost, as well as across tubes 76 and 80, which stops action of the sweep circuit 74 and the holding and discharge circuit 89. Isolation transformers 82 permit charges to be withheld in deflection coils 12 and 14 for periods of time due to high inductance and resistance. Bleed off through the ground tap in isolation transformers 82 is slow enough to allow capacitor and resistor 100 to load to a selected value.

A memorizing and transmitting circuit 96 is connected to the deflection coils 12 and 14 of the camera tube and has four armatures 98, each of which is connected to a resistor and capacitor combination 100. Each armature 98 is disposed between a pair of contacts, one of these contacts being located in an on-target position 102 and the other contact being located in an off-target position 104. The on-target contacts 102 are each respectively connected to one of the deflection coils of the camera tube and the off-target contacts 104 are each connected to a missile directional control circuit 106. If the target is not aligned with the central axis of the camera tube and it is located by a sweep of the beam the deflection coils 12 and 14 will reflect by their signals the position of the target with re-

spect to the central axis of the camera tube since the charge developed across the deflection coils of the camera tube does not immediately collapse due to the isolation transformer 82 and the high inductance and resistance within the coils and the secondary winding of the transformer. Since 50 milliseconds is the order of interval required to adequately load capacitors 100 in the memory and transmitting circuit 96, as determined by 50-millisecond delay relay 132, values of the potential relating to the charge are stored in the memory circuits 100. The off-target phase allows each memory circuit 100 to be sampled by the direction control circuit 106 through action of relay 110 and armatures 98 connecting contacts 104. These signals are memorized by capacitors 100 when the armatures 98 are connected with the on-target contacts 102 and are transmitted for guidance purposes from the capacitors 100 to the direction control circuit 106 when the armatures 98 are connected with the off-target contacts 104. These signals are then utilized by the direction control circuit 106 to drive vanes 108 of a missile to bring the central axis of the camera tube back on the target. The armatures 98 are spring-biased to an off-target position and are driven to an on-target position by the energization of an electromagnet 110, this operation being described later.

An automatic adjust circuit 112 is connected to the electromagnet 50 of the firing delay switch 40 so that upon energization it will periodically rebias the biasing capacitor 60 with another original on-target signal from the camera tube thus eliminating error within the guidance system due to changes of light intensity of the target as the camera tube assumes various distances with respect to the target. The automatic adjust circuit 112 has a grounded armature 114 which is disposed between a pair of contacts, one of these contacts being an adjustment contact 116 and the other contact being a no-adjustment contact 118 so that when the armature 114 is connected to the adjustment contact 116 the electromagnet 50 of the delay switch 40 is open-circuited. When the electromagnet 50 is open-circuited the armature 42 is spring-actuated so as to connect with the contacts 52. At this time the signal from the camera tube is relayed to the biasing capacitor 60 and the reactance tube 56 so as to reset the biasing capacitor at a level which represents the target as the camera tube presently sees it. The armature 114 is spring-biased against the no-adjustment contact 118 so that without activation there will be no resetting of the biasing capacitor 60. The armature 114 is periodically driven to the adjustment contact 116 for a short interval such as 5 milliseconds by a thyatron tube 120 and an electromagnet 122. The thyatron tube and the electromagnet have a time delay such as 1 second so that upon energization they will drive the armature 114 to connect with the adjustment contact 116 every second. As explained later energization to the automatic adjust circuit 112 is removed when the camera tube is off target so that the armature 114 remains connected to the no-adjustment contact 118, thus preventing erroneous signals from being sent to the biasing capacitor 60.

A sweep-circuit relay 124 having a delay such as 50 milliseconds has an armature 126 which is disposed between a pair of contacts, one of these contacts 128 being open circuited and in an on-target position and the other contact 130 being in an off-target position. The armature 126 is spring-biased against the off-target contact and is driven to the on-target contact 128 upon energization of an electromagnet 132, the electromagnet having a delay period such as 50 milliseconds.

The on-target and off-target indications from the tank circuit 61 are fed via a lead 134 to a trigger circuit 136, the trigger circuit being the brain of the guidance system for switching all of the heretofore-mentioned circuits as well as a no-target safety circuit which will be discussed later. The trigger circuit 136 has four armatures 138, 140, 142 and 144, the armatures 138 and 144 being connected to ground and the armature 140 being connected

to a potential source and the armature 142 being connected to the contacts 54 of the delay switch 40. Each of the armatures is disposed between a pair of contacts and operate between an on-target position and an off-target position, the armatures being spring-biased in their on-target position as shown in the drawings. Associated with the armature 140 is a contact 146 located in the on-target position and a contact 148 which is located in the off-target position, the on-target contact 146 being connected to the electromagnet 132 of the sweep-circuit relay 124 and to the electromagnet 110 of the memorizing and transmitting circuit 96. The off-target contact 148 is open-circuited. The armature 138 is associated with a contact 150 in an on-target position and a contact 152 in an off-target position, the on-target contact 150 being connected to the armature 126 of the sweep-circuit relay 124 and the off-target contact 152 being connected to a grid of one of the tubes of the monostable multivibrator 153. The armature 142 is associated with a contact 154 which is located in an on-target position and a contact 156 which is located in an off-target position, the contact 156 being connected to the sweep-circuit 74. The lead 134 from the tank circuit 61 is connected to the off-target contact 130 of the sweep-circuit relay 124 and to a grid of a triode tube 158. The output of the tube 158 is connected to an electromagnet 160, the electromagnet 160 driving all of the armatures 138 through 144 to an off-target position upon energization. As stated previously, the on-target indication from the tank circuit is an absence of signal whereas an off-target indication therefrom is the presence of a signal so that when the tank circuit has an on-target indication the armatures 138 through 144 are spring-biased against the on-target contacts thereof and upon an off-target indication from the tank circuit the electromagnet 160 is energized so as to drive the armatures 138 through 144 to connect with the off-target contacts. It can now be seen that the armature 140 of the trigger circuit 136 controls the operation of the sweep-circuit relay. However, the armature 126 of the sweep-circuit relay will not exactly follow the armature 140 since the armature 126 will be delayed for a period in contact with the off-target contact 130 after the armature 140 goes from an off-target position to an on-target position. This means that the armature 126 will remain in an off-target position for the delay period even though the tank circuit 61 is producing an on-target indication. Of course, after the delay period within the sweep-circuit relay the armature 126 will follow the armature 140 to assume an on-target position.

The monostable free running multivibrator 153 is powered by a B+ power source and is connected to one of the grids of the camera tube 10 for the purpose of partially blanking out the continual stream of electrons hitting the photo cathode of the camera tube, thereby eliminating burning or spotting of the tube. When the beam is in spiral operation, the multivibrator is disconnected from the circuit by grounding the grid of one of the tubes through the armature 138. It is necessary to produce square wave blanking signals to the camera tube so as not to alter the characteristic voltages for the target imprinted on the photo cathode.

A safety no-target circuit 162 is connected to each of the off-target contacts 104 of the memorizing and transmitting circuit 96 and to the electromagnet 50 of the delay switch 40. The safety switch 162 has four grounded armatures 164, these armatures operating between an open-circuit position and closed-circuit position (the drawings showing the armatures 164 in their open-circuit position). Located in the closed-circuit position of each armature 164 is a contact 166, each of these contacts being connected to a respective one of the contacts 104 of the memorizing and transmitting circuit 96. Accordingly, when the armatures 164 are in their open-circuit position the memorizing and transmitting circuit 96 is allowed to feed signals from the capacitors 100 to the

direction-control circuit 106. However, when the armatures 164 are in their closed-circuit position the contacts 104 are grounded out so as to prevent any signals from passing from the memorizing and transmitting circuit 96 to the direction-control circuit 106. Each of the armatures 164 is spring-biased to a closed-circuit position and each is driven to an open-circuit condition by energization of an electromagnet 168. Associated with the armature 144 is a contact 170 located in the armature's on-target position and a contact 172 located in the armature's off-target position, the on-target contact 170 being connected to the grid of a thyatron tube 174 and the off-target contact 172 being connected to the electromagnet 50 of the delay switch 40. The thyatron tube 174 has a delay period prior to conduction such as 6 seconds so that upon removal of ground to the grid thereof a potential source applied through a lead 175 causes the tube 174 to conduct after 6 seconds delay period. Accordingly, if the camera tube is off target for more than 6 seconds, the thyatron tube 174 will energize the electromagnet 168 so as to ground out the signals from the memorizing and transmitting circuit 96. Accordingly, once activated the thyatron tube 174 remains in operation and the guidance system no longer controls the missile so that the missile continues on its present course without seeking undesirable targets.

In the operation of the guidance system the pilot of an aircraft aligns the central axis of the camera tube on the desired target and then he closes the firing switch by manually operating the arm 30. At this time an original on-target signal representing the light intensity of the target when the camera tube is aligned on the target is fed for a delay period via the contact 46 of the delay switch 40 to the biasing capacitor 60 and the first reactance tube 56. This sets an original on-target signal on the biasing capacitor 60 which signal is used for comparison with subsequent signals emanating from the camera tube. After the delay period all subsequent signals of the camera tube are fed to the second reactance tube 58 after which they are fed to an oscillator 68 having the same frequency as the tank circuit 61. Both the original on-target signal from the first reactance tube 56 and the subsequent signal from the oscillator 68 are fed to the tank circuit 61 where they are compared. When the original on-target signal and the subsequent signals are equal, the tank circuit 61 produces an on-target indication by having an absence of any signal output and when the original on-target signal and the subsequent signals are not equal the tank circuit 61 becomes unbalanced so as to give an off-target indication by producing a signal output.

When there is an on-target indication produced by the tank circuit all of the armatures of the trigger circuit 136, the sweep-circuit relay 124, the memorizing and transmitting circuit 96 and the safety no-target circuit 162 are in their on-target position. In this position relay 124 is open, is deactivated, the automatic adjust circuit 112 is energized for resetting the original on-target signal every second, the capacitors 100 of the memorizing and transmitting circuit 96 are connected to memorize the signals of the deflection coils 12 and 14 and the safety no-target circuit 162 is grounded out to render it inoperative. When the central axis of the camera tube becomes misaligned with the target the tank circuit 61 will produce an off-target indication which will drive the aforementioned armatures in this paragraph to an off-target position. This is accomplished by the electromagnet 160 driving the armatures 138, 140, 142 and 144 to their off-target position. When the armature 142 is driven to its off-target position a B+ voltage is picked off of contact 156 (this voltage being received from the armature 44 via the contact 54 of the relay switch 40) and this voltage is applied to the sweep circuit 74 to cause its activation. When the armature 140 is driven to its off-target position the potential to the electromagnet 132 is removed so that

the armature 126 of the sweep-circuit relay 124 is spring-biased to its off-target position. Further, when the armature 140 assumes its off-target position, the potential to the electromagnet 110 of the memorizing and transmitting circuit 96 is removed so that the armatures 98 are spring-biased to connect with the contacts 104. Also, after the off-target indication, the automatic adjust circuit 112 is open-circuited by the armature 142 so that it will not reset erroneous original signals on the biasing capacitor 60. Further, after an off-target indication the safety no-target circuit 162 is energized so that after the delay period, namely, 6 seconds, it will ground out the signals from the memorizing and transmitting circuit 96 thus preventing the guidance system from homing upon an undesired target. As a result, the missile control surfaces remain in neutral position and the missile is no longer controlled until another "on-target" signal is received.

When the armature 126 of the sweep-circuit relay 124 assumes an off-target position, armature 126 is spring loaded against the contact 130. At this time spiral sweep of the beam of the camera tube is conducted until such time as the target is again picked up by the beam, providing this is within the 6 second delay period of the safety no-target circuit 162. Upon the beam again picking up the target the tank circuit 61 produces an on-target indication causing the armatures 138 through 144 to assume once again their on-target position. At this time the potential source on the armature 140 is applied to the electromagnet 132 of the sweep-circuit relay 124 and to the electromagnet 110 of the memorizing and transmitting circuit 96. The armature 126 of the sweep-circuit relay 124 will not immediately follow the armatures of the trigger circuit 136 since the sweep-circuit relay has a time delay, this time delay causing the armature 126 to remain connected to the off-target contact 130 for a delay period after the sweep picks up the target. During this delay period any off-target indication from the tank circuit 61 is grounded out through the armatures 126 and 138 so as to maintain the armatures of the trigger circuit 136 in an on-target position during the delay period of the sweep-circuit relay. Also, during this on-target phase the electromagnet 110, upon being energized by the potential on the armature 140, drives the armatures 98 of the memorizing and transmitting circuit 96 to connect with the contacts 102 so that the capacitors 100 will memorize the on-target signals impressed upon the deflection coils 12 and 14. Isolation is maintained between the deflection coils 12 and 14 and the memorizing and transmitting circuit 96 by the transformers 82.

After the delay period of the sweep-circuit relay the armature 126 thereof assumes its on-target position to connect with the contact 128. During the on-target phase the capacitors 90 and 92 of the holding and discharge circuit 89 are discharged through decay. Although sawtooth voltage will collapse across gas tube 79, the beam on the camera tube will not be as rapidly affected due to high inductance and resistance in isolation transformers 82, thereby allowing capacitors 100 in memorizing and transmitting circuit 96 to load. Though the sawtooth voltage will collapse across the gas tube 79, the beam on the camera tube 10 will not be effected due to the isolation of transformer 82.

After the armature 126 assumes its on-target position an off-target indication will be fed to the trigger circuit once again causing the armatures thereof to assume their off-target position. This off-target indication is developed by an overshooting of the sweep past the target, which overshooting is caused by a normal delay of the relay of the trigger circuit 136. While this relay has not been described as a delay relay even a quick-acting relay has a delay period such as 8 milliseconds which should be sufficient to allow the sweep of the beam to overshoot. If the chain of events is such that an on-target indication is present after the delay period of the sweep-circuit

relay 124 this condition will soon change to an off-target indication because of the swing of the missile.

When the off-target indication is again fed to the trigger circuit the potential on the armature 140 of the sweep-circuit relay 124 is removed from the electromagnet 110 of the memorizing and transmitting circuit 96 so as to allow the armatures 98 to be spring-biased to connect with the contacts 104. Upon such a connection, the signals upon the capacitors 100 are transmitted to the direction control circuit 106 where they are utilized for guidance purposes, and the holding and discharge circuit 89 is put into operation. Also, during this off-target phase, the potential on the armature 142 of the trigger circuit 136 is applied to the gas tube 79 of the holding and discharge circuit 89 via the Y connection so as to commence another sweep. All tubes in the sweep circuit 74 are operating and the spiral sweep is applied to the deflection coils 12 and 14 on the camera tube 10 via the transformer 82. When the on-target phase occurs, by action of the armature 142 breaking connection with the contact 156, potential is removed from Y and the tubes in the sweep circuit 74 stop conducting. The voltage across gas tube 79 is lost through decay. With introduction of another off-target phase the beam in the camera tube 10 will again start from the center and spiral sweep outward to some point where the target is located. There is no danger of losing the signal from the deflection coils on the camera tube when the sweep circuit is not operating due to the isolation of transformer 82 and the short time for the memory circuit 100 in the memorizing and transmitting circuit to absorb the signal.

In the off-target phase the beam in camera tube 10 is spiraling outward at a rapid rate. As it passes through the target, a drop in potential is felt in line 134 which triggers tube 158, causing relay 160 to throw armatures 140 and 142 to points 146 and 154, the on-target position, respectively. Since rapid motion of the spiraling beam may overshoot the target somewhat notwithstanding use of the most rapidly acting relays, the 50-millisecond delay relay 132 is installed in which the overshooting beam, showing only a pulse of on-target signal, will be sensed. In accomplishing this, the 50-millisecond delay relay 132 in sweep circuit relay 124 allows armature 126 to stay in contact with point 130 and the subsequent overshoot off-target potential through point 150 and armature 138 is grounded for 50 milliseconds. Trigger circuit 136 is thereby allowed to stay in the on-target phase for 50 milliseconds until armature 126 returns to point 128 at which time the off-target potential is applied to the grid of trigger tube 158 allowing relay 160 to activate armatures 140 and 142 to the off-target positions.

In overall operation, the system is activated upon the launching of a missile containing the present invention and capacitor 60 is charged to an amount representative of a selected target signal on camera tube 10. So long as the course of the missile continues on-target, the remainder of the system is inactive. However, should the course of the missile deviate off the target a signal will be produced whose frequency will be determined by the variation in frequencies emanating from tank circuit 61 and oscillator circuit 68, this signal being conducted to the trigger circuit by lead 134. When such an off-target signal occurs, electromagnet 160 is energized actuating armatures 138, 140, 142 and 144 from the position shown in the drawings to their alternate or off-target position. Actuation of armature 138 disconnects multivibrator 153 from the circuit by grounding the grid of one of its tubes. When on-target, the multivibrator keeps the continuous electron beam from burning the camera tube photocathode face. Since the beam would sweep across the photocathode face during off-target, its pulsing becomes unnecessary. Actuation of armature 140 deenergizes electromagnet 132 thereby allowing spring loaded armature 126 to shift to contact 130 after some delay. Its function in switching from "on" to "off-target," i.e. from

contact 128 to 130 is not important. However, when an "off" to "on-target" signal is sensed in the trigger circuit 136, armature 138 switches back to contact 150 thereby allowing any signal to travel to ground through contact 130 and armature 126 for the period of time delay set in the delay relay 132. This delay, say 50 milliseconds, will insure positive lock of all armatures in the trigger circuit 136 to on-target when the on-target frequency is momentarily recovered by trigger tube 158. During the missile's travel towards the target, in which the camera tube beam is pointed to the target and no signal is generated to the trigger circuit 136, armature 142 remains in contact with point 154 allowing some potential, for example B+, to be applied to the automatic adjust circuit 112 through armature 44 and contact 54 to Z. Circuit 112 accounts for the light intensity change of the target on the camera tube face as the missile gets closer to the target. It does this by periodically resetting the electrical bias on reactance tube 56 via the loading capacitor 60. This period, for example, 1 second, is governed by the discharge of thyratron tube 120 in the circuit 112. During the off-target phase armature 142 is mated with contact 156 thereby removing B+ from the adjust circuit and applying it at Y. There is no possibility of circuit 112 rebiassing for a change in relative light intensity during an off-target phase. The B+ is now applied to sweep circuit 74 via Y. With the sweep circuit in operation, an expanding spiral is imposed upon the centered electron beam in the camera tube through deflection coils 12 and 14. The expanding spiral beam, representing the off-target phase, is seeking the original selected target signal on camera tube 10. When the expanding spiral beam finds the original target a momentary interruption in the signal, emanating through line 134 to trigger circuit 136, will occur. This interruption will be sufficient to lock the armatures in circuit 136 to "on-target" for a period of 50 milliseconds by the action of delay relay 132 as previously explained. During this time period potential is removed from Y deactivating sweep circuit 74. The last position of the spiral electron beam in camera tube 10 is registered in memorizing and transmitting circuit 96 where the on-target signals impressed upon deflection coils 12 and 14 are transmitted to capacitors 100 via contacts 102 and armatures 98. Once the delay period of the relay 132 has expired, the system will again sense an off-target signal from the lead 134. Memorizing and transmitting circuit 96 will transmit the newly achieved relative position of the target to direction control circuit 106 by action of relay 110. With the circuit 91 disconnected from camera tube deflection coils 12 and 14 during off-target, the coils are free to generate another outward spiral sweep of the beam from the center of the camera tube. Should the camera tube beam fail to identify the original target and in its outward spiral reach the edge of the tube the spiraling beam will collapse to the center by action of thyratron tube 79 in holding and discharging circuit 89. The process will again be repeated while in this off-target phase. Should failure to acquire the target continue after a prolonged time in off-target phase, safety no-target circuit 162 will actuate to neutralize directional control circuit 106 through contacts 166 and armatures 164 to ground. The process in retrospect is as follows. Missile is launched with the target light intensity impressed upon the center of a photocathode camera tube. As the given target light intensity moves from the center of the photo cathode, a change in voltage response occurs, which is sensed by trigger circuit 136. Through mechanical switching action sweep circuit 74 rotates the electron beam within the camera which had previously been centered on the target in the center of the camera tube. As the beam spirals outwards at a rapid rate, it crosses the target image, and original light intensity, causing trigger circuit 136 to stop the outward beam spiraling process. The left-right and up-down position of the beam on camera tube deflection coils

12 and 14 are rapidly sampled by memorizing and transmitting circuit 96, and then fed to direction control circuit 106. The beam snaps back to the center for another outward sweep while the missile vanes 108 are adjusting the missile back onto its line of sight course. To account for relative change of target light intensity as the missile approaches the target, the automatic adjust circuit rebiases new target light periodically.

The trigger circuit 136, in conjunction with the sweep-circuit relay 124, continuously recycles the guidance system until it is brought back on target successfully. This continuous recycling of the guidance system brings the camera tube gradually back on the target and eliminates any overshooting or hunting thereof.

Once the camera tube has been aligned on the target after a continuous recycling of the sweep and transmission of signals to the direction control circuit 106, the tank circuit will then produce an on-target indication and the armatures of the trigger circuit 136, the sweep-circuit relay 124, and the memorizing and transmitting circuit 96 and the safety no-target circuit 162 will once again assume their on-target position.

It is obvious that the camera tube should be very responsive and, accordingly, it is desirable to use an RCA vidicon tube model 6198 as a visual pickup.

It is now readily apparent that the present invention provides a new concept in automatic guidance systems. It can be employed aboard a missile which is to be launched from an aircraft, thus relieving the pilot from the dangers that have been imposed upon him by flying previous aircraft missiles practically all the way to the target position.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. An automatic guidance system for homing on a target comprising a camera tube having a signal output proportional to the light intensity viewed by said camera, said camera being on target when an alignment axis is aligned on a target and being off target when the axis is misaligned with said target, a time delay switch means connected to the camera and to first and second reactance circuits for receiving the signal output and communicating an original on-target signal to the first reactance circuit for a time delay period and then subsequent signals to the second reactance circuit for a subsequent period, oscillator means connected to and receiving the output of the second reactance circuit for producing a signal of a predetermined frequency, capacitor means connected between the time-delay switch means and the first reactance circuit for receiving the original signal and feeding this signal to the first reactance circuit, tank means having a static band reject of said predetermined frequency connected to the first reactance circuit and the oscillator means for producing an off-target signal when there is an imbalance between the on-target signal applied to the capacitor means and any subsequent signal applied to the second reactance circuit, a sweep circuit connected to deflection coils within the camera, means for memorizing the voltage on each deflection coil, means connected to the memorizing means and responsive to indications from the tank means for connecting the memorizing means to the deflection coils when there is an on-target indication and for connecting the memorizing means to a control circuit when there is an off-target indication immediately following an on-target indication whereby the control circuit will be fed signals from the deflection coils substantially representing the condition of the coils at a time when the sweep of the camera was on target, means connected to the sweep circuit and responsive to indications from the tank means for activating the sweep circuit when there is an off-target signal, means connected to the sweep

circuit for holding the sweep substantially on the target after the sweep locates said target, means connected to the holding means and responsive to indications from the tank means for inactivating the holding means when there is an off-target indication immediately following an on-target indication and means connected to the tank means for grounding out the signals from the tank means for a delay period so that the memorizing means has sufficient time to store the signals on the deflection coils prior to their passing to the control circuit for direction-changing purposes.

2. An automatic guidance system as claimed in claim 1 including adjustment means connected to the time-delay switch means for causing the time-delay switch to periodically pass a new on-target signal to the first reactance circuit for another time-delay period whereby changes in the light intensity of the target as the camera is positioned at various distances therefrom will not introduce error into the system.

3. An automatic guidance system as claimed in claim 2 including means connected to the tank means and to the adjustment means for inactivating the adjustment means when there is an off-target indication whereby an original target signal from the camera will never represent an off-target condition.

4. In an automatic guidance system for homing a guided missile on a target the combination of:

a camera tube mounted in the nose of said missile; an image plate on the face of said tube upon which the electron beam of the tube impinges; said tube having a signal output proportional to the light intensity in the scene viewed by the tube; a target selected in the scene and means in the system for memorizing the intensity of the signal from said target;

means in the system for comparing the target signal with subsequent output signals and providing an on-target indication when the target signal and subsequent output signals are of the same intensity and an off-target indication when the target signal and subsequent signals differ in intensity, means responsive to the indication of the comparing means for causing said electron beam to commence a predetermined sweep pattern when an off-target indication is received, deflection coils in said tube for sensing the position of a subsequent on-target indication with respect to the original target position on said image plate, means for transmitting relative position information of the latter on-target indication to a direct control circuit in said system, and means adjusting the flight of said missile in response to signals from the direction control circuit to direct the missile's course toward said target.

5. The device of claim 4 and further including a delayed action switch interconnecting the camera tube and the comparing means for delaying the original target signal and then passing the original target signal and all subsequent signals, and

adjust circuit means connected to said delayed action switch for periodically resetting bias so as to adjust for light intensity changes of the target during on-target conditions as the missile approaches the target.

6. The device of claim 5 and further including means connected to the comparing means and the adjust circuit means for inactivating the adjust circuit means during off-target indications whereby said system is precluded from being rebiased for a change in relative light intensity during off-target indications.

7. In an automatic guidance system for homing a guided missile on a target the combination of:

a camera tube mounted in the nose of said missile; an image plate on the face of said tube upon which the electron beam of the camera tube impinges; said tube having a signal output proportional to the

light intensity in the scene viewed by the tube; a target selected in the scene and means in the system for memorizing the intensity of the signal from said target;

5 means in the system for comparing the target signal with subsequent output signals and providing an on-target indication when the target signal and subsequent output signals are of the same intensity and an off-target indication when the target signal and subsequent signals differ in intensity;

a sweep generator connected to deflection coils in said camera for causing said electron beam to sweep the scene viewed by the camera tube,

means interconnecting said memorizing means and the deflection coils of said camera tube for memorizing the voltages on the deflection coils and for relaying these voltages for guidance purposes; and

means receiving the on-target and off-target indications from the comparing means for actuating the sweep generator when an off-target indication is received and for actuating the memorizing means when an on-target indication is received;

whereby the camera will sweep when it is not aligned on the target and the voltages on the deflection coils will be relayed through the memorizing means for guidance purposes when the sweep picks up the target.

8. The device of claim 7 and further including means connected to the sweep generator for holding the beam of the camera substantially on the target after it is picked up by the sweep; and

means connected to and responsive to indications from the comparing means for inactivating the holding means a delay period after an on-target indication; whereby during the delay period the memorizing means has time to store the signals on the deflection coils after which the signals can be relayed for guidance purposes.

9. An automatic guidance system for homing on a target comprising:

a camera tube having a signal output proportional to the light intensity viewed by said camera; said camera being on target when its axis is aligned on a target and being off target when the axis is misaligned with said target;

a time-delay camera relay having an electromagnet and a break-make armature which is disposed between a pair of contacts;

means operated manually for energizing the electromagnet when the axis of the camera is aligned with the target and for simultaneously connecting the output of the camera to the armature of the camera relay;

the electromagnet of the camera relay after energization switching the armature thereof to one of the contacts of the pair for a delay period and then thereafter switching the armature to the other contact of said pair;

the delay contact of said armature being connected to a first reactance circuit and the other contact thereof being connected to a second reactance circuit whereby upon operating the manual means when the axis of the camera is aligned with the target an on-target signal is transmitted to the first reactance circuit for the delay period and after the delay period all subsequent indications from the camera are transmitted to the second reactance circuit;

a biasing capacitor connected between the camera relay and the first reactance circuit and charged with the on-target signal so that the first reactance circuit will be biased to the on-target signal level after the output of the camera is switched to the second reactance circuit;

the first reactance circuit having an output which is connected to a tuned tank;

said tank having a static band reject of a predetermined frequency;  
the second reactance circuit having an output which is connected to an oscillator;  
said oscillator having a frequency which is substantially 5 equal to said predetermined frequency;  
the oscillator having an output which is connected to the tank whereby so long as the camera axis stays aligned on the target a band reject will occur within the tank with no signal frequency output therefrom and when the camera axis is misaligned with the target a change in frequency will take place in the oscillator causing the tank to become unbalanced so as to produce an off-target signal indication;  
a spiral sweep generator connected to deflection coils 15 within the camera tube;  
a holding and discharge circuit connected to the sweep generator and a potential source;  
said holding and discharge circuit having a pair of capacitors connected across a gas discharge tube 20 which tube upon being charged capable of holding the beam of the camera a given distance from the center thereof and upon actuation capable of discharging the capacitors and terminating the holding action;  
a memorizing and transmitting circuit having capacitors 25 which are each alternately connectable to one of the camera tube's deflection coils and to a control circuit;  
a memorizing and transmitting relay having an electromagnet and a plurality of break-make armatures, each of the armatures being disposed between a pair of contacts;  
each of the armatures being mechanically linked together and operating between an on-target position 30 and an off-target position;  
one of the contacts for each armature being located in an on-target position and the other contact being located in an off-target position.  
the on-target contact of each armature being connected 40 to a respective one of the camera tube's deflection coils and the off-target contact of each armature being connected to the control circuit so that upon energization and de-energization of the memorizing and transmitting relay the charge on the deflection coils will be memorized by the capacitors and passed 45 on to the control circuit;  
a pair of capacitors connected in parallel in the second reactance circuit;  
a sweep circuit relay having an electromagnet and an 50 armature, the armature being connectable to ground and having an on-target position and an off-target position;  
a first one of the contacts being located in the on-target position and connected to the second reactance circuit 55 for receiving the signal from said camera tube and a second one of the contacts being located in the off-target position and connected to the output of the tank circuit;  
a trigger relay having an electromagnet and a plurality 60 of break-make armatures;  
said electromagnet being connected to said tank means so as to be energized thereby when there is an off-target signal;  
each of the trigger armatures being mechanically linked 65 together and operating between an on-target position and an off-target position;  
a first trigger armature having a contact in its on-target position which is connected to the electromagnet of the sweep circuit relay and to the electromagnet of 70 the memorizing and transmitting relay, the first trigger armature being open-circuited in its off-target position whereby the sweep circuit relay is inactivated and the memorizing and transmitting circuit is connected to the camera tube's deflection coils 75

when the camera is on target and the memorizing and transmitting circuit is connected to the control circuit when the camera is off target;  
a second trigger armature having a contact in its off-target position which is connected to the sweep circuit and the holding and discharge circuit for activating the sweep and the gas discharge tube respectively so that the sweep is conducted until such time that as on-target signal is received at which time the said pair of capacitors control the beam of the camera a given distance from the center of the camera and the gas tube will discharge the capacitors to snap the beam back to the center when the trigger relay receives an on-target signal;  
a third trigger armature having a contact in its on-target position which is alternately connectable between the on-target and off-target contacts of the sweep relay, the third trigger armature being connected to ground whereby upon an on-target indication from the tank circuit the trigger relay assumes an on-target position and is held there for the delay period of the sweep relay by grounding the on-target indication through the sweep relay and the third trigger armature and after the delay period of the sweep relay the ground to the trigger relay is removed causing the trigger relay to assume an off-target position thus commencing the sweep until such time that the signals sent to the control circuit bring the camera tube back to an on-target position.  
10. The device of claim 9 and further including an adjustment relay having an electromagnet and a break-make armature which is grounded and disposed between a pair of contacts;  
the adjustment-relay armature operating between an on-target position and an off-target position;  
one of the contacts of the adjustment relay being located in the on-target position and the other contact thereof being located in the off-target position;  
the on-target contact of the adjustment relay being connected to the electromagnet of the time-delay camera relay so that when the armature of the adjustment relay contacts its on-target contact the time-delay relay electromagnet is grounded and when the armature of the adjustment relay contacts the off-target contact thereof the time-delay relay electromagnet is open-circuited;  
the off-target contact of the adjustment relay being connected to a contact located in the on-target position of the second trigger armature so that when the electromagnet of the second trigger armature receives an on-target indication the armature of the adjustment relay will contact its on-target contact and when the electromagnet of the second trigger armature receives an off-target indication the armature of the adjustment relay will contact its off-target contact; and  
means connected to the on-target contact of the second trigger relay and to the adjustment relay for causing the adjustment relay to periodically contact the off-target contact thereof for a period so that the time-delay relay will periodically send new original signals to the first reactance circuit so as to compensate for changes in the light intensity of the target as the camera tube assumes various distances therefrom.  
11. The device of claim 10 and further including a no-target safety circuit including a safety armature corresponding to each off-target contact of the memorizing and transmitting circuit;  
the safety armatures having a no-target position and a safe position;  
a no-target contact connected to each of the off-target contacts in the memorizing and transmitting circuits which are connected to the control device and located in the no-target position of each of the armatures so that when the armatures are connected to the no-

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target contacts the memorizing and transmitting circuit is grounded out;  
 a trigger circuit grounded armature operable between an on-target position and an off-target position;  
 a contact in each of the positions of the armature;  
 the contact in the off-target position being connected to the electromagnet of the firing-delay switch and the contact in the on-target position being connected to a grid of a thyratron tube;  
 the thyratron tube having a predetermined delay upon energization and an output which is connected to a safety electromagnet; and  
 a potential source connected to the grid of the thyratron and the on-target trigger contact;

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whereby when the camera tube is off target for the delay period of the thyratron the memorizing and transmitting circuit will be grounded out so as to prevent the guidance system from homing on an undesired target.

No references cited.

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