Jan. 6, 1953 L. J. B. LA COSTE 2,624,510

ELECTRONIC AIRCRAFT GUN FIRE CONTROL COMPUTER

Filed March 22, 1945

FIG. 1

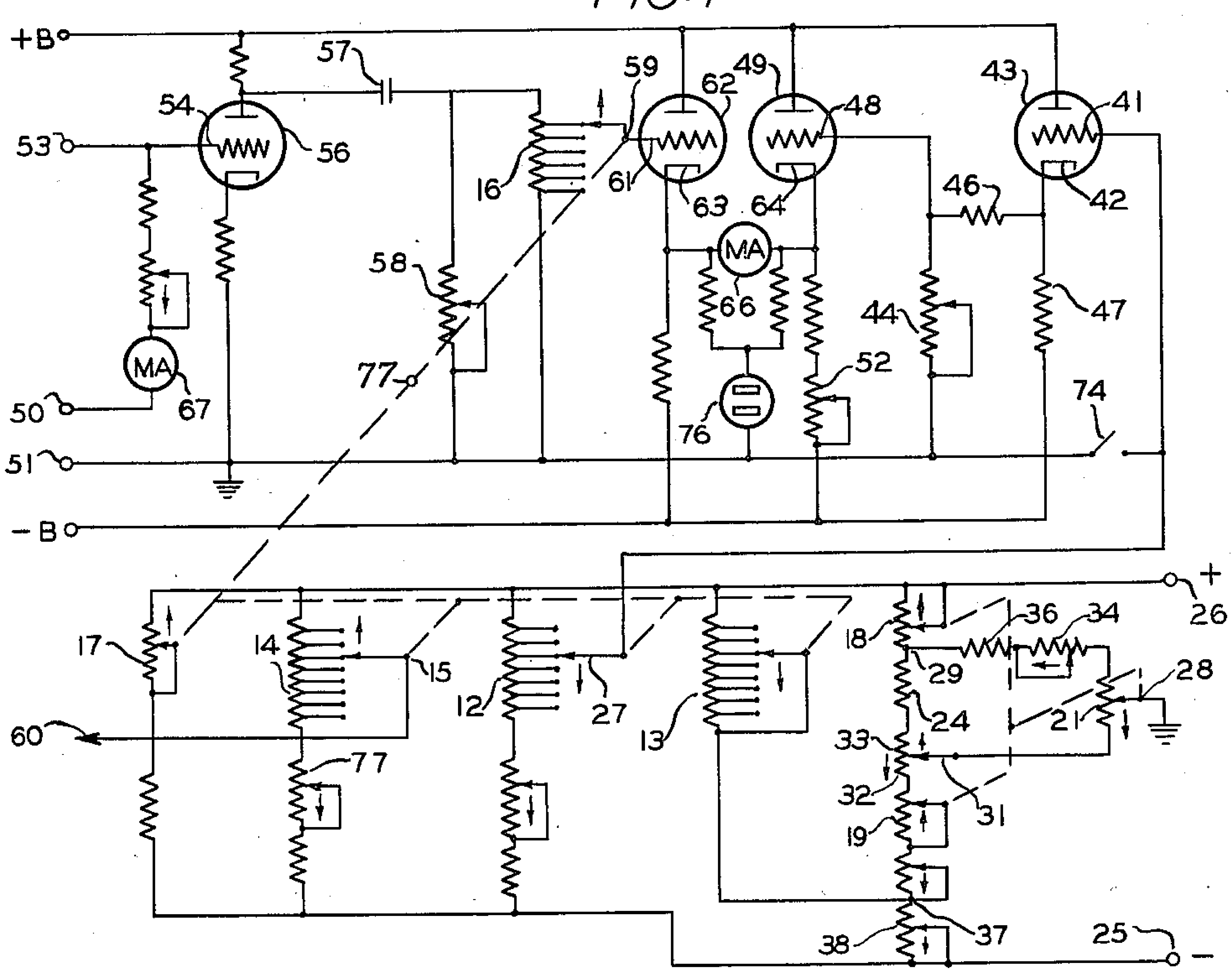
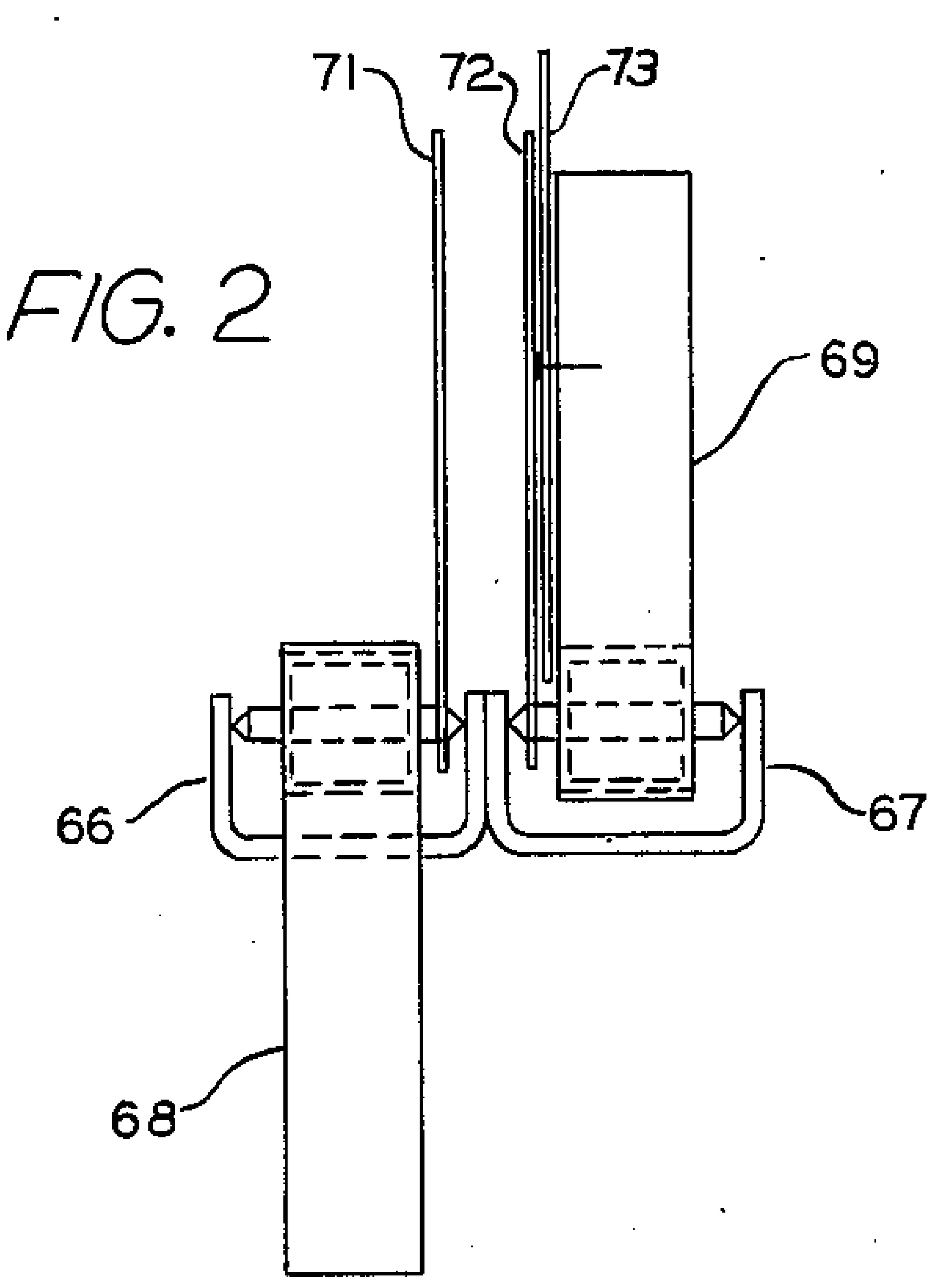


FIG. 2



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ELECTRONIC AIRCRAFT GUN FIRE CONTROL COMPUTER

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2 Claims. (Cl. 235—61.5)

This invention relates in general to electrical circuits for the solution of mathematical equations and more particularly to a computer for solving the ballistic problem presented by the firing of airborne guns.

One type of fighter plane carries guns for firing fused shells; the fuse may be adjusted so that the shells will explode at a predetermined time after firing. The plane may also carry apparatus for indicating the azimuth, elevation, and range of the target with respect to the plane.

It is an object of this invention to provide as a meter deflection an indication of the proper range at which to fire the gun so that the explosive shell will explode at the target or in its immediate vicinity.

It is also an object of this invention to provide data for the control of superelevation necessary to compensate for the gravitational drop of the projectile.

Other objects, features, and advantages of this invention will suggest themselves to those skilled in the art and will become apparent from the following description of the invention taken in connection with the accompanying drawing, in which:

Fig. 1 shows a schematic wiring diagram of a computer using the principles of this invention; and

Fig. 2 shows an arrangement of meters **66** and **67** of Fig. 1 for rapid comparison of their respective readings.

The equation which gives the necessary future range at which to fire for the particular shells to be used, is given by the following formula:

$$R_f = Vt - f_1(t)[K_1S + (1+K_2S)K_3\epsilon^{[\log(288-2H)-\log T-K_4H]}] - \dot{R}t \quad (1)$$

where:

R_f=the range at which to fire.
V=the muzzle velocity.
S=the indicated air-speed.
H=the altitude.
ϵ=the base of the Naperian logarithm system.
T=the air temperature at altitude H.
$f_1(t)$=an empirical function obtained from the ballistic data for the shell used.
t=the fuse time or time of flight of the shell.
$\dot{R}$=the time derivative of the actual range.
K_1, K_2, K_3, K_4 are constants which satisfy the ballistic equation.

Equation 1 may be rewritten in a simpler form by substituting the expression $f_2(H,T)$ for the exponential term in the bracket as shown below:

$$R_f = Vt - f_1(t)[K_1S + (1+K_2S)f_2(H,T)] - \dot{R}t \quad (2)$$

The formula consists of three terms, the first term of which simply states that the uncorrected firing range or future range is the shell velocity V multiplied by the fuse time t which gives the distance or range, e. g.

$$\frac{\text{yd.}}{\text{sec.}} \times \text{sec.} = \text{yds.}$$

The last term is a correction to be added to the first term to compensate for the changing distance between the craft and the target assuming that this distance or present range R is decreasing at a uniform rate (constant velocity). Therefore the velocity $\dot{R}$ multiplied by the fuse time t is a negative distance and will be subtracted from the first term to give an increase in the range to which the shell should be fired, e. g.

$$-\left(-\frac{\text{yds.}}{\text{sec.}} \times \text{sec.}\right) = \text{yds.}$$

The second term is also a correction of the range to compensate for the ballistic effects of air speed, temperature and altitude and is empercially derived. Dimensionally the coefficient $f_1(t)$ is time in seconds and within the bracket the terms dimensionally express velocity so that again we have,

$$\frac{\text{yds.}}{\text{sec.}} \times \text{sec.} = \text{yds.}$$

which is to be subtracted from the first term to give the firing range.

The algebraic sum of the three terms is the future of firing range R_f.

To provide a meter reading of future range, voltages proportional to the three terms of the ballistic equation are to be established and algebraically added and applied to the indicating meter **66**. Voltage proportional to the present range is applied to meter **67**. Thus meter **67** shows present range and when the reading of **66** and **67** are the same the guns should be fired. The voltage indicating present range may be obtained from other equipment, not shown, carried by the plane. Range determining equipment is well known and any such equipment giving accurate range may be used to give a voltage indicative of range to the equipment described herein.

Referring now more specifically to Fig. 1, potentiometers **12**, **13**, **14**, **16**, and **17** are ganged together and are adjusted in accordance with t, the fuse time. The arrows indicate increasing t. Considering this adjustment alone it will be evident that the voltage applied to the grid of vacuum tube 62 is increased positively and that to the grid of vacuum tube 43 is decreased if the setting of the fuse time of the shells which are to be used is increased. This is an adjustment which can be made before taking off from the ground and affects the value of t in all three terms of the equation. Potentiometers 18, 19, and 21 are similarly ganged and are adjusted in accordance with S, the indicated air-speed. The arrows indicate increasing S. Thus it will be seen that for this adjustment considered alone the voltage will be increased positively on the grid of tube 43 for increasing air speed. This adjustment would be made in the air and affects the value S in the second term of the equation. A dual adjustment of potentiometer 32, presently to be described, affects the quantities H and T in the second term of the equation. A consideration of the circuit in detail as follows:

The first term of Equation 2 is proportional to the voltage between terminal 26 and tap 27 of potentiometer 12. As the fuse time knob 77 is rotated, tap 27 varies the voltage proportional to Vt.

The second term of Equation 2 is proportional to the voltage between terminal 26 and tap 28 of potentiometer 21 which is grounded. The first term in the bracket, K_1S, appears as a voltage between terminal 26 and junction 29. Added to this is the voltage between junction 29 and tap 28 of potentiometer 21. This latter voltage represents a fraction $1+K_2S$ of the potential between junction 29 and tap 31 of potentiometer 32. The tap 31 of potentiometer 32 is adjusted in accordance with the altitude H, while the body 33 of potentiometer 32 is rotated in accordance with temperature T. Potentiometer 32 is made non-linear to obtain equally spaced scale markings. It is recognized that adjustments for altitude and temperature could both be made by movement of tap 31 of potentiometer 32; however, the described arrangement is preferred because of its greater flexibility. It is obvious that potentiometer 32 may be linear if its scales for altitude and temperature are calibrated accordingly.

In order to maintain constant current through this branch so that adjustments of indicated air speed and altitude will not interact, potentiometer 19 is so connected as to compensate for variation of potentiometer 18. Additionally, the sum of resistor 24 and a portion of potentiometer 32 is made small in comparison with the sum of resistors 34 and 36 and potentiometer 21.

The voltage thus obtained at tap 28 of potentiometer 21 with respect to terminal 26 is modified in accordince with $f_1(t)$ by potentiometer 13 which is made non-linear in such a way that the voltage between terminal 26 and junction 37 is proportional to $f_1(t)$. Minor errors in the non-linear winding of potentiometer 13 are compensated by potentiometer 38.

It is evident that the potential difference between tap 27 of potentiometer 12 and tap 28 of potentiometer 21 represents the difference between the first and second terms of Equation 2.

This potential difference is applied directly to grid 41 and through resistors 44 and 46 to cathode 42 of triode 43. Triode 43 is connected as a non-inverting amplifier, the detailed operation of which will be obvious to those skilled in the art.

The output from triode 43 appears as a voltage across resistor 47 and is applied between grid 48 of triode 49, and the remote end of cathode resistor 52 associated with triode 49. Triode 49 is connected as one-half of a differential cathode follower.

The third term in Equation 2 is obtained as follows: A direct voltage proportional in magnitude to present range R is supplied from other equipment as mentioned above between terminals 50 and 53. From here it is fed to grid 54 of triode 56 which is connected as a conventional resistance-coupled amplifier. The output of this amplifier passes through condenser 57 to potentiometer 16. The time constant of condenser 57 and the parallel combination of potentiometer 16 and resistor 58 is made small so that the voltage applied to potentiometer 16 is proportional to the time derivative of the actual range. Since the tap 59 of potentiometer 16 is adjusted in accordance with fuse time t, as previously mentioned, the voltage applied to grid 61 of triode 62 represents the product $\dot{R}t$. Cathodes 63 and 64 of tube 51 are connected through milliammeter 66 so that the latter will indicate differences of potential between said cathodes. Thus, the reading of milliammeter 66 represents R_f, the future range at which to fire.

For greater convenience of the gunner, a voltage indicative of actual range which is supplied between terminals 50 and 53 is made to appear as an indication on milliammeter 67. It is preferred that milliammeters 66 and 67 be combined so that both needles have a common pivotal axis and appear on one dial face. The gun is fired when the needle showing range at which to fire and the needle showing actual range coincide.

Referring now more particularly to Fig. 2, meter 67 is the meter indicating present range, and meter 66 is the meter indicating the range at which to fire. These meters are assembled as described above with their needle-axes in alignment. The magnet 68 of meter 66 is inverted with respect to the magnet 69 of milliammeter 67 to allow needles 71 and 72 of meters 66 and 67, respectively, to be read against scale 73.

Referring again more particularly to Fig. 1, switch 74 is used for calibration purposes by short-circuiting voltage applied to grid 41 of triode 43. With the aircraft stationary on the ground and with a fixed target, the rate of change of actual range is also zero, and milliammeter 66 is then adjusted to zero by adjustment of resistor 52.

Neon lamp 76 is included for the purpose of limiting the voltage between milliammeters 66 and 67, since a high potential between them might cause their indicating needles to be attracted to one another.

The necessary superelevation correction is given by the formula:

$$E=K\{Vt+f_1(t)\,[K_1S+(1+K_2S)\,f_2(H,T)\,]\}\quad(3)$$

where the symbols have the same significance as before. It is seen that this this expression is very similar to Equation 2 for R_f, in that the term in the bracket is identical. However, in Equation 3 the voltage Vt must be added to the voltage between terminal 26 and tap 28 of potentiometer 21 rather than subtracted. Therefore, the direction of rotation of potentiometer 14 is reversed from that of potentiometer 12 so that the voltage between terminal 26 and tap 15 of potentiometer 14 represents a constant minus Vt. This causes the potential between taps 15 and 28 to be proportional to the sum of these terms as required in Equation 3, potentiometer 77 being so adjusted as to apply the correct constant of proportionality.

This resulting potential difference appearing between terminal 60 and ground is fed to the apparatus determining the azimuth and elevation of the target with respect to the plane. Such apparatus is well known and any such apparatus may be used which will supply accurate information as to the azimuth and elevation of the target. The axis of said apparatus is depressed with respect to the axis of the plane by a servo mechanism controlled by said potential difference, so that although said apparatus indicates that the plane and its fixed guns point at the target, the plane is actually pointed up sufficiently to overcome the fall of the projectile due to gravity.

The necessary voltage for operation of the network between junctions 25 and 26 is supplied by a voltage-regulated power supply which is ungrounded and can float in accordance with the requirements of this network. In order to aid further in maintaining constant potential between terminals 25 and 26, an additional current branch containing potentiometer 17 is added. This is varied also in accordance with fuse time *t* in such a manner as to give approximate compensation for the current requirements of the other branches.

While there has been described what is at present considered to be the preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the scope of the invention as set forth in the appended claims.

The invention claimed:

1. In an aircraft gun fire computer, an electrical circuit for establishing and coordinating a plurality of potentials representing a corresponding plurality of ballistic factors to predict the future range at which the guns should be fired, comprising means for establishing a first direct current potential representing the time rate of change of range, said means including a potentiometer-capacity network, said potentiometer being coupled to the control grid of a vacuum tube, means including a plurality of potentiometers for establishing a second direct current potential representing a summation of the parameters of muzzle velocity, air speed, altitude and temperature, means including an indicating meter for differentially combining said potentials, said means for differentially combining potentials comprising a pair of vacuum tubes, one of which is said vacuum tube, each of said tubes having cathode output load resistors and having said meter connected between the two cathodes, and means comprising a unicontrol of said potentiometers for simultaneously altering all of said potentials in accordance with the fuse time of the shell to be fired.

2. In an aircraft gun fire computer, an electrical circuit for establishing and coordinating a plurality of potentials representing a corresponding plurality of ballistic factors to predict the future range at which the guns should be fired, comprising means including a resistance-potentiometer for establishing a first direct current potential representing the time rate of change of range, means for establishing a second direct current potential representing a summation of the parameters of muzzle velocity, air speed, altitude and temperature, said last named means including an ungrounded direct current source having a first resistance-potentiometer branch in parallel therewith to provide a potential relative to ground which represents the components of air speed, altitude and temperature, and a second resistance-potentiometer branch in parallel with said first branch for subtracting a potential representing the range correction component of muzzle velocity, thereby to provide said second direct current potential, a third resistance-potentiometer branch in parallel with said potentiometer branches for adding a correction component for muzzle velocity to provide a source representing the ballistic correction for super-elevation of the aircraft's guns, means including an indicating meter for differentially combining said potentials, and means comprising a unicontrol of said potentiometers for simultaneously altering all of said potentials in accordance with the fuse time of the shell to be fired.

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