April 1, 1947. E. BRUCE 2,418,158

GUN-FIRE CONTROL

Filed Sept. 16, 1943 2 Sheets-Sheet 1

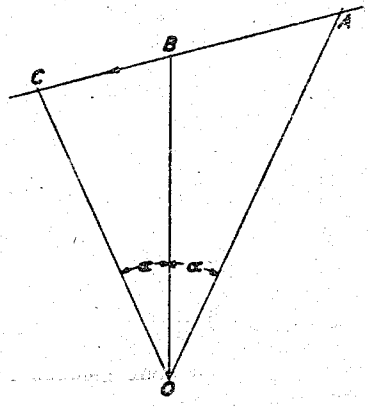


FIG. 1

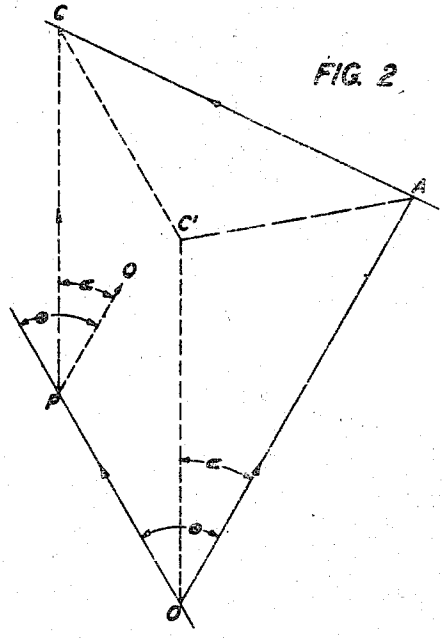
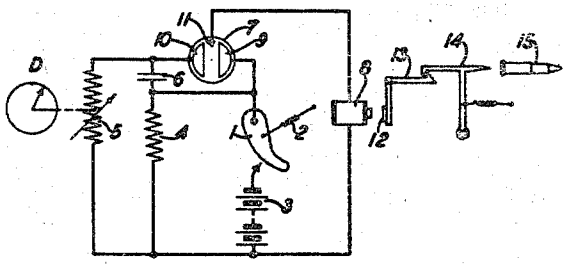


FIG. 2

FIG. 3



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Filed Sept. 16, 1943 2 Sheets-Sheet 2

FIG. 4

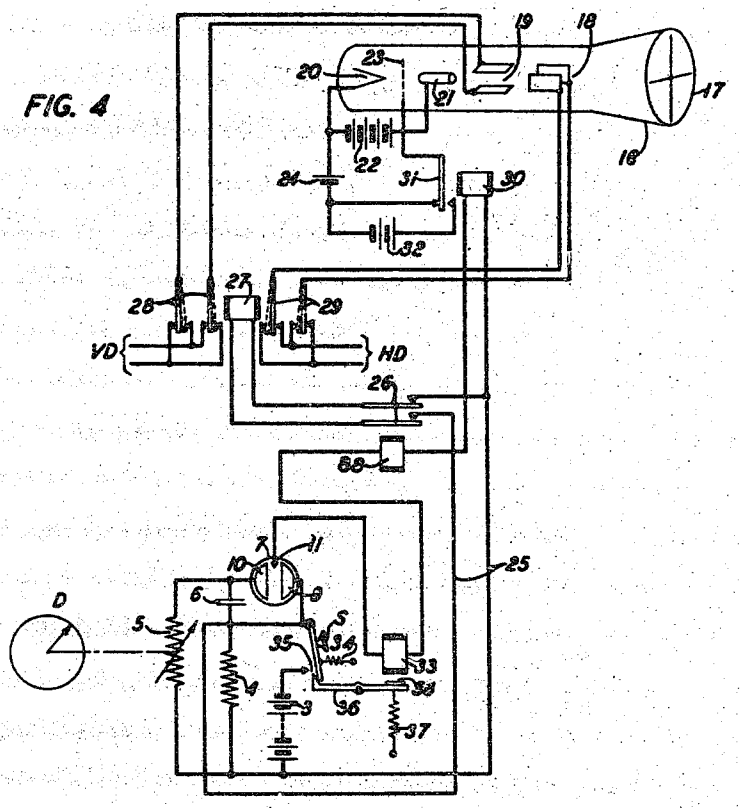
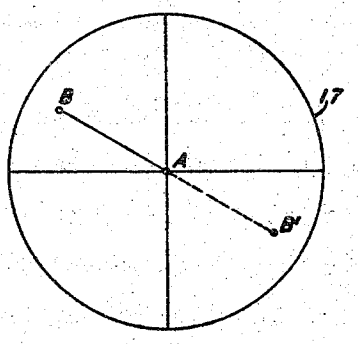


FIG. 5



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GUNFIRE CONTROL

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Application September 16, 1943, Serial No. 502,656

4 Claims. (Cl. 89—41)

1

This invention relates to an improvement in means for controlling gun-fire, particularly useful when a target to be fired on has a component of motion which is moving transversely to the line of sight.

In the case of such transverse relative motion of a gun and target, it is necessary to control the aiming of the gun appropriately in advance of the moving target and to fire when the gun points in such a direction that the target and projectile shall meet. Means are well known for determining the range from gun to target and for controlling simultaneously the axis of the gun and that of the sighting means to maintain between these axes an angle which may be constant or increasing as desired. Means also are known for computing from continuously observed data the predicted position of the target and the time of projectile flight to that position. Such computing means are in general too massive and too complex to be carried in an airplane pursuing an enemy plane or for use with mobile ordnance.

It is therefore the object of the present invention to provide means for the control of gun-fire on a target having a motion component transverse to the line of sight.

Where the range is short and ballistic corrections can be disregarded, the shell trajectory is assumed to be flat and the wind is disregarded. This is the case in the air and frequently afloat and ashore. Here the guns are previously loaded and must be fired as soon as possible after the target is sighted. It is therefore another object of the invention to provide a gun-fire control capable of operating with negligible delay.

A feature of the invention is an electrical timing circuit, energized by the gunner at the moment he obtains the initial range and direction of the target, which automatically fires the gun after the lapse of a time interval equal to the time of projectile flight over the initial range. Alternatively, this timing circuit cooperates with electrical ranging and pointing equipment to indicate to the gunner the appropriate instant and direction of fire.

It is therefore another object of the invention to provide means for indicating the required time and direction of fire from a gun position on a target moving in a direction having a component perpendicular to the line of sight from the position to the target.

The invention will be understood from the following description read with reference to the accompanying drawings, in which:

2

Figs. 1 and 2 exhibit the geometric relations underlying the principle of the invention;

Fig. 3 is a diagrammatic illustration of the electrical timing circuit employed in a gun firing circuit;

Fig. 4 is a diagram of the circuit of a cathode ray oscilloscope of an electrical ranging and pointing apparatus incorporating the timing circuit of Fig. 3; and

Fig. 5 illustrates the appearance on the screen of the cathode ray oscilloscope of Fig. 4.

In all figures like numerals indicate like elements.

Referring to Fig. 1, ABC represents in the plane of the paper the path in space of a moving target in respect to the position O of the gun. The target's initial position is A and its initial range is OA. Where S is the velocity of the projectile, if it were fired from O toward the target at A, the time of flight over the initial range would equal

$$\frac{OA}{S}$$

Let the speed of the target, assumed for the sake of simplification to be moving along the straight line AC at constant speed, be such that after a time interval

$$\frac{OA}{S}$$

the target will reach point B. Its motion in this interval subtends at the gun position the angle $AOB=\alpha$. The target continues its motion, reaching the point C where the angle BOC also equals α. If, when the target reaches B, the gun is fired in the direction OC, the projectile will meet the target at C. This follows from the fact that since OB bisects the angle AOC,

$$\frac{AB}{BC}=\frac{OA}{OC}$$

The time taken for the target to move from A to B is that which would be taken by a projectile in traveling from O to A, namely

$$\frac{OA}{S}$$

and so the target will move from B to C in the time

$$\frac{OC}{S}$$

which is the time of projectile flight from O to C. This is true whatever may be the relative speeds of target and projectile and whatever the direction of the path AC relative to O, except when

the target speed equals or exceeds that of the shell, in which case the triangle AOC cannot be drawn.

The construction of Fig. 1 applies to the case of a moving target and a fixed gun; in other words, that of anti-aircraft battery firing on an enemy plane. If now the gun itself is moving to pursue the target, as in a pursuit plane whose guns are handled independently, the same conclusion follows. This will be clear from consideration of Fig. 2. In Fig. 2, let O and A be the initial positions of gun and target, respectively, and let OA be the initial range. Further, let the target move from A to C while the pursuit plane moves from O to P. The new range is PC. Call θ the angle between the initial target direction OA and the direction of movement OP of the pursuit plane. Draw PQ parallel to OA, CC' parallel and oppositely directed to OP and equal thereto. Draw OC' and AC'. AC' represents the relative motion of the target with respect to the pursuit plane and the angle CPQ equals the angle C'OA designated by α. The projectile fired from the pursuit plane is endowed with that plane's velocity so that the time and direction of fire are to be determined as in the case shown in Fig. 1.

The practice of the invention therefore requires that the initial range be determined, that the direction of fire make with the initial line of sight an angle twice that subtended at the gun position by the motion of the target in a time interval equal to the time of projectile flight over the initial range and that the instant of firing be later by this interval than the instant of determining the initial range. It will be assumed in what follows that the projectile velocity is known and that the gunner possesses means for ranging and sighting the target. These ranging and sighting means may be optical or radio instruments of the type known as radar equipment, and provided in either case with a range dial such as D, Figs. 3 and 4. Further, it will be assumed, except in the case of an airplane with fixed armament, that the aiming mechanism and the sighting mechanism normally provided in the mounting of the gun to be controlled are connected by a linkage which permits the sight to be kept in line with the gun until, at any desired instant, the sighting device may be caused to travel in angle half as fast as the gun itself. Such linkages are familiar to machine designers and, being in themselves no part of the present invention, will not herein be described or shown. Optical range finding means may be of the coincidence type described in "Elements of Ordnance," pages 522 to 524, inclusive, T. J. Hayes, New York, 1938. Means for aiming and sighting aircraft guns, with a desired angle between the line of aim and the line of sight, are disclosed in United States Patent 1,481,248, January 15, 1924, to E. A. Sperry. With the facilities assumed, the gunner can follow the target with both gun and sighting device until he determines the range as for target position A, after which he follows the target by the sighting means to position B while the gun simultaneously swings in angle twice as fast as the sight to point toward the future target position C when the sight is toward B.

The electrical timing circuit will now be described with reference to Fig. 3. Preliminary trigger 1 is normally held back by spring 2. When operated, trigger 1 connects battery 3 across resistance 4 in shunt with which is the current path comprising variable resistance 5 in series with condenser 6. Also shunting battery 3 and trigger

1 is the path comprising tube 7 in series with the winding of electromagnet 8. Tube 7 is suitably a cold cathode gas-filled tube such as the Western Electric 313A. Cathode 9 of tube 7 is connected as shown to the junction of resistance 4 and condenser 6. Control electrode 10 is connected as shown to the junction of resistance 5 and condenser 6. Anode 11 is connected through the winding of magnet 8 to positive terminal of battery 3 to which is connected also the junction of resistances 4 and 5. When trigger 1 is pulled, the voltage across condenser 6 rises at a rate determined by the voltage of battery 3 and the setting of resistance 5 together with the capacitance of condenser 6, ultimately reaching the breakdown voltage of tube 7. When tube 7 breaks down, current from battery 3 flows in the winding of magnet 8 attracting armature 12 carried on pivoted lever 13 to release firing pin 14 and fire shell 15.

Variable resistance 5 is controlled by the range finder dial D by any desired coupling. The capacity of condenser 6 may be so chosen that its voltage rises to the breakdown value of tube 7 in a required time which is substantially a linear function of the resistance 5. For example, if the initial range, OA in Figs. 1 and 2, is a thousand yards and the projectile velocity is 1000 yards per second, the time of flight over the initial range is one second and tube 7 should fire one second after trigger 1 is pulled. If the voltage of battery 3 is 95 volts and the breakdown voltage of tube 7 is 60 volts, breakdown will occur at the end of time RC seconds after the operation of trigger 1. Here R is the value in megohms to which resistance 5 is adjusted by dial D and C is the value in microfarads of condenser 6. Conveniently C is 10 microfarads and R equals the initial range divided by ten times the speed of shell 15; that is, one-tenth of the time of flight over the initial range. For the initial range and shell speed illustratively chosen, resistance 5 should be one-tenth megohm, making RC equal one second. The shell velocity is known to be substantially constant from shell to shell so that resistance 5 may be made proportional to the range according to the relation above stated.

The gunner's procedure is as follows:

On sighting the target, he trains thereon the gun and the sighting means simultaneously until he obtains the range. The range finder dial is assumed to control resistance 5 so that RC equals the time of shell flight over the range determined. Immediately the operator pulls trigger 1 and simultaneously sets in operation the mechanism, not herein shown, which causes the gun and the sight to move simultaneously in the same angular sense but moving the gun in angle twice as fast as the sight. The operator continues to follow the target by the sighting device, and when tube 7 fires shell 15 will be launched at the instant the sight is along line OB and the gun points along line OC, Fig. 1. As shown in the discussion of Fig. 1, shell 15 will strike the target at C. On releasing trigger 1, condenser 6 discharges through the resistances 4 and 5, the former having a value several times that of the latter.

The invention has so far been described as it may be applied to control the time and direction of fire of a gun manipulated independently of its own support, for example, an anti-aircraft gun afloat or ashore or a gun carried in an airplane and controlled by its own operator. For an airplane equipped with fixed armament, the guns being permanently aimed dead ahead, the direc-

tion of fire is the heading of the plane and it is necessary that this heading be suitably in advance of the moving target at the moment of fire. The additional circuit elements which permit the timing circuit of Fig. 3 to coact with electrical equipment for ranging and sighting a target will be understood from the description of Fig. 4.

Referring to Fig. 4, cathode ray oscilloscope 16 forms the indicating element of an electrical pointing scope and the target is indicated by the position of its representative spot on screen 17. The location of this spot, in the center of screen 17 when the target is dead ahead, is determined by horizontal and vertical deflecting voltages derived from the receiving circuits of the pointing scope applied across the terminals HD and VD, respectively, to plates 18 for the horizontal deflection and to plates 19 for the vertical deflection. Electrical means for producing such a spot in a position representing the direction of a target are described by J. Lyman in United States Patent 2,231,929, granted February 18, 1941, while electrical apparatus for ranging a target are shown in British Patent 535,120, March 28, 1941 to Compagnie Generale de Telegraphie sans Fil. It is to be understood that such means or their equivalent are provided to furnish spot positioning voltages HD and VD and to indicate the range which is to be set on dial D. Electrons are emitted from cathode 20 heated by the usual means, not shown, and are accelerated by anode 21, battery 22 being connected between cathode 20 and anode 21. Grid 23, normally having with respect to cathode 20 a negative potential derived from battery 24, may be varied in potential to control the brightness of the electron spot on screen 17.

The timing circuit employed is similar to that of Fig. 3 except that trigger 1 is in Fig. 4 replaced by switch S. The pilot sights and ranges the target by means of the electrical ranging and pointing equipment. Simultaneously the range is measured and set on dial D as the target spot is centered on screen 17 at which time switch S is manually closed and the course maintained. On the closing of switch S, lever 36 is caused by spring 37 so to turn that the left end of lever 36 moves up to block switch S in a closed position. Switch S thereafter remains closed until by the energization of magnet 33, as later described, spring 37 is overcome and lever 36 turns to release switch S which is thereupon opened by the action of spring 34. Condenser 6 then charges through resistance 5 which is understood to be set by its connection to the range dial D to a value such that tube 7 will break down after an interval equal to the time of projectile flight over the initial range. When switch S is closed, the voltage of battery 3 is applied over conductors 25 through normally closed contacts 26 to energize relay 27. Relay 27 at once operates switches 28 and 29 from their normal positions shown in Fig. 4 to the alternate positions shown, thereby reversing the connections of plates 18 and 19 to the deflecting voltages at terminals HD and VD. Tube 7 fires at the end of the interval determined by the value at which resistance 5 has been set in the operation of finding the initial range. Current thereupon flows through the windings of relays 88 and 30 and of magnet 33. Relay 88 operates to open contacts 26 whereupon relay 27 is deenergized and switches 28 and 29 return to their normal positions, restoring the normal connection of the

deflecting voltages to plates 18 and 19. At the same moment as contacts 26 open, relay 30 operates contact 31 to connect battery 32 in series with battery 24 and control grid 23. Battery 32 is so poled as to make the potential of grid 23 positive and thus brighten the target spot on screen 17. The current flowing through relays 88 and 30 and magnet 33 is short lived, lasting only for the time tube 7 is conducting, so that the spot is brightened only momentarily in the false position B (Fig. 5) reached while the deflecting voltages were reversed. When switches 28 and 29 return to their normal positions, the target spot assumes its proper place (B', Fig. 5) on the screen.

Switch S is normally held open by spring 34, but may be made to close contact 35 by moving its free end past the lever 36. Lever 36, of insulating material, is by spring 37 normally held in the position shown in Fig. 4, a position it recovers after being displaced during the closing of switch S. Carried on the end of lever 36 remote from switch S is armature 38. When tube 7 fires, magnet 33 attracts armature 38 and causes lever 36 to release switch S which is thereupon opened by spring 34.

Fig. 5 serves to explain the use of the circuit just described. The pilot closes switch S at the moment of finding the range when the plane is headed toward the target in its initial position, A being then the position of the spot on screen 17. The plane's heading is kept unchanged until tube 7 fires. It is here assumed that the target is traveling from right to left across the line of sight and that the pointing scope inverts this motion as does the usual optical apparatus. The true spot position at the end of a time interval equal to the time of shell flight over the initial range is B', where the spot appears just after tube 7 breaks down. The operation of relay 27 is delayed by a minute time interval after the simultaneous operations of relays 88 and 30. Thus the target spot is brightened momentarily in a false position B. After said breakdown, the momentary brightening of the false spot at B leaves this area of the screen luminous for a short while and as soon as the true spot appears at B', the pilot is called upon to swing the plane's heading to the left to bring the true spot into coincidence with the decaying trace left by the false spot B, whereupon he manually fires the guns. It will be clear that B' is diametrically opposite to B and equally displaced from the center of the screen.

A little consideration will show that the spot movement from A to B' is a measure of the angle through which the line of sight from pursuit plane to target has moved in a time equal to the initial range provided by the shell velocity, that is the angle α of Figs. 1 and 2. It will also be apparent that the sudden change of heading of the aircraft made by the pilot at the end of the flight turns the plane through the angle 2α in moving the true spot from B' to B in Fig. 5. In other words, the pilot heads along the direction OA, Fig. 1, until the angle α is described by the line of sight whereupon he instantly changes heading to the direction OC and fires on the target. The timing circuit serves to indicate the proper instant of fire and the travel on the cathode ray screen indicates the angle through which the pursuit plane must shift from its initial heading.

The specific apparatus described constitutes a preferred embodiment of the invention, but it is

clear that the invention may be employ using electrical or mechanical equivalents of the timing circuit of Fig. 3. Also, except for work at night or in fog, optical means may replace the electrical equipment assumed available in the description of Fig. 4 and may be provided with appliances for showing in the optical field of view images corresponding to the spot positions B and B' of Fig. 5.

What is claimed is:

1. Means for automatically firing a gun provided with releasable firing means comprising magnetically operable means for releasing said firing means, an electromagnet adapted to operate said magnetically operable means and provided with a pair of terminals, an electrical gaseous discharge tube provided with a cathode, a control electrode and an anode, said anode being connected to one terminal of said electromagnet, a source of unidirectional voltage having a positive and a negative terminal, said positive terminal being connected to the other terminal of said electromagnet, manually operable switching means for connecting said cathode to said negative terminal, a capacitance in shunt between said control electrode and said cathode, a resistance in shunt between said cathode and said positive terminal and a variable resistance in shunt between said control electrode and said positive terminal.

2. For the control of fire on a moving target by a gun equipped with firing means and with range finding means for finding the initial range of said target, means for automatically operating said firing means at an instant later than the instant of finding said initial range by a time interval proportional to said initial range comprising an electromagnet adapted to control said firing means and provided with a pair of terminals, an electrical gaseous discharge tube provided with a cathode, a control electrode and an anode, said anode being connected to one terminal of said electromagnet, a source of unidirectional voltage having a positive and a negative terminal, said positive terminal being connected to the other terminal of said electromagnet, a capacitance in shunt between said cathode and said control electrode, a resistance in shunt between said cathode and said positive terminal, a variable resistance in shunt between said positive terminal and said control electrode, means for adjusting said variable resistance to be proportional in a selected ratio to said initial range and switching means manually operable simultaneously with said adjustment to connect said negative terminal with said cathode.

3. For an airplane mounting fixed guns capable of firing projectiles of known velocity on a moving target having a component of motion transverse to the line of sight between the airplane and the target, the airplane being equipped with electrical means for finding the range of the target in an initial position thereof and with electrical pointing means for defining the initial heading of the airplane towards that position including a cathode ray oscilloscope provided with a screen on which the target is represented by a luminous spot controlled in brightness by a normal source of fixed voltage and in position by a pair of sources of varying voltage, the voltages of said pair normally cooperating to cause the spot position to indicate continuously the true bearing of the target relative to the airplane; means for determining the heading of the airplane requisite for firing on the target comprising an additional source of fixed voltage, an electrical circuit for measuring a time interval equal to the range divided by the projectile velocity including means for reversing at the instant of defining said initial heading the normal cooperation of the sources of varying voltage and for momentarily connecting at the end of said time interval said additional source in series with said normal source and immediately thereafter restoring said normal cooperation whereby there appear on said screen at the end of said interval a pair of luminous spots of which the diametral separation is proportional to the angle between said initial heading and said requisite heading.

4. For the control of gun-fire from a firing positon on a moving target, said position being provided with means for measuring the range of the target and with guns capable of firing projectiles of known velocity, an electrical circuit including a timing circuit for measuring a time interval subsequent to the instant of an initial measurement of the range and equal to said range initially measured divided by the projectile velocity, said timing circuit comprising an electrical gaseous discharge tube provided with a cathode, a control electrode and an anode, a capacitance connected between the cathode and the control electrode, a source of unidirectional voltage having a positive and a negative terminal, a resistance connected between said positive terminal and the cathode of said tube, a second resistance connected between said positive terminal and the control electrode of said tube and variable in magnitude to constitute with said capacitance a circuit having a time constant equal to said initially measured range divided by said velocity, switching means operable at the instant of said initial measurement to connect said negative terminal to the cathode of said tube and an output circuit connected between said positive terminal and the anode of said tube including an electromagnetic device operative subsequently by said time interval to the instant of said connection.

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