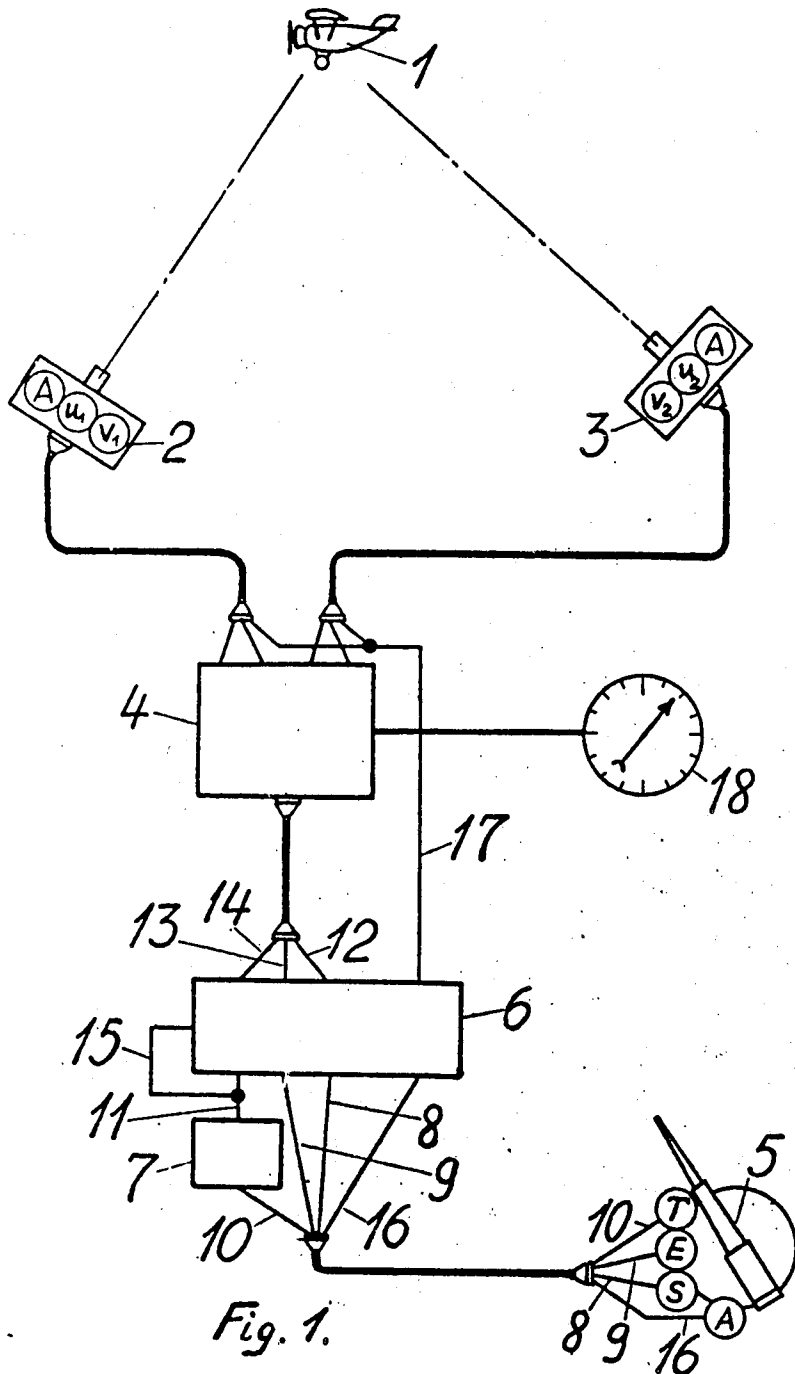


March 9, 1943.

F. E. FISCHER
APPARATUS FOR ASCERTAINING SIGHTING AND
FIRING ERRORS IN GUNNERY PRACTICE
Filed Nov. 26, 1938 **3**

2,313,136

3 Sheets-Sheet 1



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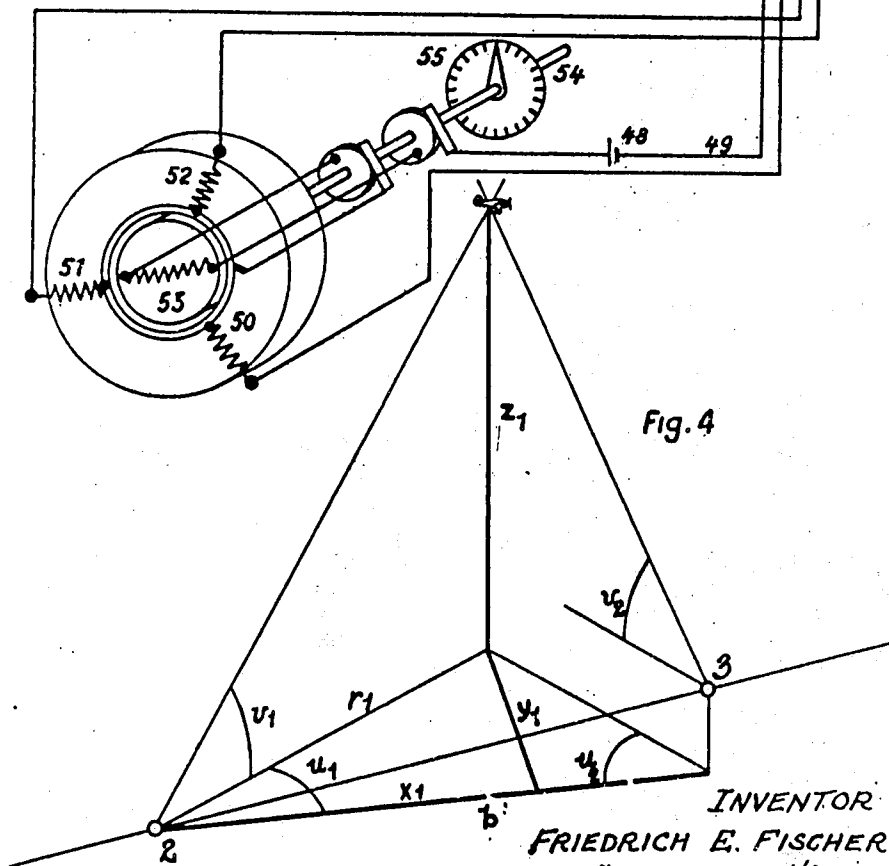
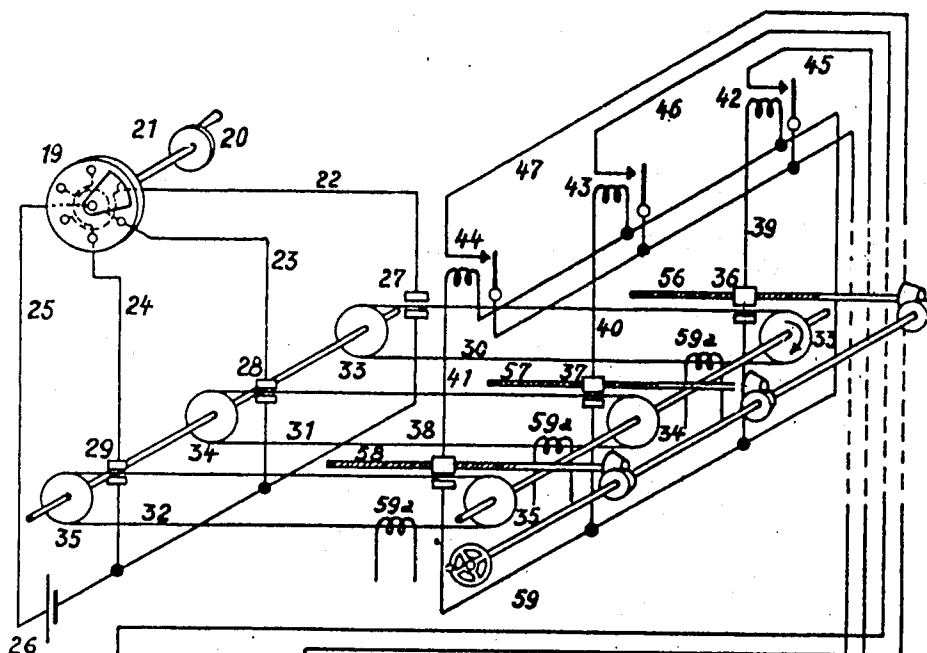
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Fig. 2



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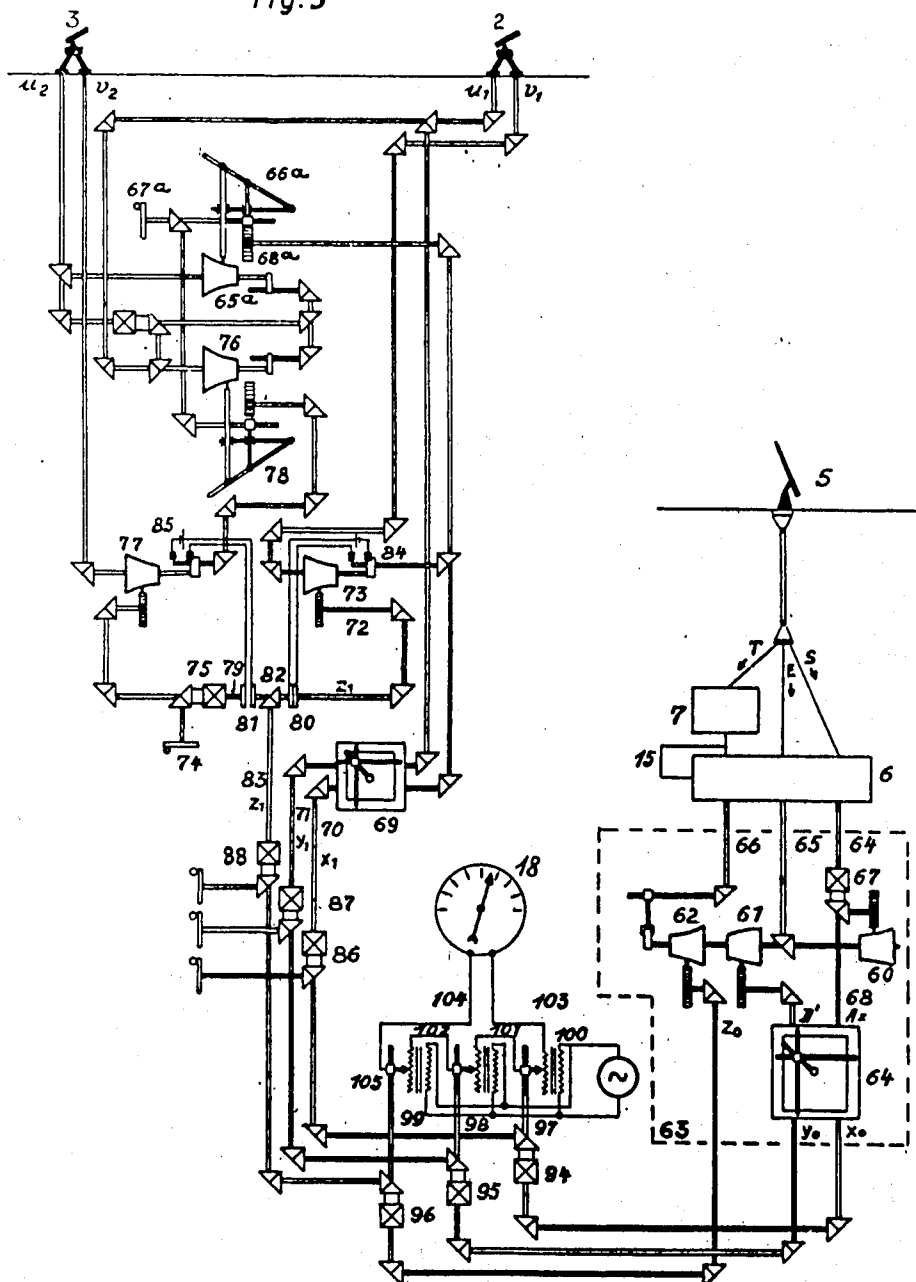
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Fig. 3



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UNITED STATES PATENT OFFICE

2,313,136

APPARATUS FOR ASCERTAINING SIGHTING
AND FIRING ERRORS IN GUNNERY PRACTICE

Friedrich Ernst Fischer, Erlenbach, Switzerland

Application November 26, 1938, Serial No. 242,511
In Switzerland January 14, 1937

15 Claims. (Cl. 35—25)

The present invention relates to improvements in devices and apparatus for ascertaining sighting and firing errors in gunnery practice against moving targets, especially in anti-aircraft gunnery practice; and the objects of the improvements are, first, to provide an apparatus which will simplify and speed up the procedure of observation and computation involved in such target practice; and, second, one which will determine directly the sighting and firing errors with the aid of a delaying device which artificially increases the time of transmission of certain data characterizing a translatable movement or adjustment so as to take into account certain variables determining the accuracy of sighting and firing.

This application is a continuation-in-part of my application, Ser. No. 133,015, filed March 25, 1937.

The causes of sighting and firing errors are well known. They originate in the fact that, when a moving object is fired at, it is necessary, owing chiefly to the time of flight of the projectile, to aim the gun at a point which the target has not yet reached at the moment when the gun is aimed. In order to determine this point, it must be assumed that the target will follow a trajectory to which, however, it need not necessarily adhere. A sighting or firing error arises whenever this hypothetical trajectory does not coincide with the actual trajectory followed by the moving target.

The ascertaining of sighting errors in anti-aircraft gunnery practice has heretofore been accomplished almost exclusively by means of photogrammetric surveys and subsequent lengthy computations, and has accordingly proved complicated and tiresome. In accordance with the present invention, the directional readings of two transits or theodolites, as well as those of the gun and the timing apparatus for the gun, are transmitted continuously to a central apparatus by way of remote control, and the time required for the transmittance of the said readings or settings of gun and timing apparatus is artificially increased—in a fixed or variable measure—by means of special delaying devices. Any other kind of sighting device—known per se—may take the place of the said theodolites for the purpose of surveying or intersecting the true position of the airplane. The theodolites or the sighting devices also may be connected with photographic camera shutter mechanisms for verification purposes or for the purpose of simulta-

neously ascertaining both sighting and firing errors.

The accompanying drawings show schematically by way of example, an arrangement embodying the present invention. In said drawings,

Fig. 1 shows schematically the general organization of parts according to the invention;

Fig. 2 illustrates a suitable form of delay mechanism forming part of the arrangement of Fig. 1; and

Fig. 3 shows in detail the construction of the coordinate changing and computing mechanism.

Fig. 4 is a diagrammatic view illustrating one spatial arrangement of the sighting devices or theodolites and the object sighted, and indicating also certain of the measured and computed variables, the theodolites being at different elevations.

The apparatus according to the invention for the measurement of gunnery errors consists essentially in the combination of a central apparatus 4 which contains a computing mechanism for determining the distance between two points, with a delay mechanism 6 which registers the movements of an electrical sender and transmits such movements after an adjustable delay interval. As will be explained more fully below, the central apparatus is so connected with a gun and its ignition mechanism as well as with two sighting devices by means of electrical conductors that both the positions of the gun and its timing mechanism as well as the positions of the two sighting devices or theodolites are transmitted continuously by remote control to the central apparatus. The theodolites sight the moving target continuously, while the gun is aimed repeatedly at a "be" or future position of the target; hence, in order that the computing mechanism may compare the future position of the target, as fixed in space by the gun adjustments, with the actual position of the target at the future moment as determined by the two theodolites, in order to compute the sighting error, it is necessary that the time for the transmission of the values of the movements of the gun and the timing mechanism to the central apparatus be delayed by the time required for the projectile to reach the assumed future position of the target (also called "point of aim"). This is accomplished in accordance with the invention by the cutting in of a delay-producing mechanism into the electrical conductors between the gun and the timing mechanism on the one hand, and the central apparatus on the other. Accordingly, the trans-

mission time for the gun data is artificially increased by a fixed or variable extent depending upon the time of flight of the projectile.

In the practice of my invention, the moving target 1, i. e. an airplane, is followed up and intersected by means of sighting devices, e. g. by means of two transits or theodolites 2 and 3. Let the co-ordinates, i. e., the elevation and azimuth readings, measured by the two transits be u_1 and v_1 and u_2 and v_2 , respectively, the base line for the directional or azimuth readings being the horizontal line b' (Fig. 4) connecting the theodolites 2 and 3, or their projections on a horizontal plane. The true position of the airplane is thus given by the readings of the two transits. The said settings are transmitted to the central apparatus 4 by way of electric remote control. The two transits or theodolites 2 and 3 are directed continuously at the progressively changing positions of the target, and the co-ordinates u_1 , v_1 , and u_2 , v_2 of the two theodolites are continuously transmitted to the central apparatus 4. As the two theodolites are at considerable distances from each other (as much as several kilometers), the central apparatus includes a coordinate changer which reduces the co-ordinates of the two theodolites to the same co-ordinate system, i. e. to measurements with reference to the same base line and zero point and thereby the progressive actual positions of the airplane in space are determined in the central apparatus 4.

The gun 5 is, of course, set toward a point in front of the moving airplane considered in the direction of movement of the latter. The distance and direction of this point of aim (future position) from the position of the airplane at the moment of firing are determined in known manner from the assumed time of flight of the projectile, the speed of the airplane, and the sighting data. The settings of gun and timing apparatus 5 similarly are transmitted to the central apparatus 4 by way of electric remote control.

The assumed time of flight of the projectile being T , the function of the central apparatus 4 is to determine the relative positions of the projectile and the airplane after this time T has elapsed. To this end, the central apparatus is provided with coordinate changing and computing mechanism which may be of the type shown in my Patent No. 2,283,922, dated May 26, 1942, Serial No. 242,510, filed simultaneously herewith, or of any other suitable construction. The actual position of the airplane is determined by the co-ordinates of the theodolites 2 and 3; the theoretical position of the projectile, on the other hand, is determined by the coordinates of the gun 5. However, since the coordinates of the gun change more or less continuously, and even immediately after the firing of the projectile, it is necessary to introduce into the central apparatus 4 simultaneously with the coordinates of the theodolites 2 and 3 at the end of the time of flight T , the coordinates of the gun 5 at the moment that the flight began. Transmission of the coordinates of the gun 5 and timing mechanism to the central apparatus 4 must accordingly artificially be delayed by the assumed time of flight of the projectile, which may be fixed or variable. This is the function of the delaying apparatus 6 and 7. The transmitting lines 8—14 serve for translating the gun or ballistic coordinates or data, such as side or azimuth S , elevation E and timing T , from the gun 5 to the central apparatus 4.

The latter data S , E and T are sent to the

main delayer 6 by way of the lines 8—11, and there delayed for the amount of time anticipated for the shell to cover its trajectory; this length of time, which also is called time of flight, corresponds to the timing T . After the said time of delay has elapsed, the said data S , E and T are dispatched to the central apparatus by way of the lines 12—14.

The assumed time of flight of the projectile, according to which the gun has been set, is likewise transmitted to the central apparatus 4. This time of flight begins, of course, with the firing of the gun, and as an appreciable interval elapses between the setting of the timer and the actual firing of the gun, the transmission of this timing value may be and preferably is further delayed in a pre-delayer 7 by a period, called the charging delay, which corresponds to the interval between the moment of setting of the timing or the primer and the moment of firing. The pre-delayer 7 is interposed in the transmitting line 10—11 (which serves for transmitting the timing value T) between the gun or the appurtenant timing apparatus 5 and the main delayer 6.

The thus pre-delayed timing value T , together with the data S and E of the gun at the moment of firing, form the simultaneously appurtenant values of the gun or ballistic coordinates of the future target position or point of aim.

The line 15 not only transmits the timing value T onto the main delayer 6 for the purpose of delaying the further transmittance, but at the same time controls the delay by regulating the latter automatically by remote control or by means of a follow-up indicator adjusted by hand in accordance with the timing T (time of flight). The delaying mechanism, the preferred form of which is described hereinbelow, is in general known; see, for example, United States Patents Nos. 1,391,652, 1,809,070, 1,883,907; 1,979,998, and 2,079,959; German Patents Nos. 216,938, 425,109 and 568,994; and British Patent No. 348,154.

The firing signal A may be transmitted onto the transits 2 and 3 by the lines 16 and 17; the firing signal A —in the case of photo-theodolites—may be made to operate the shutter mechanisms at a moment delayed by the time of flight of the projectile.

The central apparatus 4 thus receives simultaneously the coordinates of the theodolites 2 and 3 corresponding to a given moment, and the coordinates of the gun and the assumed time of flight corresponding to an earlier moment. In such central apparatus 4 the sighting error is continuously determined from the coordinates of the true position of the airplane and those of the theoretical point of bursting as the distance between the said two points. The sighting error may be registered in, or read from an instrument 18.

The individual mechanisms forming part of my improved arrangement may be built in any known manner. Thus the computing mechanism for measuring the distance between two points, the coordinate changers and the delay-producing devices may follow known constructions and principles. The delaying mechanism may, for example, be of the continuous belt type and may be constructed in the manner illustrated in my Patent No. 2,162,707, dated June 20, 1939 and in my application Serial No. 242,510, above referred to.

However, in order that my invention may be better understood, I have illustrated in Figs. 2

and 3 the detailed construction of certain of the devices shown schematically in Fig. 1.

Fig. 2 shows by way of example one form of construction of a delaying device with three transmission channels.

In the diagram, 19 represents an electric control unit, which converts a rotary movement (represented by the hand-wheel 20 on its shaft 21) into electrical impulses by connecting either one or two of the three circuits 22, 23 and 24 together with the common return channel 25 and the battery 26, by which means the direction and degree of movement are definitely characterized in a manner known in itself. Circuits 22, 23 and 24 each include a so-called speaker head 27, 28 and 29, respectively, consisting of a coil which, when current is passed through it, magnetises at corresponding places a steel tape which is conducted past it. The steel tapes 30, 31 and 32 are conducted over rollers, 33, 34 and 35 respectively, which are mounted three to a shaft. One of these shafts is rotated, in a manner not shown in detail, at a constant number of revolutions per minute, the direction of rotation being indicated in Fig. 2 by means of an arrow.

The electrical impulses characterising the movement and transmitted by the speaker heads 27, 28 and 29 in the form of magnetic registrations on the steel tapes 30, 31 and 32, are re-transformed into electrical impulses in the hearer heads 36, 37 and 38. A hearer head consists essentially of a coil in which an electric current is induced when a magnetised portion of the steel tape is led past it. The currents induced in the hearer heads 36, 37 and 38 are amplified and conducted via the channels 39, 40 and 41 to relays 42, 43 and 44, and in their passage close the corresponding circuits 45, 46 and/or 47 together with the battery 48 in the common return channel 49.

The electrical impulses flowing in these latter circuits thus correspond exactly with those in circuits 22 to 25, thus also characterising the movement to be translated in the shaft 21. They are conducted in known manner to the stator coils 50, 51 and 52 of a receiver motor, the rotor 53 of which adjusts itself according to the current passing through and the shaft 54 of which accordingly executes the same movement as shaft 21. The position of the control 19 at any time can therefore be read off on an indicator 55.

The movement of shaft 54 thus corresponds exactly to the movement of shaft 21, there only intervening between the two a certain interval (time of run) which is identical with the period elapsing between the magnetic registrations in the sending devices 27, 28 and 29, and the reception of these registrations and their re-conversion into electrical impulses by the hearer heads 36, 37 and 38. This so-called running time of the translation of the movement can be altered in a simple manner, e. g. by displacing similarly the hearer heads 36, 37 and 38 along spindles 56, 57 and 58 by means of a hand-wheel 59. In order to render the steel tapes receptive for new registrations after previous registrations have been transferred to the hearer heads 36, 37 and 38, so-called erasing coils 59a are provided in known manner.

Fig. 3 shows a detailed diagram of one form of construction of the central apparatus 4 together with the appurtenant co-ordinate converters and computing apparatus.

The settings, i. e. the ballistic co-ordinates of side or azimuth S, elevation E and timing T emanating from the gun 5 are transferred, after being each retarded by the assumed time of flight of the projectile in the delaying device 6, by means of the shafts 64, 65 and 66 to the ballistic co-ordinate converter 63, which consists essentially of the three cams 60, 61 and 62. This type of mechanism is known and is shown in greater detail in German Patents Nos. 620,385 and 611,497. The timing T is not, however, taken off the gun simultaneously with the values S, E and the firing signal A, but rather earlier by the time which is necessary for the charging of the gun. The transmission of the timing value must, therefore, be delayed additionally by this so-called charging period, and this occurs in the pre-delayer mechanism 7.

Cam 60, for example, is cut according to the lateral deviation (lateral divergence of a projectile path from the vertical plane established by the axis of the gun-barrel), so that the value taken off cam 60 as a function of elevation E and timing T can be added in the differential 67 to the ballistic side S (shaft 64) and thus yields the azimuth Az at the shaft 68. The latter is suitably oriented upon the base direction (line connecting theodolites 2 and 3) as the zero direction.

The two cams 61 and 62 are similarly cut in dependence upon elevation and timing corresponding to the horizontal projection of the target distance D' and to the target height z, referred to the gun. The obtained values of azimuth and horizontal projection of the target distance are transmitted to the sine-cosine drive 64a, in which the horizontal projection of the target distance is resolved into its components in relation to a horizontal rectangular x, y-co-ordinate system. The sine-cosine mechanism is likewise known and may be of the type shown in German Patents Nos. 370,956, 578,764, 607,318 and 647,296.

To enable comparison to be made of the co-ordinates of the airplane position (u₁ and v₁, u₂ and v₂ respectively) measured by the two theodolites 2 and 3, with the ballistic co-ordinates converted into x₀, y₀ and z₀, they must likewise be converted into co-ordinates of the x, y, z co-ordinate system.

When the theodolites are set by the co-ordinates u (azimuth) and v (angle of ground=angle of sighting direction to horizontal plane), this conversion can be accomplished mechanically, for example, according to the known mathematical relationships:

$$x_1 = b \frac{\cos u_1 \sin u_2}{\sin (u_1 + u_2)}$$

$$y_1 = b \frac{\sin u_1 \sin u_2}{\sin (u_1 + u_2)}$$

$$z_1 = b \frac{\sin u_2}{\sin (u_1 + u_2)} \cdot \operatorname{tg} v_1$$

In these equations, b indicates the horizontal projection of the base length, i. e. the horizontal distance between the two theodolites 2 and 3. The co-ordinates x₁, y₁ and z₁ are illustrated in Fig. 4 and are referred to the position of theodolite 2 as the co-ordinate zero point and the base direction as the direction of the x-co-ordinate. The magnitude

$$\frac{\sin u_1}{\sin (u_1 + u_2)}$$

is taken off cam 65a in the form of construction

illustrated by way of example, and is multiplied in the multiplication drive 66a by the magnitude b which is adjustable by the hand-wheel 67a. The product

$$b \cdot \frac{\sin u_2}{\sin (u_1 + u_2)}$$

is taken off with the aid of a member at the rack 68 and conducted to the sine-cosine drive 69. Into this drive 69 the angle u_1 is also introduced so that at the two shafts 70 and 71 the values $x_1 = b$.

$$\frac{\sin u_2}{\sin (u_1 + u_2)} \cdot \cos u_1$$

and

$$y_1 = b \cdot \frac{\sin u_2}{\sin (u_1 + u_2)} \cdot \sin u_1$$

are obtained.

The value of z_1 is obtained at the shaft 72 by multiplication of the term

$$b \cdot \frac{\sin u_2}{\sin (u_1 + u_2)}$$

by $\tan v_1$ with the aid of the correspondingly cut cam 73. In the form of construction illustrated, the value of z_1 is determined quite analogously according to the formula

$$z_1 = b \cdot \frac{\sin u_1}{\sin (u_1 + u_2)} \cdot \tan v_1 - \Delta h$$

Δh representing the difference in height of the theodolites 2 and 3, for which allowance can be made by means of the hand-wheel 74 by way of the differential 75. The mechanism for evaluating the above formulas is known, and may be of the type illustrated in German Patents Nos. 370,956, 433,936, 567,054 and 632,489.

A double tracing (double determination) of z_1 is necessary in order to avoid the singularity position of the selected u, v co-ordinate system which occurs when the airplane 1 flies vertically over the base point which was selected as the co-ordinate zero point. To this end the cams 76 and 77, as well as the multiplication drive 78 and the differential 75, are required, these parts yielding the second value of z_1 at the shaft 79. By means of the couplings 80 and 81, one of which is always thrown in when the other is thrown out, one or the other value of z_1 can be selectively transmitted to the shaft 83 through the bevel wheels 82. The reversal of the couplings 80 and 81 is effected by closing an electrical circuit. Such a circuit is, for example, closed by the pairs of contacts 84 and 85 when the value

$$b \cdot \frac{\sin u_2}{\sin (u_1 + u_2)}$$

or

$$b \cdot \frac{\sin u_1}{\sin (u_1 + u_2)}$$

falls below a definite value.

The electric circuit which disconnects the coupling 80 or 81 is indicated schematically in Fig. 3 by the electrical connection to a battery and the two contacts 84 and 85. The coupling is of the electromagnetic type, that is, it becomes engaged when an electric circuit is closed. The closing of the circuit is accomplished for example by small switches which are actuated when, during the rotation of the spindle, the nut rotated thereon reaches an end position. If this reversal of the couplings 80 and 81 were not provided the danger would exist that the theodolites 2 and 3 would be rotated in their positional angle over 90° , which in general is not feasible

for constructional reasons and further would lead to uncertainty in the measurement.

The values x_1, y_1 and z_1 obtained in this way at the shafts 70, 71 and 83 suffice to fix definitely the position of the aircraft in space. They are, however, referred to the position of the theodolite 2 as the co-ordinate zero point; in order that they may be compared directly with the converted ballistic co-ordinates x_0, y_0 and z_0 referred to the gun position, parallax corrections be applied to them. This is accomplished in simple and known manner by the addition of the parallax corrections to the co-ordinates x_1, y_1 and z_1 of the aircraft's position by means of the differentials 86, 87 and 88.

The ascertaining of the distance between two points (position of aircraft and theoretical bursting point of the projectile) which are given in the same co-ordinate system (x, y, z) is effected in known manner with simple computing apparatus. In the example of construction illustrated in Fig. 3 the components of the distance are first determined, these, as is known, being $(x_0 - x_1'), (y_0 - y_1')$ and $(z_0 - z_1')$, and are formed in the differentials 84, 85 and 86; Z , the distance proper, i. e. the aiming error, is then yielded by the relation:

$$Z = \sqrt{(x_0 - x_1')^2 + (y_0 - y_1')^2 + (z_0 - z_1')^2}$$

Corresponding to the values of the components $(x_0 - x_1'), (y_0 - y_1')$ and $(z_0 - z_1')$ obtained at the shafts 97, 98 and 99, the withdrawn secondary voltages are regulated at the three electric transformers 100, 101 and 102 with primary windings in parallel circuit. If the secondary windings of the transformers 100, 101 and 102 are so constructed that the withdrawn voltage increases quadratically with the displacement of the current remover 103, 104 and 105, the sum of the partial voltages withdrawn at the three secondary windings corresponds to the square of the sighting error, and the sighting error itself can be read off at an instrument 15 provided with suitable scale graduation. A construction of this type is illustrated in German Patent No. 370,956 above referred to.

I claim:

1. An apparatus according to claim 14 wherein the delay mechanism includes an electromagnetic circuit with at least one sender and one receiver, and at least one travelling endless steel tape for receiving magnetic registrations of the movements of the said sender for the purpose of delaying the transfer of the said movements to the said receiver.

2. An apparatus according to claim 14, wherein the delay mechanism includes an electromagnetic circuit with at least one sender and one receiver, and at least one travelling endless steel tape for the reception of the magnetic registrations of both the forward and the backward movements of the said sender for the purpose of delaying the transfer of the said movements to the said receiver.

3. An apparatus according to claim 14 wherein the transmission time of the settings of gun and timing apparatus to the said central apparatus is adjusted according to the individual time of flight of the projectile.

4. An apparatus according to claim 14 including means for effecting the said artificial increase of the time of transmission in a plurality of steps.

5. An apparatus according to claim 14, wherein the sighting devices comprise two theodolites.

6. An apparatus according to claim 14, wherein the said artificial increase of the transmission time takes place ahead of the transformation of co-ordinates.

7. An apparatus according to claim 14, wherein the said artificial increase of the transmission time takes place between the transformation of co-ordinates.

8. An apparatus according to claim 14, wherein the said artificial increase of the transmission time takes place after the transformation of co-ordinates.

9. An apparatus according to claim 14, including a travelling endless steel tape operating as a pre-delayer; the said tape taking into account the so-called charging delay and correspondingly pre-delaying the transfer of the timing for an adjustable length of time in order to enable one to obtain simultaneously appurtenant values of the ballistic co-ordinates, side, elevation and timing.

10. An apparatus according to claim 14, including a steel tape, speaker-heads and hearer-heads, and characterized in that the length of the said tape between the said two classes of heads is variable for the purpose of increasing the time of run of a translatory movement.

11. Apparatus for determining sighting errors in gunnery practice comprising, in combination, a sighting mechanism adapted to be directed continuously at a moving target, a central apparatus, means connecting the latter with said sighting mechanism and acting to transmit thereto the coordinates of such mechanism, said central apparatus including computing mechanism operative to determine the position of the target from such coordinates, means for transmitting to said central apparatus the settings of a gun and its timing mechanism, and mechanism for delaying the transmission to said computing mechanism of the settings of the gun and timing mechanism, and means in said central apparatus for relating the position of the target with the point of aim as established by the settings of the gun and thereby determining the sighting error.

12. Apparatus according to claim 11, wherein the delaying mechanism comprises a uniformly moving magnetizable member, a speaker head adapted to convert electrical impulses corresponding to the settings of the gun and timing

mechanism into magnetic registrations on said member, and a hearer head associated with said member in spaced relation to said speaker head and acting to convert said magnetic registrations into electrical impulses, said hearer head being connected with said central apparatus.

13. Apparatus according to claim 11, including a predelayer for additionally delaying the transmission of the setting of the timing mechanism by the time interval elapsing between the moment of setting such mechanism and the instant of firing.

14. Apparatus for surveying and registering sighting errors in shooting practice against moving targets, such as airships, comprising the combination of a central apparatus including a computing device for determining the distance between two points, an electrical sender for converting the adjustments at a gun station into electrical impulses, a delay-producing mechanism for registering the movements of the electrical sender and transmitting the impulses after a predetermined period of delay, two sighting devices, and electrical conductors between the central apparatus on the one hand and the gun and its timing mechanism and the two sighting devices on the other, said conductors transmitting both the settings of the gun and timing mechanism as well as the settings of the two sighting devices continuously to the central apparatus, said delay mechanism being interposed in the conductors between the central apparatus and the gun and its timing mechanism, whereby the duration of the transmission of the movement of the gun and timing mechanism to the central apparatus is brought into relationship with the time of flight of the projectile at any time by the said delay mechanism by being artificially increased in correspondence with such time of flight by the said predetermined period of delay.

15. An apparatus according to claim 14, including photographic cameras for verification and recording, each of said sighting devices being provided with a photographic camera, the opening of the shutter mechanisms of the said cameras being controlled by the firing signal at a moment delayed by the time of flight of the projectile.

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