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SEARCH ROOM

CROSS REFERENCE

May 26, 1942. F. E. FISCHER 2,283,922

APPARATUS FOR SURVEYING AND ASCERTAINING SIGHTING ERRORS IN SHOOTING PRACTICE AGAINST MOVING TARGETS ESPECIALLY AIRPLANES

Filed Nov. 26, 1938 4 Sheets-Sheet 1

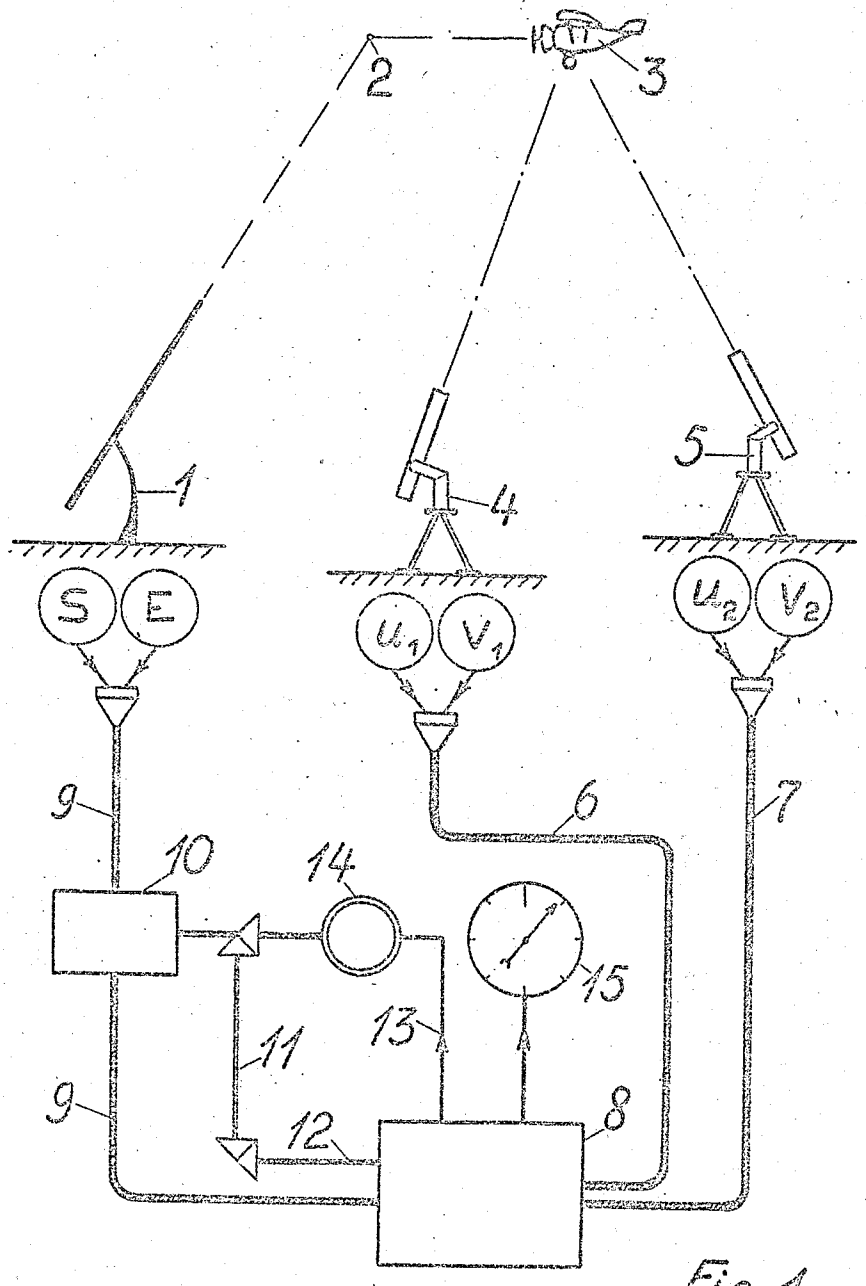


Fig. 1.

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Fig. 3.

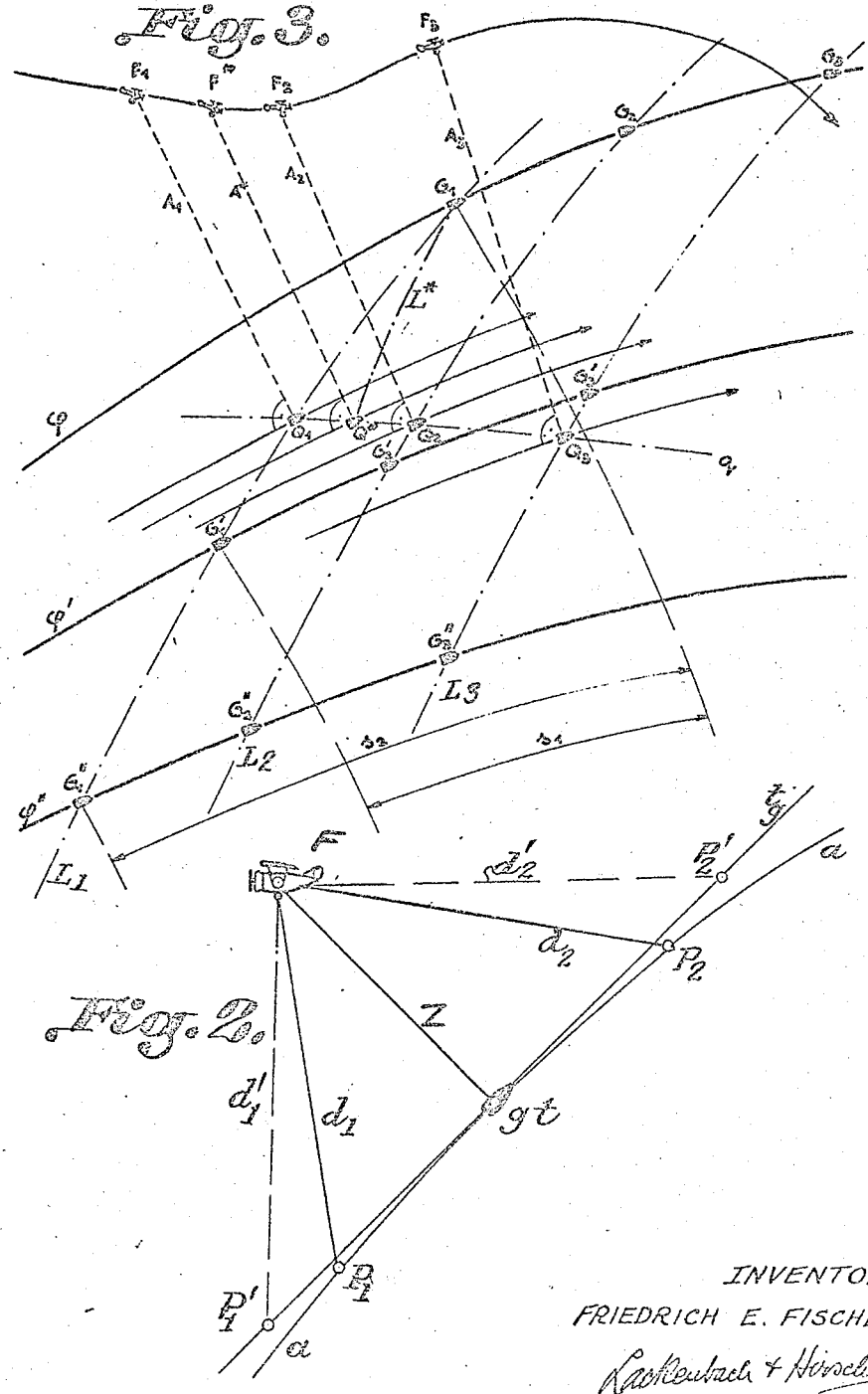


Fig. 2.

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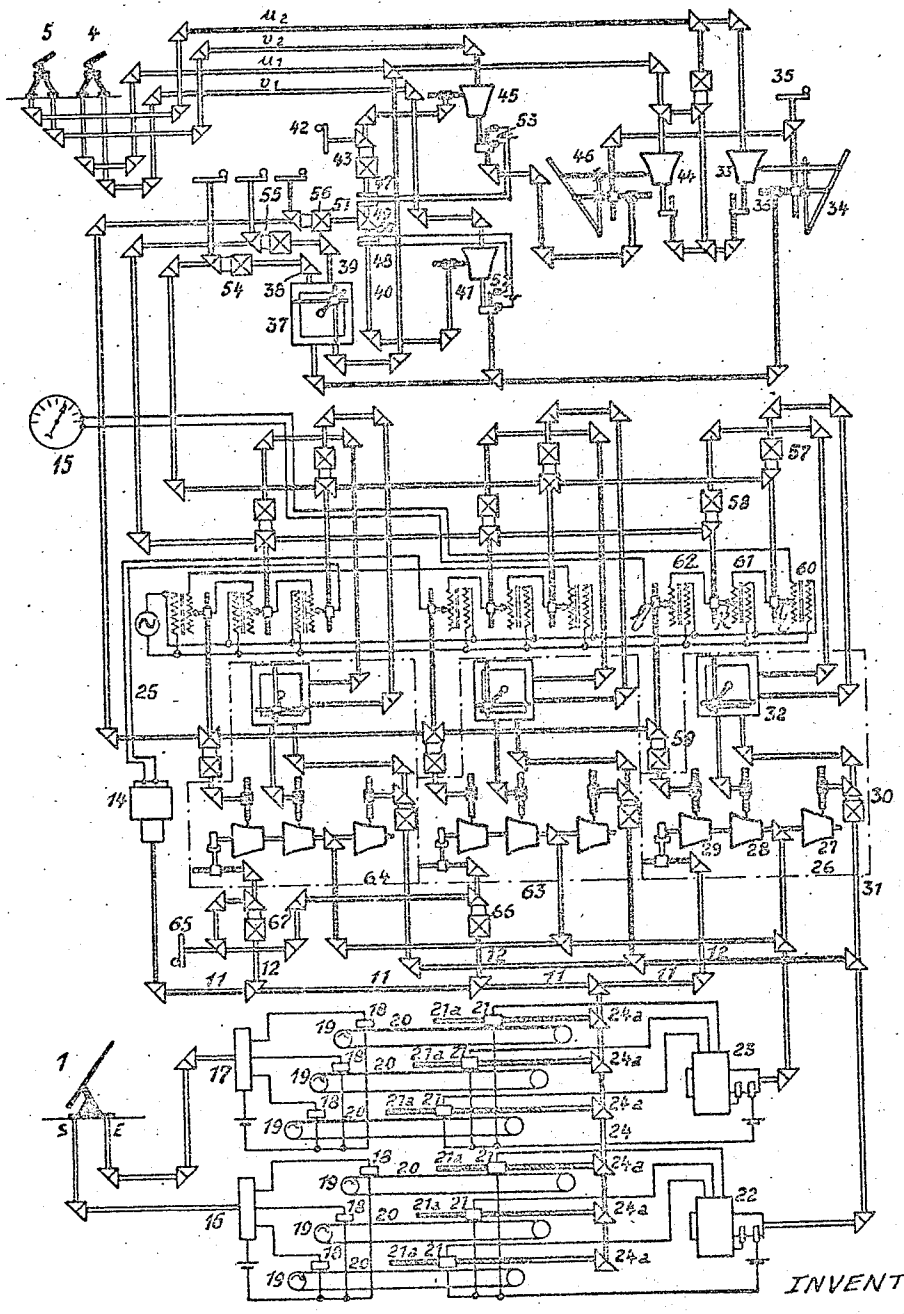
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Filed Nov. 26, 1938 4 Sheets-Sheet 3

Fig.4



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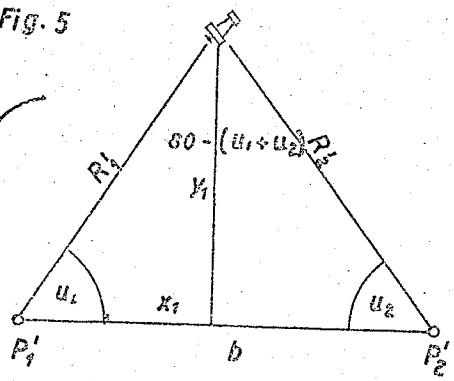
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APPARATUS FOR SURVEYING AND ASCERTAINING SIGHTING ERRORS IN SHOOTING PRACTICE AGAINST MOVING TARGETS ESPECIALLY AIRPLANES

Filed Nov. 26, 1938 4 Sheets-Sheet 4

Fig. 5

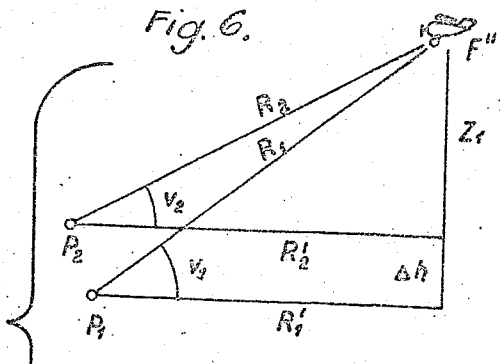


$$R'_1 = b \cdot \frac{\sin u_2}{\sin(u_2 + u_1)}$$

$$X_1 = R'_1 \cdot \cos u_1$$

$$Y_1 = R'_1 \cdot \sin u_1$$

Fig. 6.



$$Z_1 = R'_1 \cdot tg.\ v_1 =$$

$$= R'_2 \cdot tg\ v_2 + \Delta h$$

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UNITED STATES PATENT OFFICE

2,283,922

APPARATUS FOR SURVEYING AND ASCERTAINING SIGHTING ERRORS IN SHOOTING PRACTICE AGAINST MOVING TARGETS, ESPECIALLY AIRPLANES

Friedrich Ernst Fischer, Erlenbach, Switzerland

Application November 26, 1938, Serial No. 242,510
In Switzerland February 9, 1937

9 Claims. (Cl. 35—25)

The present invention relates to an improved apparatus for surveying and ascertaining sighting errors in shooting practice against moving targets, especially airplanes, and particularly in shooting practice employing percussion-primed ammunition.

This application is a continuation in part of my copending application Ser. No. 133,016 filed March 25, 1937 and abandoned after the filing of the present application.

The primary objects of the invention are, first, to afford facilities for the continuous survey of sighting errors without the help of photographic exposures; and, second, to provide means enabling one to quickly obtain the error of aim without the necessity for making lengthy and tedious calculations. Other objects and advantages of the invention will appear as the description thereof proceeds and the features of novelty will be set forth in the appended claims.

The survey of shooting errors and pertaining timing errors in shooting practice against quickly moving targets, especially in connection with anti-aircraft gunnery practice, has heretofore been carried out almost exclusively by photogrammetric methods or by way of analytical computations. Both of these methods are tedious and time-consuming and, furthermore, do not give one the instantaneous sighting error. The photogrammetric method, moreover, can be employed only in the case of firing projectiles equipped with time-controlled primers or fuses; firing by means of percussion-primed ammunition is, however, also of great importance, especially with small-calibered anti-aircraft guns.

In accordance with the present invention, sighting errors may be quickly and continuously determined also with percussion-primed ammunition. The sighting or gunnery error is taken as the shortest distance at any time between the projectile and the target, such as an airplane. A satisfactory embodiment of the invention is illustrated by way of example on the accompanying drawings, wherein is shown an arrangement operating automatically to vary the time of flight factor entering into the computations by establishing equality between the distances from the target of two points upon opposite sides on the projectile trajectory of the base of a line drawn from the target perpendicular to the trajectory and representing the sighting error.

In said drawings,

Fig. 1 shows schematically an arrangement according to the invention;

Fig. 2 is a diagram illustrating the method of computing the time of flight of the projectile;

Fig. 3 shows in detail the positions of different projectiles at different moments and at different firing elevations;

Fig. 4 illustrates in greater detail the construction of certain mechanisms employed in the arrangement shown in Fig. 1; while

Figs. 5 and 6 show diagrammatically the computations involved in the conversion, effected automatically in the apparatus of Fig. 4, of the data fixing the airplane position, into coordinates of an x, y, z system for determining the distance between the airplane and a projectile in the computation of the sighting error.

In accordance with the present invention, the settings of two theodolites 4 and 5, which define the airplane position, as well as the settings of a gun (directive or ballistic data namely, side, or azimuth, and elevation) are continuously transferred by electric remote control to a computing mechanism 8 composed of coordinate changers, distance comparing devices and other elements described hereinbelow and which for convenience will be referred to as a central apparatus, the time of run or transmission of the translatory movement of the said directive data being automatically and artificially increased, by way and means of special delaying mechanism 10, to such an amount that the said time of run equals the time of flight of the projectile in question. The latter time refers to that point of the trajectory which possesses the shortest distance from the true position of the airplane. The setting of the said delaying mechanism 10 with reference to the said time of run, which corresponds to the time of flight of the projectile, is transferred onto a computing apparatus, shown in diagrammatic detail in Fig. 4, pertaining to the said central apparatus. The said computing apparatus continuously determines the distances between the true position of the airplane on the one hand and two arbitrarily fixed points, set a certain and suitably chosen distance apart, and from the projectile position on the other hand, the projectile position, as explained more fully below, being initially determined from an arbitrarily selected time of flight of the projectile. The latter two points can either lie upon the projectile trajectory which is defined by the values of side movements and elevation of the gun which are transmitted to the central apparatus (points P_1 and P_2 in Fig. 2), or they may lie upon a tangent t_g to this trajectory (points P'_1 and P'_2). In the first case they are at the same distances

(d_1 d_2—see Fig. 2) from that point g of the trajectory a which is determined by the (assumed) time of flight T of the projectile on the trajectory a corresponding to the transmission time increase; they can be moved along the trajectory in correspondence with the transmission time adjustment (change in T). In the second case, the points, designated as P'_1 and P'_2 lie upon a tangent t_g to the trajectory a, being removed by equal distances from the point of tangency g, the latter corresponding to that projectile position determined by the (assumed) time of flight T of the projectile, the said point of tangency being moved along the trajectory in accordance with the said setting of the time of run or transmission in the delaying device.

As soon as the two distances d_1 and d_2 or d'_1 and d'_2 are found to be of different length, the said computing apparatus, as will be described below, releases the automatic control for the setting of the time of run in an additional or subtractional sense so that the distances again become of equal length. The said releasing is accomplished by regulating a servomotor.

The arrangement illustrated in the drawings includes at least one delaying device 10 which may consist, in known manner, of at least one revolving or continuously moving endless steel tape for the purpose of increasing the time of run of the transfer of the ballistic or gun coordinates to the central apparatus 8. The said tape, as will be described more fully below, receives magnetic registrations of the movements of a sender for the purpose of a delayed transfer of the said movements onto at least one receiver, the length of the said tape between the speaker heads and the hearer heads with which it is associated, being automaticaly controlled and regulated by electrical and mechanical means.

This type of delaying device, which is indicated in Fig. 1 at 10, is shown in greater detail in Fig. 4. Referring to the latter figure, 16 and 17 represent simple electrical senders of known type which, for example, convert the lateral movement and the elevation of the gun 1, respectively, into electrical impulse which are conducted in each of three identical transmission channels to each of the three speaker or registering heads 18. The latter are in the form of coils which—when they are traversed by current—magnetize the parts of the steel tapes 20 which pass them, the tapes moving uniformly over the rollers 19, which are driven at constant speed in any suitable way. The magnetic registrations are taken up in the hearer or receiving heads 21 from the steel tapes 20. The hearer heads are coils in which an electric current is induced when a magnetized point of the steel tape passes them. The magnetic registrations which are taken up by the hearer heads 21 and re-converted into electrical impulses always characterize the movements of the senders 16 and 17; they are transmitted to the receiver motors 22 and 23 by which they are again converted into mechanical movements. The movements of the receivers 22 and 23 thus correspond exactly to the movements of the senders 16 and 17, only with the difference that they lag behind them somewhat in time and indeed—disregarding the practically infinitesimal natural time of travel of the electric current—by the time which the magnetic registrations on the steel tapes 20 require to travel from the speaker heads 18 to the hearer heads 21. The artificial running time increase of the movement transmission in the delay mechanism 10 can be made variable; for example, the hearer head can be constructed in the form of, or may be mounted upon, screw nuts and be adjustable along screw spindles 21*a*. It is obvious that to maintain the movements, all hearer heads must be moved equally; in the construction shown by way of example in Fig. 4, this is accomplished by driving all of the screw spindles from the same shaft 24 by way of pairs of bevel wheels or gears 24*a*. The shaft 24 is driven by the motor 14 which rotates in accordance with the voltage supplied thereto by the conductors 25.

The mode of operation of the apparatus according to the present invention for surveying the sighting errors in sharp-shooting practice by means of percussion-primed ammunition against aircraft is as follows:

As pointed out above, the sighting or gunnery error is the shortest distance betwen the projectile and the target, i. e. their distance at their closest approach. For determining the sighting error, an assumption is made for purposes of simplification. This assumption is that the line (distance) representing the sighting error and connecting the target with the projectile is perpendicular to the tangent to the projectile trajectory at the projectile position. The difference between the sighting error so measured and the true shortest distance is relatively small and can be neglected. The measurement of the sighting error can be carried out as soon as the target position and the projectile position at the shortest distance from the target are known. The first problem which the mechanism in the central apparatus 8 must solve is, therefore, the exact determination of these two points in space.

The target position can be continuously determined by measurements with two theodolites 4 and 5. The measurements with the two theodolites (azimuth and elevation, the latter being the angle made wtih the horizontal plane) is effected in accordance with the three coordinate equations set out below. By these three values, the position of the target is definitely established in a rectangular coordinate system with the zero point at the theododite 4, and the base direction as the zero line for the azimuth.

The gun 1 is aimed by means of any direct or indirect sighting contrivances which, being known, are not shown, at the future station 2 of the airplane, the said station having been computed beforehand (extrapolated) for the corresponding time of flight of the projectile. The directive data are the side (azimuth) S and the elevation E. The true station of the airplane at the moment of firing is located at 3; and is continuously intersected from two observation stations, e. g. by means of the two theodolites 4 and 5 lying a certain distance apart; for less exacting measurements the two theodolites may be replaced by a single telemeter or range-finder. The measured topographical co-ordinates determine the true position 3 of the airplane. The system of coordinates employed for the survey may be chosen at will; in the drawing, e. g., the letters u_1, u_2 and v_1, v_2 respectively denote the azimuth and the vertical angles measured from the two points. The angle readings of the true position 3 of the airplane are relayed to the central apparatus 8 over the lines 6 and 7.

Whereas in the case of firing practice with projectiles controlled by time fuses, the position of the explosion point can, at any time, be determined by the three ballistic or gun coordinates of azimuth, elevation (this term throughout the

specification means the total elevation of the gun barrel) and timing (the azimuth and elevation being the adjustments of the gun, while the timing is the adjustment of the igniter), in firing practice with percussion-primed ammunition only the projectile trajectory can be initially established upon which the projectile is located because the timing coordinate (the time-adjustable igniter) is lacking. To determine the projectile position, the gun adjustments, both lateral and elevational, must be supplemented by a time value for the period of projectile flight (equivalent to the timing of the fuse on a fuse-controlled projectile). At this point, the improvements effected by the present invention come into play.

If, in accordance with the invention, there is at first selected any arbitrary but appropriate time value T and if the gun adjustments S (azimuth) and E (elevation) are combined with this time value T, then the three ballistic values S, E, and T constitute together the coordinates of the projectile position. This condition is, in general, valid and sufficient for determining a projectile position; for the assignment of a time value T establishes in space an approximately spherical surface, with the gun position as center, which represents the geometric position of all projectiles which could be fired prior to the time T. At this time (moment of discharge of the projectile) the gun was adjusted at the coordinates S and E and could naturally fire only one projectile at a given instant. S, E, and T, therefore, together always characterize the position of one flying projectile.

The directive elements or data side S and elevation E of the gun are relayed to the said central apparatus 8 over the lines 9, the time of run of this transfer being artificially and in a variable measure increased, as above explained, by means of the delaying device 10 connected to the lines 9. The setting of the time of run in the delaying device 10 is relayed to the said central apparatus 8, e. g. mechanically by means of the shafts 11 and 12; and corresponds, in accordance with the present invention, to the initially arbitrarily selected time of flight of the projectile, and characterizes accordingly any at first selected projectile point g (Fig. 2) lying on the trajectory fixed by the elements S and E.

The procedure for continuously measuring the impact sighting error, according to the present invention, resides in first finding continuously upon each projectile trajectory defined by the continuous adjustments at the gun, that projectile position which has the shortest distance from an airplane at the correct time, and secondly, to determine the distance of the projectile position from the airplane at this moment.

As mentioned above, in the determination of the projectile position with the shortest distance from the airplane, a slight simplification is undertaken. According to the invention, it is not the absolutely shortest distance that is determined, but the shortest distance perpendicular to the projectile trajectory. The difference between this latter distance and the distance defined as the impact sighting error is small; it depends upon the relationship of the airplane speed to the projectile speed, and at the most amounts to a few percent of the value to be measured. Since we are dealing here with an error in the measurement of an error (impact sighting error) this difference plays only a very subordinate role and can be neglected.

The spatial-geometrical side of the impact sighting error measurement—considered as a continuous process—is shown most clearly in Figs. 2 and 3. In these figures the impact sighting error determination is shown for the case of a plane (i. e. two-dimensional) problem; it can, however, easily be seen that all conclusions reached upon the basis of these two figures are valid also when the actual impact sighting error measurement is undertaken in three-dimensional space.

Referring to Fig. 3, F_1, F_2 and F_3 signify the positions of an airplane at the times t_1, t_2, t_3. The airplane is fired at with a gun which at the time t_1-T' was directed at the elevation ϕ, T' indicating the time of flight of a projectile G to the point G_1. At the time t_2 or t_3, the projectile fired at the moment t_1-T' is located at G_2 or G_3, respectively. At the time t_1, t_2, and t_3, not only the projectile G but also other projectiles are in flight. These other projectiles are located at the time t_1 at G'_1 or G''_1 . . . etc. if the gun was directed at the time

$$t_1-\left(T'+\frac{s_1}{V_g}\right)$$

or

$$t_1-\left(T'+\frac{s_2}{V_g}\right)$$

with the elevation ϕ' or ϕ''. (V_g in these expressions indicates the projectile velocity.) The latter projectiles are located at the time t_2 at the points G'_2, G''_2 . . . and at the time t_3 at the points G'_3, G''_3 . . . As the gun is continuously moved, its elevation changing continuously from ϕ through ϕ' to ϕ'', there results one and only one line G_1 G'_1 G''_1 . . ., which in the case of an infinitely rapid succession of firing represents the geometrical locus of all projectiles at the time t_1.

Upon this line l_1, there is a point Q_1 which has the distance A_1, measured perpendicularly to the tangent to the projectile trajectory, from the airplane position F_1 at the same moment (time t_1). This distance is smaller than the distances of the airplane position F_1 from all other points lying upon the trajectory passing through the point Q_1.

If the airplane were immovable at the point F_1, the distance A_1 would correspond exactly to the impact sighting error. A_1 in this case represents actually the shortest distance between the airplane and a traveling projectile. If, however, the airplane moves at its own velocity, the distance A_1 is no longer exactly equal to the absolutely shortest distance, that is, equal to the impact sighting error; nevertheless, the difference is negligibly small from the practical standpoint. For this reason and in accordance with the procedure of the present invention, only the distances A_1, A_2 . . . measured perpendicularly to the projectile trajectories at any moment are continuously ascertained and are measured in place of the true impact sighting error.

The manner of continuously ascertaining the points Q_1, Q_2, Q_3 . . . will be best understood from Fig. 2, wherein a projectile g is shown traveling upon the trajectory a. At the moment t, at which it is located at the position g, the airplane should be exactly at the point F. If in this case the connecting line from F and g runs perpendicularly to the tangent t_g to the trajectory a at the point g (hence perpendicular also to the trajectory) then it clearly represents the approximate impact sighting error Z. Under normal conditions, that is, when the projectile velocity is greater

than that of the airplane there results one and only one connecting line Z between the airplane F and the projectile g which is perpendicular to the trajectory a.

If Z is perpendicular to a, then the two connecting lines FP'_1 and FP'_2, that is, d'_1 and d'_2, from the airplane F to the points P'_1 and P'_2 which are equally distant from the projectile position g, are equal to each other. For the triangle $F-P'_1-P'_2$ must be an isosceles triangle if the median line Fg is perpendicular to the side $P'_1P'_2$.

The momentary projectile position g is clearly defined coordinately by the time of flight T which a projectile requires to reach the point g, and by the adjustments of side and elevation of the gun which existed before the time T elapsed, that is, at the moment of firing.

If one imagines, for example, that at a given moment t_1, the momentary positions of all of the projectiles already in the air are connected with each other upon their individual trajectories, then the line indicated by L_1 in Fig. 3 represents this connecting line. At a later moment t_2 all projectiles have flown further along their paths so that at such moment the geometrical locus of the momentary positions of the projectiles is represented by the line L_2 in Fig. 3. All these geometrical loci pass through the mouth of the gun because, assuming a continuous procedure, a shell is always just leaving the mouth of the gun at any moment under consideration.

Each of these geometrical loci L_1, L_2, L_3 . . . which are definitely associated with the moments t_1, t_2, t_3 . . . possesses, under the assumption that the airplane velocity is smaller than the projectile velocity, one and only one point Q_1, Q_2, Q_3 . . . as already explained, which has the property that the straight connecting line from it to the airplane position at the moment under consideration is perpendicular to the projectile trajectory. These projectile positions Q_1, Q_2, Q_3 . . . must be ascertained for the impact sighting error measurement and only after that can the determination of the distance to the airplane itself be undertaken.

In the central apparatus 8, the ballistic coordinates of the projectile point g, namely the side or azimuth S and elevation E of the gun 1 (these coordinates being available at the shafts of the motors 22 and 23), as well as the time of projectile flight T or the delay period setting or adjustment of the delaying device 10 (shafts 11 and 12), which take into account the curved (ballistic) trajectory, are converted into topographical co-ordinates to enable comparison to be made between them and the topographic coordinates of the target position for determining the sighting error, and they are accordingly converted into the same topographic coordinates of the rectangular x, y, z coordinate system having the gun position as zero point. This conversion is effected with the aid of a co-ordinate changer of known construction, for example, of the type described in detail in German Patents Nos. 620,385 and 611,497. One form of construction thereof is shown, for example, in Fig. 4 at 26. It is composed essentially of the three cams 27, 28 and 29.

The cam 27 is cut, for example, according to the derivation, so that the value taken off the cam 27 as the function of elevation and timing can be added in the differential 30 to the azimuth reading of the gun (shaft 31) and thus yields the resultant azimuth of the projectile. (The derivation means the lateral deflection of a projectile out of the vertical plane which passes through the axis of the barrel of the gun.) The azimuth is suitably oriented upon the base direction. The two cams 28 and 29 are likewise cut in dependence upon elevation and timing corresponding to the horizontal projection of the target distance D' and to the target height z_0, referred to the gun. The obtained values of azimuth and horizontal projection of the target distance are transmitted to the sine-cosine drive 32, in which the horizontal projection of the target distance is decomposed into its components x_0 and y_0 in reference to a horizontal rectangular x, y-coordinate system.

To be able to compare the coordinates of the airplane postion 3 (u_1 and v_1, or u_2 and v_2), measured by the two theodolities 4 and 5, with the artilleristic coordinates of the projectile position which have been converted into x_0, y_0 and z_0, they must likewise be converted into coordinates of the x, y, z coordinate system.

This conversion can be accomplished, for example, mechanically according to the known mathematical relationships (see Fig. 5):

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

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

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

In these equations, b indicates the horizontal projection of the base length, that is, the horizontal distance between the two theodolities 4 and 5. The coordinates x_1, y_1 and z_1 are referred to the position of the theodolite 4 as the coordinate zero point and the base direction as the direction of the x-coordinate. The values x_1, y_1 on the horizontal plane are represented diagrammatically in Fig. 5, while the vertical height z_1 is similarly represented in Fig. 6. It will be seen that the above equations are desirable from the equations given in Figs. 5 and 6 by simple substitution of the value given for R'_1. The magnitude

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

is taken off the cam 33 in the construction illustrated by way of example, and is multiplied in the multiplication drive 34 by the magnitude b which is adjustable by the hand-wheel 35. 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 36 and conducted to the sine-cosine drive 37. Into the latter there is also introduced the angle u_1, so that at the two shafts 38 and 39 the values

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

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 40 by multiplication of the expression

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

by $t_g\ v_1$ with the aid of the correspondingly cut cam 41.

The determination of the value z_1 is accomplished in the illustrated construction quite analagously according to the formula

$$z_1 = b \cdot \frac{\sin u_1}{\sin (u_1 + u_2)} \cdot \text{tg}\ v_2 - \Delta h$$

Δh representing the difference in height of the locations of the theodolites 4 and 5, which can be taken into account by means of the hand-wheel 42 by way of the differential 43.

This double determination of z_1, for which the cams 44 and 45, as well as the multiplication drive 46 and differential 43 are required, and which yields the second value of z_1 at the shaft 47, is necessary in order to avoid the singularity position or point of instability or variability of a function of the selected u, v-coordinate system which occurs when the airplane 3 flies vertically over the base point which was selected as the coordinate zero point; this singularity position occurs when the airplane or target 3 flies vertically above the point which was selected as the coordinate zero point (for example P_1), the value of the v-coordinate being then 90° and tg v_1 of the formula becoming infinite. By means of the couplings 48 and 49, 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 51 through the bevel wheels 50. The reversal of the couplings 48 and 49 is effected by closing an electrical circuit. Such a circuit is, for example, closed by the pairs of contacts 52 or 53 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 double determination of z_1, as already indicated, is necessary in order to enable the height of the target to be ascertained even when it flies over a theodolite when the elevational angle is 90° and its tangent accordingly infinite. As the two theodolites are, in most cases, several kilometers apart, then both elevational angles u_1 and u_2 are never simultaneously very large and thus also their tangents. It is for this reason that the two couplings 48 and 49 are provided, with whose aid the value of z_1 directly ascertained from the cam 45, or the value of z_1 determined from the cam 41, by way of the value of z_2, is transmitted to the shaft 51.

These reversals or the cutting in and out of the couplings 48 and 49 occur automatically. Thus if the target F approaches the zenith of the theodolite 4, the angle u_1 becomes larger and larger and approaches the value of 90°; thereby the cam 45 is shifted upwardly as viewed in the drawing. At a definite displacement, that is, at a definite value for the angle u_1 (for example, when u_1 is 72° and its tangent is equal to about 3) a contact mounted upon the nut which shifts the cam, and forming part of the contacts 53, engages the other contact, whereupon an electrical circuit through a battery is closed. In this way, the coupling 47 is cut out and the coupling 48 cut in, so that the value of z_1, determined by way of z_2, with the aid of the cam 41, is transmitted to the shaft 51.

Similar electric contact devices are actuated or rendered inoperative in the longitudinal displacement of the cam 41, so that at a predetermined value of angle u_2 the coupling 48 is thrown out and the coupling 47 cut in. With a sufficiently long base line, a simultaneous increase of the angles u_1 and u_2 to the point where they can be no longer evaluated, is avoided.

The illustrated mechanism for the evaluation of the above formulas is of the type described in German Patents Nos. 370,956, 433,936, 567,054 and 632,489. The sine-cosine drives and the construction of the cams 33 and 44 and associated parts are shown in greater detail, for example, in German Patents Nos. 370,956, 578,764, 607,318 and 647,296.

The values x_1, y_1 and z_1 obtained in this way at the shafts 38, 39 and 51 suffice to fix definitely the position of the airship in space. They are, however, referred to the position of the theodolite 4 as the coordinate zero point; in order that they may be compared directly with the converted coordinates x_0, y_0 and z_0 referred to the gun position, parallax corrections must be applied to them. This is accomplished in simple and known manner by the addition of the parallax corrections to the coordinates x_1, y_1 and z_1 of the airship's position by means of the differentials 54, 55 and 56, whereupon the new coordinates x'_1, y'_1 and z'_1 are obtained.

These corrections are, of course, constant values for any given position for the gun and theodolites, and are introduced into the mechanism by suitable hand wheels or the like, by way of the differentials 54, 55 and 56.

For the purpose of determining the distance of a projectile position from the target position, the coordinates of these two positions, defined in the same rectangular coordinate system with the gun position as the zero point, are compared with each other, the projectile position still representing only an arbitrary point in space based upon the arbitrarily chosen time value T.

Computing apparatuses for ascertaining the distances between two points defined by coordinates are likewise known. They can resolve the distance, for example, into its components by simple subtraction of the coordinates of both points (airship position and "be" point or point of aim, that is, projectile explosion point, determined by side (azimuth) elevation and timing of ignition) defined in the same coordinate system, yielding the coordinates $(x_0 - x'_1)$ $(y_0 - y'_1)$ and $(z_0 - z'_1)$. The distance itself (target to projectile) is then clearly determined by its components and can be obtained in known manner from the relation

$$Z = \sqrt{(x_0 - x'_1)^2 + (y_0 - y'_1)^2 + (z_0 - z'_1)^2}$$

The individual differentials $(x_0 - x'_1)$, $(y_0 - y'_1)$ and $(z_0 - z'_1)$ are formed, for example, in the differentials 57, 58 and 59. The evaluation of z is effected by devices which themselves are known. On the drawing an electrical mechanism is shown by way of example. This mechanism includes three small electric transformers 60, 61 and 62 with parallel connected primary windings whose primary voltage is constant and is supplied by a generator 63. At the secondary windings of the three transformers, current can be withdrawn by means of the current removers i, k and l in the form of nuts mounted upon rotatable screws 60b, 61b and 62b, and are shifted, by shafts forming an extension of the screw spindles, along the secondary windings. The secondary windings of the transformer are so dimensioned that the

voltage taken off by the voltage remover between one end of the coil and the movable contact, varies according to the square of the displacement of the contacts along their spindles. Since the linear displacement of the contacts corresponds to the components (x_0—x'_1), (y_0—y'_1) and (z_0—z'_1) of the value z, then the withdrawn secondary voltages correspond respectively to the square of these components. The magnitude z (the distance to be measured) is therefore obtained in simple fashion by connecting in series, as illustrated, the portions of the secondary coils subtended by the movable contacts. The sum of the voltages is then transmitted by electrical conductors to the instrument 15 whose scale is so graduated that it always gives the value of z itself. A construction of this type is illustrated in German Patent No. 370,956.

For distance determination, devices are also suitable which depend upon a spatial reproduction of the two points and directly ascertain the distance. The distance z, serving for determining the sighting error can be read off on an instrument 15 and/or can be registered continuously by such instrument.

The distance z so determined, is however, not the shortest distance between the projectile and target and does not represent the sighting error because it is based upon the arbitrarily selected value of T. Up to this point the time magnitude T by which the transmission of the gun adjustments were delayed and which served for determining a projectile position upon the projectile trajectory defined by the adjustments at the gun, corresponded to any arbitrarily selected time of projectile flight. If, however, the above described distance determination (ascertaining of Z) is to give the impact sighting error, then the condition must be fulfilled that Z lies vertically upon the projectile trajectory. This is purely geometrically the case, for example, when the distances of the airship's position F (Fig. 2) from two points on the projectile trajectory, for example, P_1 and P_2 are equal, such points being equally far removed from the base point g of the impact sighting error vector Z.

Accordingly, in order to ascertain automatically in which direction the initially and arbitrarily selected value of T (which, in by far the greater number of cases, is incorrect) must be altered in order to establish the correct projectile position for measuring the sighting error, the two additional points P_1 and P_2 in space are measured which are equally distant from the projectile position g and which lie either upon the same trajectory or upon the tangent to the trajectory at the projectile position g.

For establishing the true projectile time of flight, which determines the base point g of the true impact sighting error Z, the topographical coordinates of two points upon the projectile trajectory are thus ascertained in the central apparatus 8 with the aid of the coordinate converters 63 and 64, such points being at the same distance from the projectile position g. The two coordinate converters 63 and 64 can be constructed quite similarly to the coordinate converters 26; there are then simply conducted to them the same gun positions side S and elevation E as to the converter 26; on the other hand, to one (for example, 63) there is conducted a projectile time of flight (timing) which has been increased by a certain amount and to the other (for example, 64) a projectile time of flight which has been decreased by the same amount. The amount by which the values are increased or decreased can be introduced, for example, by means of the hand-wheel 65 acting through the differentials 66 and 67. The distances of the so-determined points P_1 and P_2 from the airplane position, namely d_1 and d_2, are ascertained in the same way as the impact sighting error Z. It is not necessary to read off the distances d_1 and d_2 at the instruments; the difference d_1—d_2 can be obtained immediately in simple manner by electrical interconnections and must be kept at zero. This occurs automatically in that the differential voltage which is proportional to the difference d_1—d_2 is applied to the motor 14 through the conductors 25, the motor rotating correspondingly and thus varying the projectile time of flight to be introduced. The control of the motor 14 by the described differential voltage can be accomplished directly through the conductors 25 or through an amplifier and special control device. In this way the correct value of the projectile flying time is always conducted both to the delaying mechanism 10 by way of the shaft 24 as well as to the coordinate converters 26, 63 and 64 by way of the shafts 11—12.

Obviously it is possible to utilize the procedure and apparatus according to the present invention for the purpose of determining sighting errors in connection with the use of time-primed ammunition by relatively simple rearrangements.

Variations from the details of construction and procedural steps above described may be resorted to within the scope of the appended claims without departing from the spirit of the invention.

I claim:

1. Apparatus for surveying sighting errors in target practice against moving objects, especially airplanes and in particular by means of percussion-primed ammunition, comprising a pair of theodolites, a central computing apparatus, means for transmitting the settings of the two theodolites as well as those of the gun continuously to the said central apparatus, and means for automatically delaying the time of run of the translatory movement of the gun-settings for an amount of time corresponding to that required by the projectile to cover its trajectory up to a point lying at the shortest distance from the true station of the airplane.

2. Apparatus according to claim 1, including means for transmitting the setting of the said time of run in the said delaying device to the said computing apparatus which latter is constructed to determine the distance between the true position of the airplane on the one hand and two relatively fixed points lying a suitably chosen distance apart on the trajectory of the projectile on the other hand, the said two latter points being moved along the said trajectory in accordance with the said setting of the time of run, and means controlled by the computing device for regulating the setting of the time of run in the one or the other direction at the moment when the distances of said points from the airplane become of unequal length.

3. Apparatus according to claim 1, wherein the computing apparatus determines the distances between the true position of the airplane on the one hand and two points lying on a tangent to the trajectory at equal and suitably chosen fixed distances from the point of tangency on the other hand, and means controlled by the computing apparatus for adjusting the

time of run to cause the said point of tangency to move along the said trajectory in accordance with said adjustment.

4. Apparatus according to claim 1, wherein the delay device comprises at least one revolving endless steel tape, at least one sending and one receiving device, at least one hearer-head and one speaker-head, and a servomotor; and means controlled by the computing apparatus for actuating the servomotor to effect automatic adjustment of the time of run by changing the length of the said tape between the said speaker-head and the said hearer-head.

5. Apparatus according to claim 1, wherein the delay means comprises an electromagnetic mechanism including at least one revolving endless steel tape and at least one sending and receiving device, the said tape being arranged to receive the magnetic registrations from the said sending device and convey them to the said receiver, and means for regulating the length of the said tape between the said sending and receiving devices.

6. Apparatus according to claim 1, wherein the delay means includes an endless steel tape running between a speaker head and a hearer head, servomotor for altering the effective length of the tape between the speaker-head and the hearer-head, and means for regulating the speed of the servomotor.

7. Apparatus for surveying sighting errors in target practice against flying objects, comprising means for continuously sighting the flying target, a gun provided with instruments for determining its azimuth and elevation, a computing mechanism for determining the distance of the projectile fired by the gun from the target, means for transmitting to said mechanism the sighting and gun data, and mechanism arranged in the path of transmission between the gun and computing mechanism for delaying the transmission of the gun data for the period of flight of the projectile.

8. Apparatus as set forth in claim 7, wherein the computing mechanism includes means for measuring the distance from the target to each of two points equally spaced from the projectile at the end of a given time of flight and approximately along the projectile trajectory, a motor for regulating the transmission time delay effected by the delay mechanism, and means controlled by the measuring mechanism for causing operation of the motor in one or the other direction until the distances between the said two points become equal.

9. Apparatus as set forth in claim 7, wherein the said computing mechanism includes coordinate converters for converting the data of the sighting mechanism and the gun into the same coordinate reference system.

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