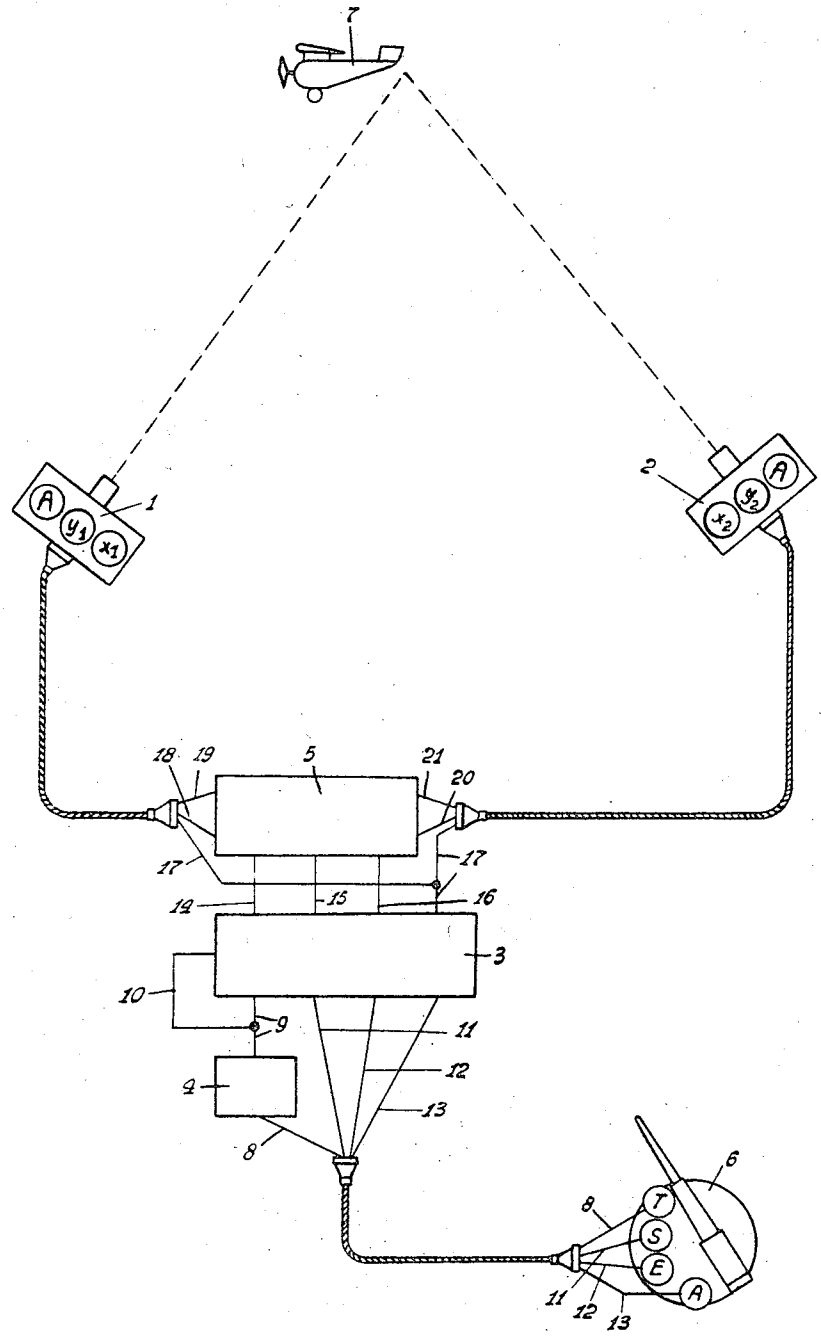
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APPARATUS FOR MEASURING ERRORS OF AIMING AND FIRING IN PRACTICE FIRING AGAINST MOVING TARGETS

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APPARATUS FOR MEASURING ERRORS OF AIMING AND FIRING IN PRACTICE FIRING AGAINST MOVING TARGETS

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The present invention relates to apparatus for photogrammetrically surveying or ascertaining sighting or gunnery errors for the case of moving targets, especially with relation to anti-aircraft gunnery practice.

In gunnery practice against moving targets, especially aircraft, we have to distinguish fundamentally between two different methods of procedure, i. e. gunnery against towed targets with the aid of live ammunition on the one hand and gunnery with the aid of blank ammunition together with a simultaneous survey of the airplane-trajectory on the other hand.

The shooting against towed targets has the disadvantage that these towed targets are by far less mobile or movable than the airplane itself. Gunnery practice with blind or blank ammunition up to now has followed more or less the following lines: The airplane-trajectory is surveyed and recorded both as to position and time in a continuous way and manner by means of cinematographic photo-theodolites, and the time, the timing of the projectiles, side and elevation of the guns are recorded at the moment of discharging the gun; with the aid of said records it then is possible to determine the sighting error.

Since the speed of an airplane is of the order of magnitude of that of the projectile, we must determine beforehand a future station of the airplane (point of aim) on the basis—as is well known—of various hypotheses. The point of aim is a surmised future station of the airplane, in which connection the word "future" is of critical importance. After the span of time (mean time of flight of the projectile), for which the station of the airplane has been assumed beforehand, has elapsed, the airplane should be stationed at the assumed point (be-point). This, however, only comes true when and if the hypothesis was based on the real factors and conditions. The anti-aircraft guns, at the moment of their discharge, are sighted toward the point of aim; they, however, shoot at the be-point, since the shell arrives at its point of destination (be-point) only after the time of flight of the projectile has elapsed. The sighting elements of the guns thus have been chosen so as to bring the mean point of hit—with all due forecast—into coincidence with the be-point. A point of aim then, after a certain length of time has elapsed (the so-called timing period), turns into the be-point. The geometrical distance between the be-point and the true airplane-station (is-point) is called the sighting error.

The true airplane-station is found by means of film pictures which have been taken—figures from the moment of the gun's discharge—after the timing period has elapsed. The co-ordinates of the be-point are computed on the basis of the shooting tables, giving us the data of side, elevation and timing. The sighting error then is found by way of a geometrical formation of differences. We thus will have to figure the absolute co-ordinates of both of be-point and is-point. This method of procedure is complicated and tiresome and thus consumes much time.

The procedure according to the present invention allows us to directly determine the sighting error or, as the case may be, the gunnery error in an essentially more simple way and manner in cases where the photo-theodolites or the cinematographic photo-theodolites are controlled and steered by and from the guns, timing machines, commander apparatus and the like by means of motors. According to the method of procedure along the lines of the present invention, the translation of the movements onto the photo-theodolites is effected by way of co-ordinate changers and translatory systems with an increased fixed or changing time of run, i. e. so-called delayers.

In this way the photo-theodolites are continuously directed to the be-point, and the sighting error can be ascertained from the distances of the airplane photos from the middle point of the picture upon two related photographs.

The apparatus for photogrammetrically measuring sighting and gunnery errors according to the present invention includes at least two theodolites of known construction which are electrically connected with the gun and the charging machine and are directed by the latter by remote control. The actuation of the shutter mechanisms of the phototheodolites likewise proceeds from the gun by remote control, for example, by the firing signal. An important part of the apparatus of the present invention is formed by special delay-producing devices which are connected in the electrical conductors between the gun and the phototheodolites and which increase the time for transmitting the values from the gun to the photo-theodolites by a flight interval corresponding to the ignition timing in any particular case.

A satisfactory form of construction for the delaying devices is one embodying a moving steel tape. This delaying device includes at least one moving endless steel tape upon which, by means of a so-called speaker head, magnetic registrations are produced which are received by means

of a so-called hearer head. The transmission of the series of electrical signs which represent the movement of the transmitter or sender at the gun and at the ignition timing machine, and are registered magnetically by the speaker upon the steel tape, and are received by the hearer head, is in this way delayed by the time interval which the steel tape consumes in travelling from the speaker head to the hearer head. For characterizing a movement, it is necessary to employ series of signs in several transmission channels. In general, a steel tape delayer must be included in every transmission channel for increasing the time interval required for the transmission, which otherwise would be practically instantaneous. This can, however, be eliminated, if according to the present invention the registrations of the series of signs of the different channels are spatially separated from each other upon the steel tape or are accomplished by means of several superposed carrier currents which are modulated by the sender movements to be transmitted.

The changing of the degree of increase of the time interval for transmitting the sender movements is accomplished by changing in known manner the length of steel tape between the speaker head and the hearer head, which can be accomplishd by shifting one of the heads relatively to the other or by keeping the heads stationary and varying the length of the path of travel of the tape therebetween.

A satisfactory construction of the apparatus mentioned above is illustrated—by way of example—schematically in the accompanying drawing.

The apparatuses 3 and 4 house the delayers with the steel tapes for recording the registrations of the sender-movements for the purpose of an artificial amplifying of the time of run of the transmission of movements and signals onto the photo-theodolites 1 and 2. The apparatus 5 contains the changers of co-ordinates which—in a manner well known—change the artilleristical co-ordinates with which the guns 6 (in the drawing but one of the latter is shown) are sighted toward the point of aim 7 into the sighting co-ordinates for the photo-theodolites 1 and 2. For the purpose of transmitting movements pertaining to the artilleristical co-ordinates (side—S, elevation—E and timing—T) from the guns 6 onto the photo-theodolites 1 and 2 as well as for transmitting the signal A of discharge, electrical circuits 8—21 are provided. The transmittance, however, also could take place in a wireless, optical, acoustical or mechanical way and manner.

The data of the co-ordinates side S, elevation E and timing T as well as the signal A of discharge or firing are conveyed onto the main delayer 3 by way of the lines 8, 9 and 11—13. Said data are delayed in the said main delayer by the amount of the time of flight of the projectile corresponding to the timing T. After the time delay has elapsed, the values of side S, elevation E and timing T are transmitted to the co-ordinate-changers 5 by way of the lines 14—16 and there changed into the sighting co-ordinates of the photo-theodolites 1 and 2.

This coordinate changing is necessary because the gun coordinates must take account of the curved trajectory and, therefore, for example, the elevation of the gun is not equal to the angle at which the photo-theodolite is directed. In this connection there are, of course, taken into account in known manner the different locations of the photo-theodolites and of the gun.

The co-ordinates suitably are so chosen as to render the photogrammetrical evaluation or mapping of the photographic pictures simple. They are transmitted to the photo-theodolites 1 and 2 by way of the lines 18, 19 and 20 and 21, respectively.

The firing signal A, which in the main delayer 3 has been delayed by the amount of the time of flight of the projectile, is transmitted to the photo-theodolites 1 and 2 by way of the line 17 and acts on their shutter mechanisms. A pre-delayer 4 is connected to the line 8, 9, which latter transmits the value of timing T, between the gun or appurtenant timing machine and the main delayer 3. Said pre-delayer takes the so-called charging delay into account by pre-delaying the transmittance of the timing index by the amount of the charging delay. The latter is set down as that length of time which elapses between the setting of the timing on the projectile and the moment of firing, and it depends upon the performance of the operating crew.

The timing value T, thus pre-delayed, together with the data as to elevation and side of the guns at the moment of firing constitute the collective values of the artilleristical co-ordinates of the point of aim.

The timing value T not only is transmitted by way of the line 16 to the main delayer 3—for the purpose of a further delayed transmittance—but at the same time is made use of, in known manner, for regulating the delay apparatus, since the latter, automatically or in combination with a time indicator, is controlled corresponding to the timing (time of flight of the projectile).

Amplifiers may be hooked up—in known manner—to all lines of transmittance. The apparatuses 3, 4 and 5, however, also may be interconnected in a different way from the one shown, in particular in such a way that the delay arises between or after the transformations of the co-ordinates.

The center of the picture or a special mark on the film corresponds—in the photo-theodolites pointed by way of the delaying devices in accord with the sighting of the guns—to the be-point (theoretical, mean point of detonation).

The field of view of the photo-theodolites may be so chosen—by way and means of a suitable photographical optical system—that the airplane to be shot at is represented on the pictures with the greatest degree of probability. The linear distance then between the picture of the airplane and the center of the picture is a direct measure for the sighting error in question. In order to be able to ascertain this error then, a single twin-exposure, for example, is sufficient instead of the film exposures of the whole trajectory of the airplane by means of two theodolites as used heretofore. No extensive analytical transformations are necessary any longer, since the center of the picture corresponds to the be-point.

Gunnery practice with live ammunition also may be surveyed photogrammetrically—e. g. against manned or unmanned fully movable airplanes—in the following manner set forth by way of an example:

The airplane is continuously sighted at and its position registered or surveyed by means of a sighting or observation apparatus. The ascertained co-ordinates of sight are transformed in a commanding or corresponding apparatus into artilleristical ones, and this is done for that be-point at which the airplane is expected to arrive, after the time of flight of the projectile has elapsed, according to the method of extrapolation

on which the commanding apparatus is based. The guns now, however, are not sighted toward this computed point, but instead toward the appurtenant reflected image of the latter, e. g. with relation to the vertical plane passing through the connecting line of the two exposure apparatuses (base line) or with relation to any vertical line in space, suitably one through the center of the base line. If now we point two of four exposure apparatuses—which are set up in pairs and which may be represented e.g. by cinematographic theodolites—toward the true point and two toward the said mirrored point, computed in advance, and if now, furthermore, we release the shutters of the four apparatuses at the same moment, the gunning and sighting errors may be found from the appurtenant exposures in question and thus also the performance factor of extrapolation of the commanding apparatus according to the geometrical art of photogrammetry.

The use of live or ordnance ammunition will not be fatal to the crew of a manned airplane because the manned airplane is only used to be aimed at, the anti-aircraft artillery being enabled thereby to be operated in correspondence with the mobility of a war-like airplane; the guns however are not sighted toward this manned plane or toward the point extrapolated by the fire-director, but toward a point which is in a definite and well-known geometrical relationship to the former point, e. g. toward a point which is always the geometrically reflected image of the former point with relation to the vertical plane passing through the connecting line of the two exposure apparatuses.

What I claim and desire to secure by Letters Patent is:

1. Apparatus for photogrammetrically measuring sighting and gunnery errors in gun practice against moving targets, such as aircraft, comprising at least two photo-theodolites provided with shutter mechanisms, means for electrically connecting said photo-theodolites with the gun and its ignition timing machine, mechanism controlled by impulses transmitted by said connecting means and corresponding to the gun coordinates for directing said photo-theodolites in accordance with the adjustments of the gun and ignition timing machine, mechanism connected in said conductors for transforming the transmitted gun coordinates into appropriate photo-theodolite values, means controlled from the gun for actuating the shutter mechanism of the photo-theodolites, and a delayer device in the electrical conductors between the gun and its ignition timing machine on the one hand and the photo-theodolites on the other for increasing artificially the time of transmission of the values of the gun and its ignition timing machine to the photo-theodolites by the time of flight of the projectile, so that the photo-theodolites are directed upon the same point of aim as the gun, but always after the instant of the discharge of the projectile by a time interval corresponding to the time of flight of the projectile.

2. Apparatus according to claim 1 wherein the delaying device in the electrical conductors between the gun and the photo-theodolites includes at least one moving endless steel tape adapted to receive magnetic registrations for conveying them to a remote point, and including further for each steel tape a speaker head for producing the registrations and a hearer head for receiving the same.

3. Apparatus according to claim 1, wherein the delayer device for increasing the time required for transmitting a forward and rearward sender movement is composed of a single moving endless steel tape, a plurality of speaker heads arranged to register at spaced points upon the steel tape the multiplicity of magnetic registrations required for characterizing a forward and rearward movement, and a plurality of hearer heads for receiving the registrations.

4. Apparatus according to claim 1, wherein the delayer device for increasing the time for transmission of a forward and rearward sender movement is composed of a single moving endless steel tape, a speaker head associated with the tape and adapted to produce the multiplicity of registrations required for characterizing the forward movements by means of at least two carrier currents modulated by the sender movement, and a hearer head for receiving the registrations.

5. Apparatus according to claim 1 wherein the delaying device in the electrical conductors between the gun and the photo-theodolites includes at least one moving endless steel tape adapted to receive magnetic registrations for conveying them to a remote point, and including further for each steel tape a speaker head for producing the registrations and a hearer head for receiving the same, and means for varying the increase of the time interval for transmitting a signal from the gun to the photo-theodolites, said means acting to shift the hearer head in the delayer device along the length of the steel tape relative to the speaker head.

6. Apparatus according to claim 1 wherein the delaying device in the electrical conductors between the gun and the photo-theodolites includes at least one moving endless steel tape adapted to receive magnetic registrations for conveying them to a remote point, said apparatus including further for each steel tape a speaker head for producing the registrations and a hearer head for receiving the same, and means for varying the increase of the time interval for transmitting a signal from the gun to the photo-theodolites, said means acting to shift the speaker head in the delayer device along the length of the steel tape relative to the hearer head.

7. Apparatus according to claim 1, wherein the delaying device in the electrical conductors between the gun and the photo-theodolites includes at least one moving endless steel tape adapted to receive magnetic registrations for conveying them to a remote point, said apparatus including further for each steel tape a speaker head for producing the registrations and a hearer head for receiving the same, and means for varying the length of the steel tape between the speaker and hearer heads in the delayer device, whereby the degree of increase of the time of transmission of a signal from the gun to the photo-theodolites is regulated.

8. Apparatus according to claim 1, including a plurality of delayer devices arranged in series in the electrical conductors for transmitting the values of the gun to the photo-theodolites, and means for varying the degree of time increase of said delayer devices independently of each other.

9. Apparatus according to claim 1 for photogrammetrically measuring sighting and gunnery errors in sharp gun practice upon displaced targets, including at least four photo-theodolites arranged in pairs of which one does not intersect the target at the time of firing but delayed by the time of flight of the projectile, and a mechanical drive for so coupling the photo-theodolites with

each other in pairs, that the second theodolite is directed upon a displaced point of aim when the first intersects the true target.

10. Apparatus according to claim 1 for photogrammetrically measuring sighting and gunnery errors in sharp firing practice upon displaced targets, including at least four photo-theodolites arranged in pairs of which one intersects the target not at the time of firing but after an interval corresponding to the time of flight of the projectile, and a device having interchangeable connections for electrically coupling the photo-theodolites with each other in pairs in such manner that the second photo-theodolites of each pair is directed to a displaced point of aim when the first intersects the true point of aim.

11. Apparatus according to claim 1 for the continuous obtainment of associated artilleristic coordinates of the point of aim, including a delayer device located in the electrical conductors for transmitting the ignition timing value, said delayer device comprising at least one moving endless steel tape, a speaker head associated with each tape for producing magnetic registrations thereon and a hearer head for each tape for receiving said registrations, said delayer device increasing, by the charging period, the time of transmission of the ignition timing value from the ignition timing machine and one of the aforementioned devices to which the correlated adjustments of the side and elevation at the gun are directly transferred.

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