No. 777,508. PATENTED DEC. 13, 1904.

E. W. HUBBARD.

AUTOMATIC GUNNERY CORRECTING DEVICE.

APPLICATION FILED MAR. 21, 1904.

NO MODEL. 5 SHEETS—SHEET 1.

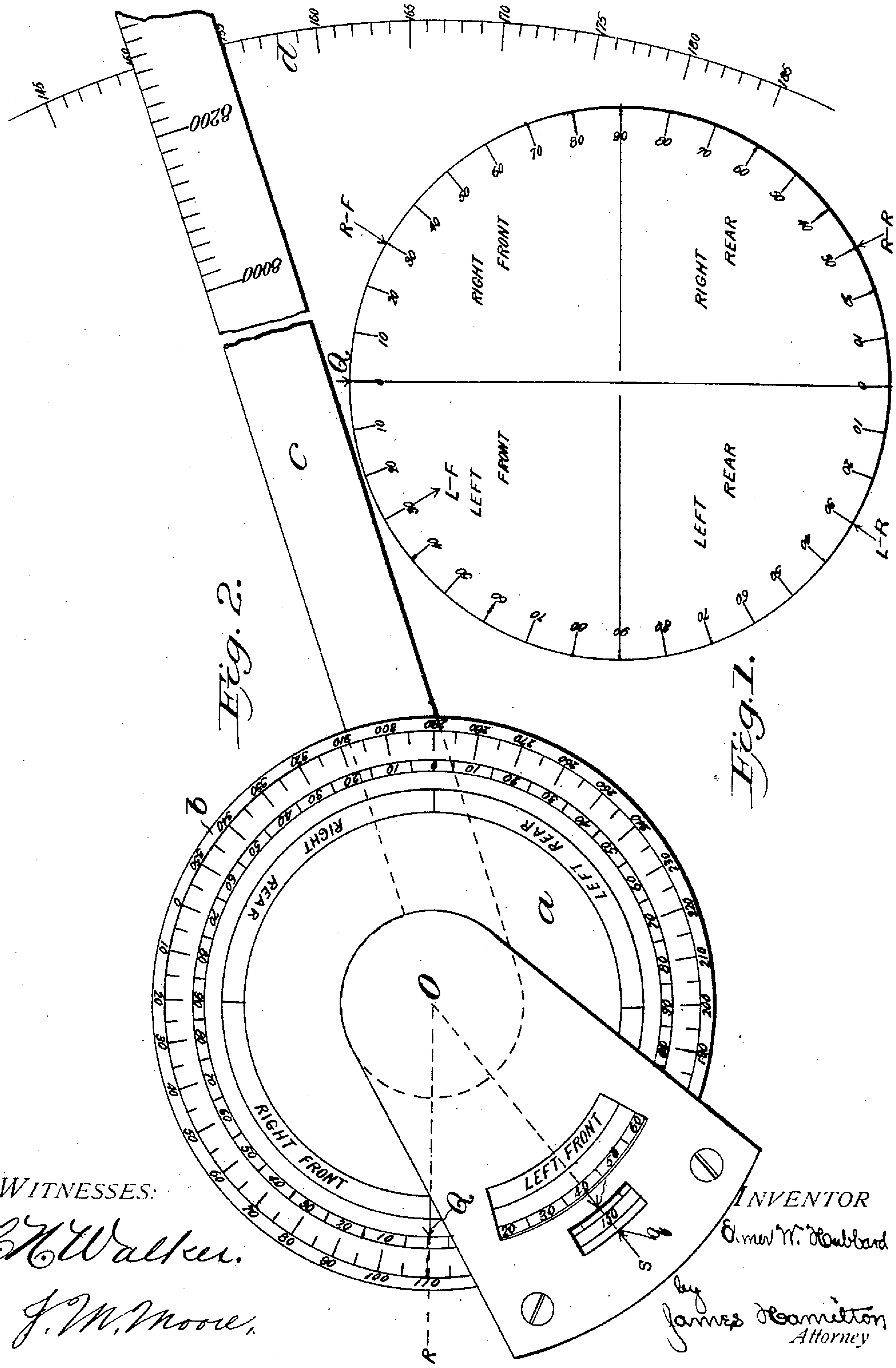

Fig. 1.

Fig. 2.

WITNESSES:

C. H. Walker.

J. W. Moore.

INVENTOR

Elmer W. Hubbard

by James Hamilton

Attorney

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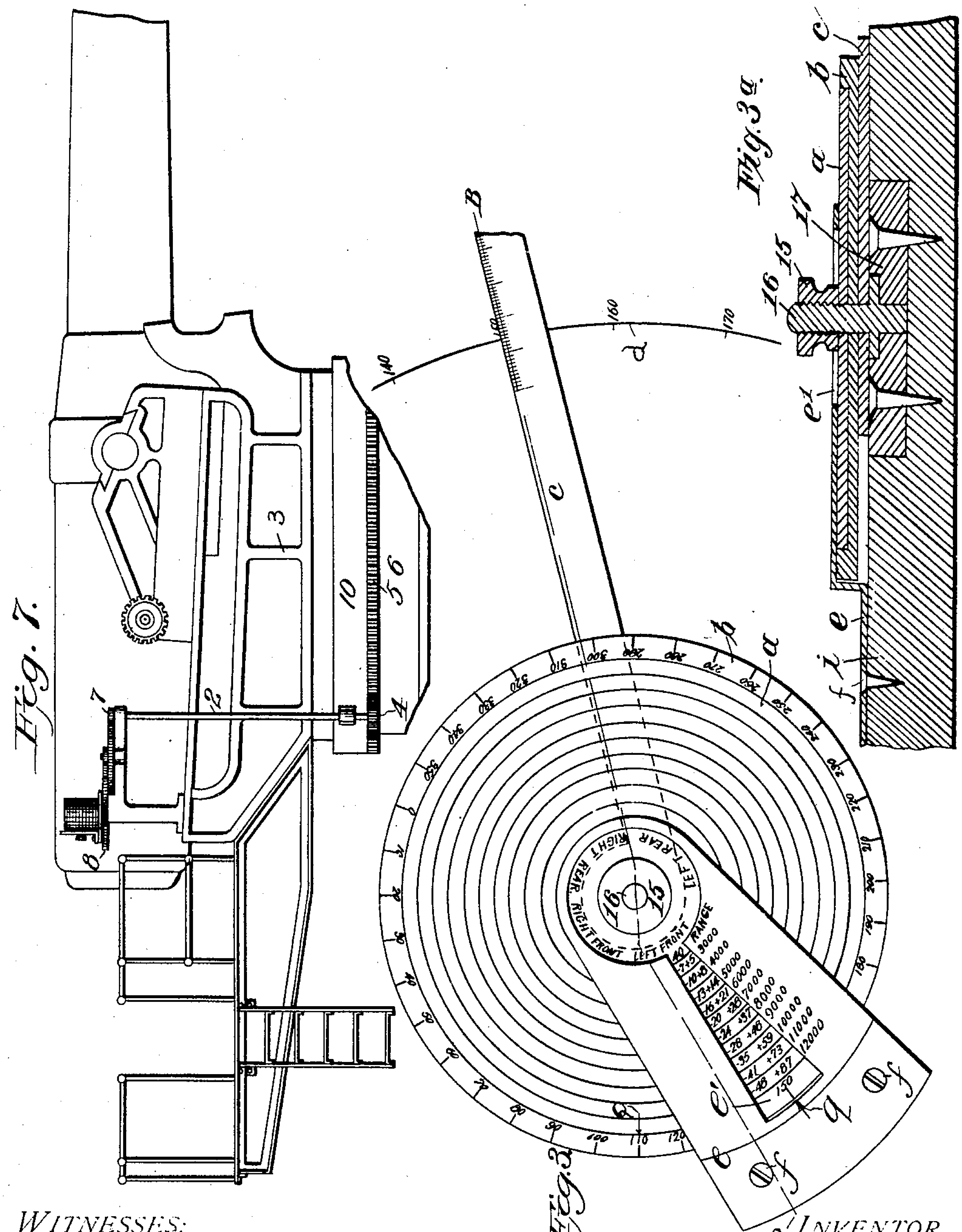
NO MODEL. 5 SHEETS—SHEET 2



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BY

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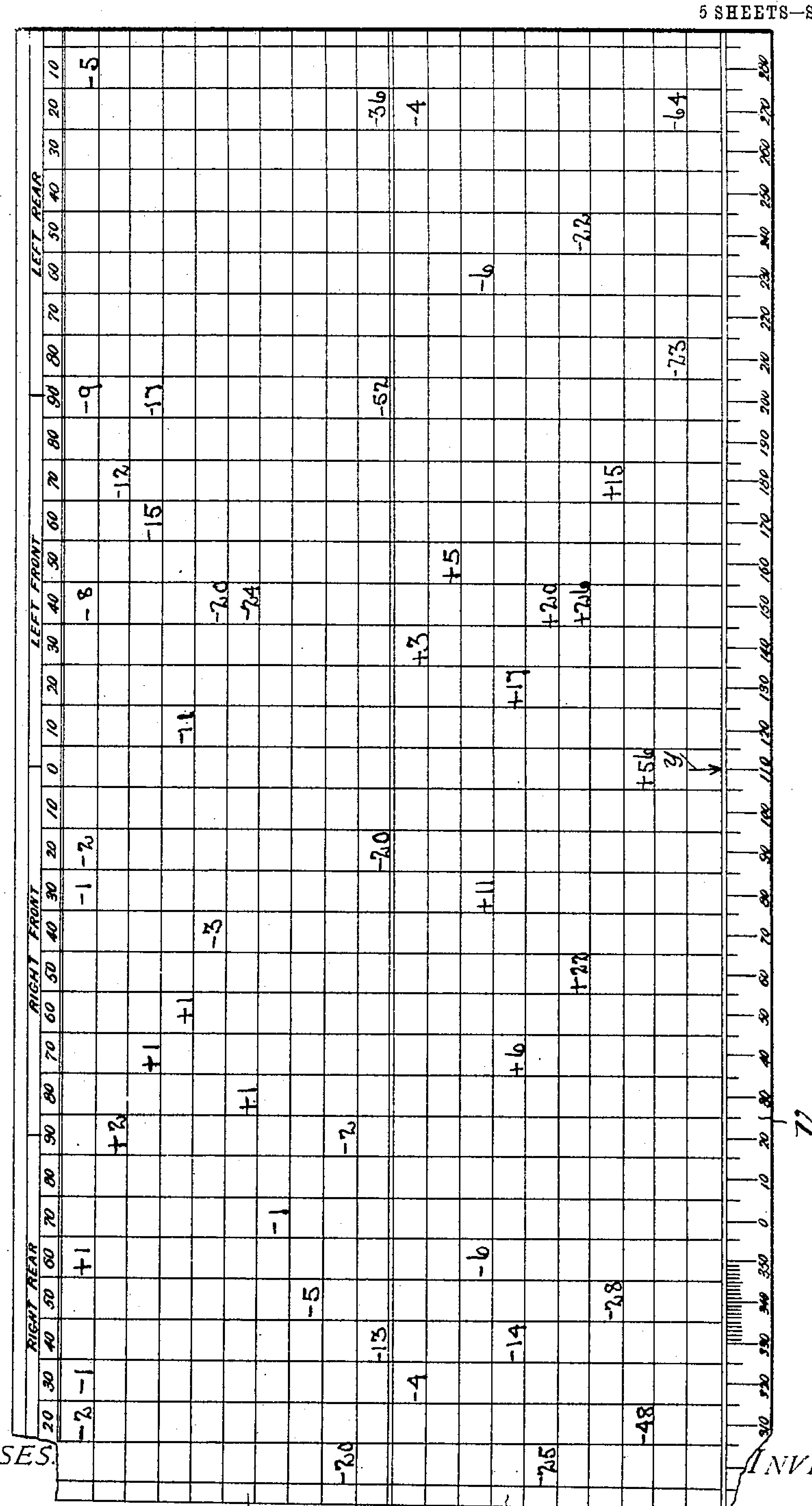
NO MODEL. 5 SHEETS—SHEET 3.

Fig. 4.



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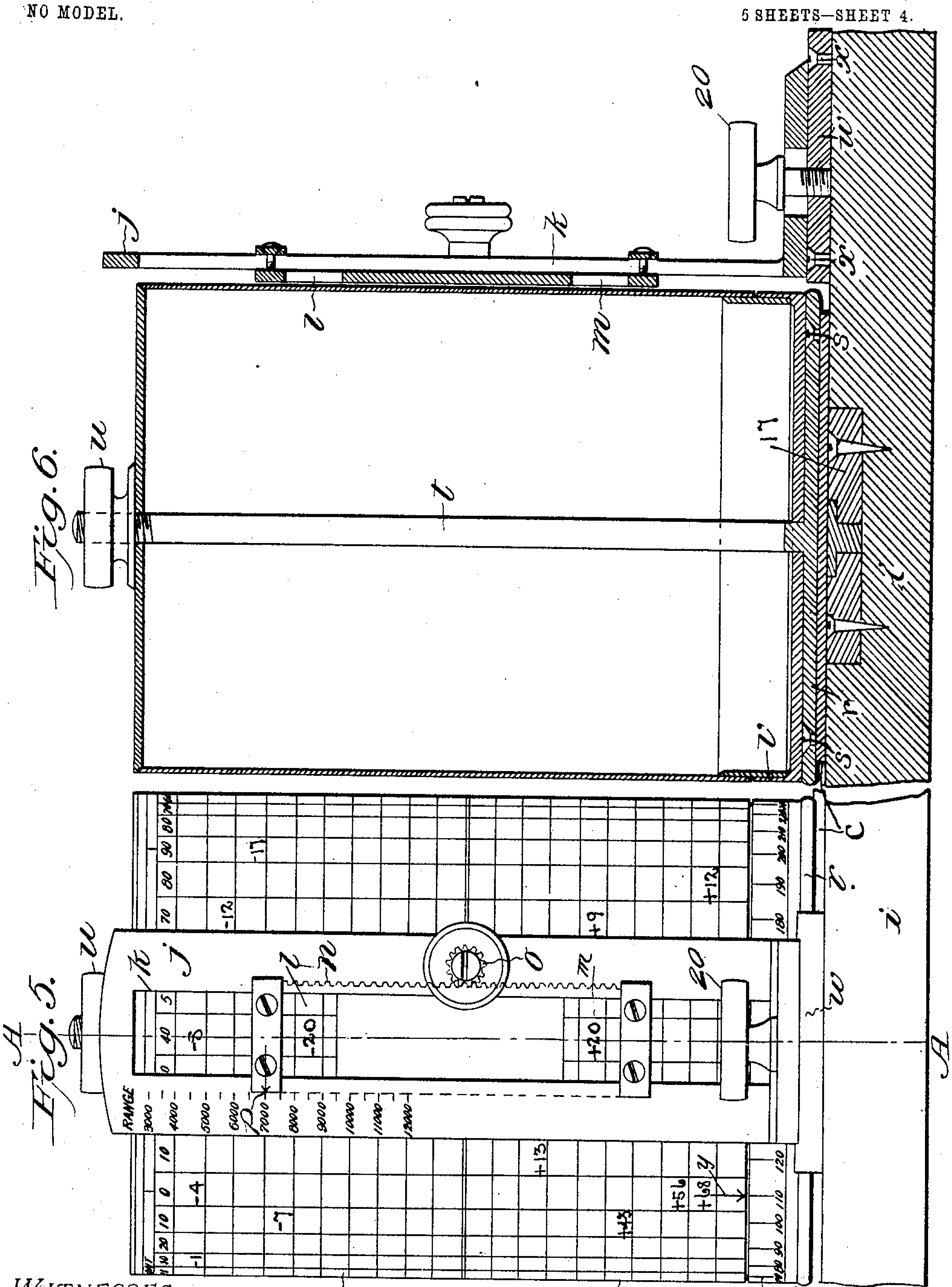

WITNESSES:

C. N. Walker

J. M. Moore,

INVENTOR

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BY

James Hamilton

Attorney

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NO MODEL. 5 SHEETS—SHEET 5.

Fig. 9.

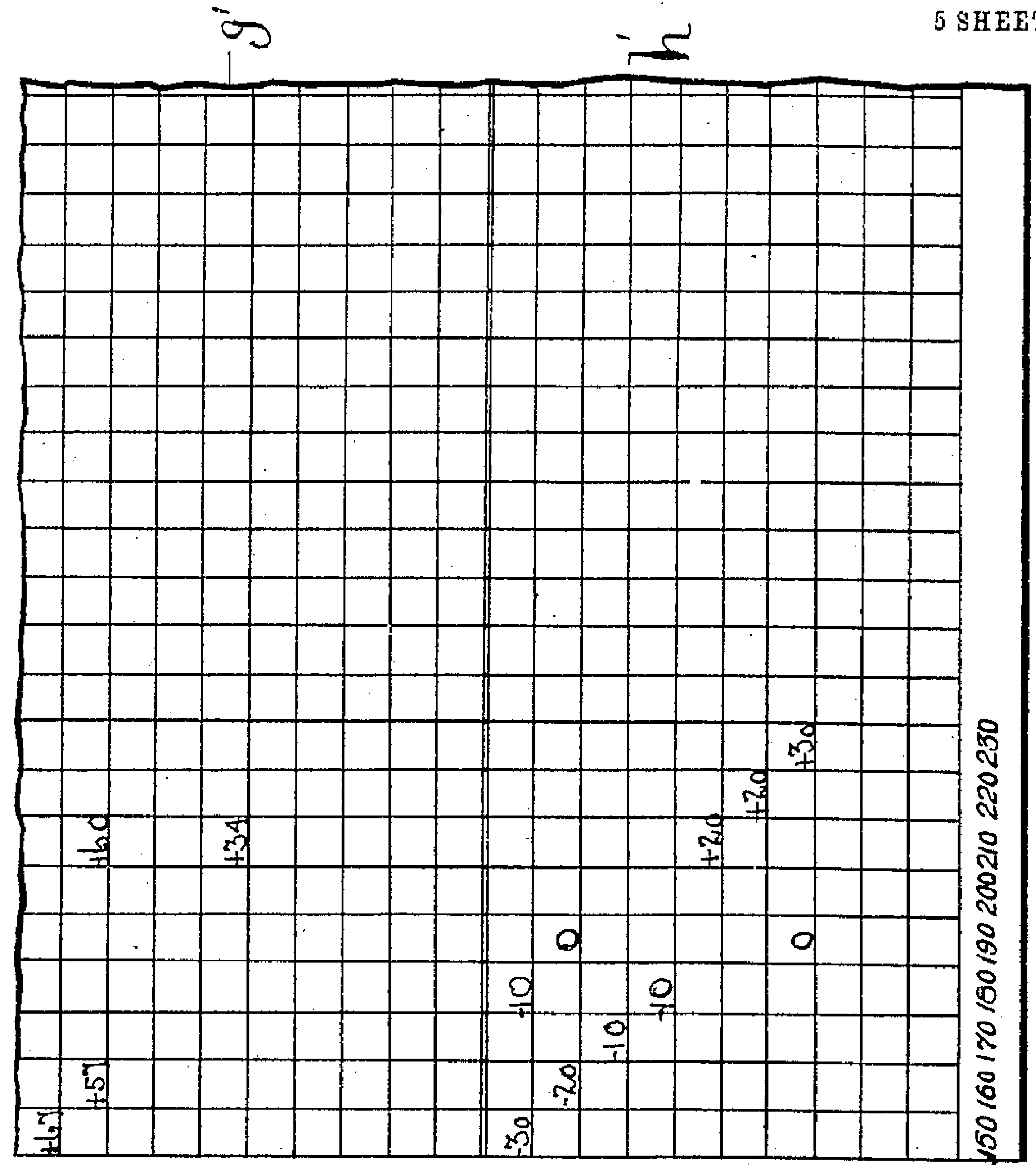
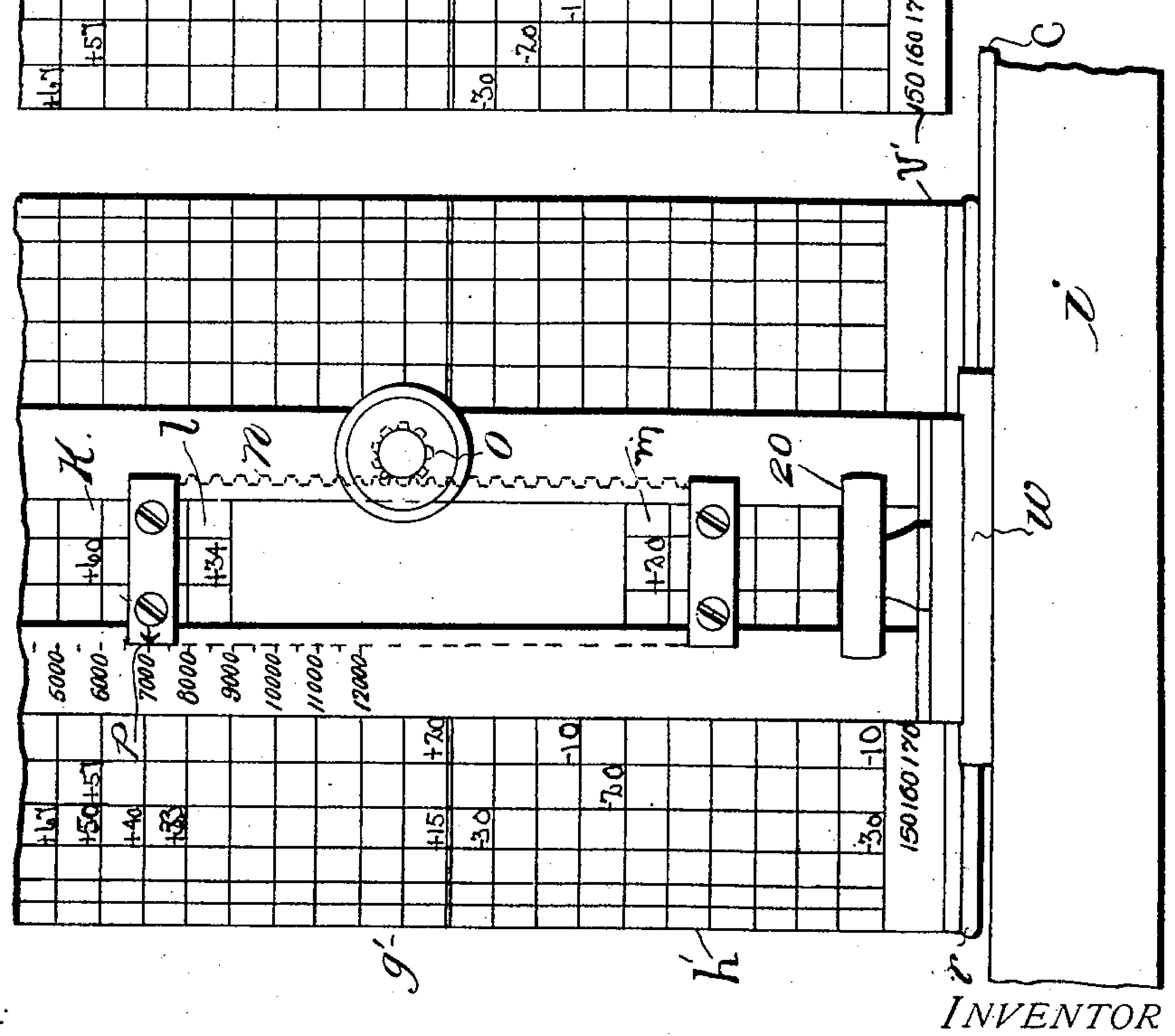


Fig. 8.



WITNESSES:

C. M. Walker,

Fred. P. Hinkel

INVENTOR

Elmer W. Hubbard

BY

James Hamilton

Attorney

No. 777,508. Patented December 13, 1904.

UNITED STATES PATENT OFFICE.

ELMER W. HUBBARD, OF THE UNITED STATES ARMY, ASSIGNOR TO W. & L. E. GURLEY, OF TROY, NEW YORK.

AUTOMATIC GUNNERY-CORRECTING DEVICE.

SPECIFICATION forming part of Letters Patent No. 777,508, dated December 13, 1904.

Application filed March 21, 1904. Serial No. 199,281. (No model.)

To all whom it may concern:

Be it known that I, ELMER W. HUBBARD, a captain in the Artillery Corps of the United States Army, stationed at Fort Revere, Hull, in the county of Plymouth and State of Massachusetts, have invented a new and useful Improvement in Automatic Gunnery-Correcting Devices, of which the following is a specification, reference being had to the accompanying drawings.

My invention relates to improvements in devices for giving the necessary corrections in artillery firing; and the object of my invention is to provide a device of the class described which shall give with greater speed and facility and with less liability to error the necessary gunnery corrections for use in artillery firing (especially with heavy seacoast guns) than any device heretofore known and which shall interfere in no way with the usual operations of plotting at the plotting-board or with working of the gun itself.

In gunnery, as is well known, the effect of the wind on the flight of the projectile is usually twofold, viz: It shortens or increases the range attained by the projectile in perfectly still air and it also usually causes it to depart from the plane of fire. These two effects vary in magnitude with the force or velocity of the wind and with the angle made by its direction with the plane of fire, and the magnitude of these effects can be separately determined by the resolution of forces according to the well-known principle of the parallelogram of forces. The effect of the wind in increasing or diminishing the range which would otherwise be attained by the projectile may be termed the "range" effect of the wind, and the effect of the wind in causing the projectile to depart from the plane of fire may be termed its "deviation" effect.

In heavy-artillery firing the range effect of the wind is corrected for practically by adding to or subtracting from (as the case may require) the actual distance from the gun to the target a certain number of yards, the result being a corrected or working range in yards upon which is based the elevation to be given the gun. Similarly correction must be made for the deviation effect of the wind, and since there are other deviating causes besides the cross component of the wind this correction enters as one element of the sum of the corrections due to all said deviating causes. The sum of these corrections is represented by the angle at the gun which the plane of fire must make with the vertical plane through the target at the instant the gun is discharged in order that the projectile may strike the target. Such angle is usually called the "deflection" and is laid off either on the deflection-slide of the sight or on the azimuth circle of the gun.

In heavy-artillery firing at moving targets the total deflection is made up usually of the following elements, due to the following causes, each being taken with its proper relative sign: First, the correction for the deviation effect produced by the cross component of the wind, either positive or negative; second, the correction due to drift of the projectile, always negative in the United States system of artillery; third, the correction for "lateral travel" or angular motion of the target during the time of flight of the projectile for the range considered, and, fourth, the correction for the lateral angular error of the last shot. The two last-named corrections may be either positive or negative. The total deflection is thus the algebraic sum of the several corrections for the effects of the various deviating causes and errors above enumerated. The sign to be given each correction is determined by the direction in which the muzzle of the gun must be moved horizontally to compensate for the effect of the particular element or error. If such movement must be to the right of the vertical plane through the gun and target, the correction is taken as positive; if to the left, as negative.

Under present methods, the wind being given as of a certain azimuth or direction and velocity, (both determined by well-known methods, which need not be described herein,) it is necessary to go through the following operations, viz: First, find the angle made by the direction of the wind with the plane of fire. This may be done by well-known graphical or mechanical means. Second, resolve the wind into its two components, the range component parallel to the plane of fire and the cross component perpendicular to that plane. This may be also done by like methods to those used in the preceding operation. Third, determine the corrections necessary to compensate for the effects of these two components by entering appropriate tables, giving to the corrections the proper sign by the rule above established. To the correction for the effect of the cross component of the wind is algebraically added the (in our system negative) correction for drift, the sum being the deflection correction due to these two effects, wind and drift, or by known methods this latter correction can be obtained in one number in one operation by setting an index to a curve plotted for wind components and to include drift.

The various operations just described result in much loss of time and are very liable to introduce or be attended by errors, especially in the rapid firing which is now considered so important.

My new device is designed and adapted to overcome the objections urged against present methods, and therefore to give the gunnery corrections with greater speed and facility and with less liability to error than under the present system. It passes from the primary data of azimuth and velocity of wind directly to the actual units as applied, avoiding thereby all intermediate steps and gives by inspection automatically and instantly the desired corrections. The device works as fast as the plotting can be performed. Greater speed results, as does also greater accuracy. To aid in obtaining these beneficial results, the wind is considered in the use of my new device according to the simple and natural system hereinafter described. While this system is in many respects similar to that ordinarily used, it gives greater facility in calculating the corrections desired, in describing the particular wind, and in testing the setting or adjustment of my new device.

In the drawings, Figure 1 shows diagrammatically the nomenclature adapted by me in my new system of wind designation. Fig. 2 shows a circle similar to that illustrated in Fig. 1 combined with a reversed azimuth circle and is schematic. Fig. 3 illustrates my new automatic correcting device in disk form. Fig. 3[a] is a sectional view on line B B, Fig. 3. Fig. 4 is a rectification of the cylinders and cup used in the cylindrical form of my new device. Fig. 5 is an elevation of my new device in its cylindrical form. Fig. 6 is a sectional view on line A A, Fig. 5. Fig. 7 shows my new device as applied at the gun. Fig. 8 shows the lower cup extended and containing range and azimuth differences, and Fig. 9 is a rectification of the cup shown in Fig. 8.

As shown in Fig. 1, the angle between the direction of the wind and the plane of fire is given in degrees numbered from "0" to "90" in each direction from the trace of the plane of fire. This permits the classification of all winds by quadrants, the division of all winds into four classes corresponding to the four quadrants, and the use of a simple system of designating them. Thus a wind blowing in the direction of the arrow R F is designated a "right-front" wind of thirty degrees, one coming from the direction of the arrow L F a "left-front" wind of thirty degrees, one having the direction of the arrow R R a "right-rear" wind of thirty degrees, and one traveling in the direction of the arrow L R a "left-rear" wind. Thus we have a quadrant of right-front winds, one of left-front winds, another of right-rear winds, and a fourth of left-rear winds. According to the rule above enunciated the deflection corrections for the deviation effects of winds coming from the right of the plane of fire (in Fig. 1 winds in quadrants to the right of the trace of the plane of fire) are positive, while like corrections for winds in the other two quadrants are negative. For all rear winds the range corrections are negative and for all front winds positive. The deviation effect of a wind blowing from the direction of the arrow R F is equal to that of a wind traveling along the line of the arrow R R, and the deflection corrections in the two cases are equal and of the same sign, since they make equal angles with the plane of fire; but while the range effect of the two winds are equal the range correction for the first is of opposite sign to that for the second. This system of wind classification and designation is not only a natural one for the gunner, but it is also one which facilitates description and calculation.

In Fig. 2, which is diagrammatic and intended to illustrate principle rather than structure, the outer disk *b* is provided with the graduations of a reversed azimuth circle. The azimuth circle is reversed or counter-clockwise, because the disk *b* moves. At the gun the azimuth circle is marked clockwise and is fixed, while the gun and its attached pointer or index move. Mounted free to rotate concentrically within the disk *b* is a disk *a*, having upon its upper face graduations similar to those shown in Fig. 1. *d* is an azimuth circle from which by means of the plotting-ruler *c* the azimuth of the gun is laid off for a given position of the target, and by means of graduations upon the ruler *c* the distance from the gun to the target is determined in yards, all in accordance with present plotting-board practice. Let O be the plotted position of the gun on the plotting board or chart and let the two disks *a* and *b*, which are concentric, be centered upon this point O.

The azimuth of the wind is the angle in degrees made by its direction-line when measured from the south point as an origin around through the west, or clockwise. For the sake of illustration let us assume the following set of conditions: azimuth of the wind, one hundred and ten degrees; azimuth of the gun, one hundred and fifty degrees.

In Fig. 2 draw the lines O R and O S from the center O through the divisions "110" and "150," respectively, upon the graduated limb of the outer disk *b*. It is obvious that the angle R O S is the angle between the plane of fire and the direction of the wind, the line O R corresponding to the trace in Fig. 1. Rotate the inner disk *a* until the point Q is in the line O R. Then opposite the gun-azimuth reading of one hundred and fifty degrees on the disk *b* will be found on the inner disk *a* the character of the wind with respect to the gun—namely, a left-front wind of forty degrees. Clamp both disks together and to the ruler *c* in the relative position shown. Then as the ruler is swung on its pivot at O both disks will turn with it through an equal angular distance, and a fixed index *q* will point on disk *b* to the correct gun-azimuth corresponding to that laid off on the azimuth circle *d* by the ruler *c*, and opposite the said index *q* will be found on the disk *a* the character of the wind for that gun-azimuth and the then position of the target. Thus the device just described gives instantly and automatically the angle between the direction-line of the wind and the plane of fire and the character of the wind according to the above-described system of wind designation; but I do not use this angle directly. It is used only as a means of determining the gunnery corrections. Hence I proceed thus:

The caliber and muzzle velocity of the gun are known. Assume a given velocity for the wind, as twenty-five miles an hour. The cross or deviation effect of this wind for various angles made by its direction-line with the plane of fire may be computed in the following manner, which is that usually adopted: The range-table for the particular gun gives by simple multiplication the correction for the deviation effect of a wind of the assumed velocity (twenty-five miles per hour) blowing directly across the plane of fire, or, as I call it, a "ninety-degree" wind. The range component of such a wind is of course zero. Let this correction be B. Then the correction for the cross component of a wind of the same velocity, but the direction-line of which makes an angle of thirty degrees (30°) with the plane of fire, will be given by the formula: deflection = B sin. 30°, the range being the same. So we may proceed to compute the deflection corrections for winds of the assumed velocity but varying in direction by, say, ten degrees, the range, gun, and muzzle velocity being the same. Then another range varying by, say, five hundred (500) yards may be taken, and a new series of deflection corrections for winds of the same velocity, but varying by ten degrees (as before) in direction, may be computed. Another range may then be assumed and a new series of deflection corrections may be computed as before, and so on. These deflection corrections in each series are given their proper sign according to the rule enunciated above, and to them are added algebraically the correction for drift (negative in the United States system) for the particular range for which the series has been computed. This drift correction is obtained from a range-table for the particular gun, as will be readily understood. The range corrections may be similarly computed for the same gun and muzzle velocity. From a range-table for the particular gun we find that the range correction for the range effect of a head or direct-front wind, or a zero-degree wind as designated in my system, is A. Then the range correction for a wind of the same velocity, but the direction-line of which makes an angle of, say, thirty degrees with the plane of fire, will be given by the formula: range correction = A cos. 30°.

A series of range corrections for the particular range assumed may now be computed for winds of the same velocity, but the direction-lines of which make angles with the plane of fire varying by ten degrees, as taken in the case of the deflection corrections. Another range varying by five hundred yards (as before) from the range previously assumed may be taken and another series of range corrections for this new range may be computed, then another range and another series, and so on, as in the case of the deflection corrections. The range corrections in each series are given their proper sign. We now have two sets of corrections for the particular gun and muzzle velocity and velocity of the wind taken, one set being algebraic sums of the corrections which it is necessary to apply for drift and the deviation effect due to the cross component of the wind and the other set being the range corrections to compensate for the range effect of the range component of the wind. Each set is made up of several series, each series corresponding to a particular range. These ranges vary in the case which I have computed from three thousand to twelve thousand yards by one thousand yards. We may now set off radially on the disk *a* these ranges and through the points so determined describe circles concentric with the disk. Along these circles and in the proper angular position (corresponding to the angle between the direction-line of the wind and the plane of fire) are inserted the several series of range and of deflection corrections. In order to allow room for putting in the corrections, the wording for the wind designation and the numbers representing the angle of wind are closed in toward the center in Fig. 3. The disks *a* and *b* are shown in Figs. 3 and 3ª as clamped to the ruler *c* upon the pintle 16 by the thumb-nut 15 in the same relative position as in Fig. 2. The socket-piece 17 serves as a bearing for the pintle 16, and the window-plate *e* bears the range-divisions and is secured to the plotting-board by screws *f f*, and as the disks *a b* turn with the ruler *c* the corrections may be read off from the disk *a* through the window *e'* for the various gun-azimuths corresponding to the several successive positions of the target as plotted. The arrangement shown in Fig. 3 and Fig. 3[a] forms, essentially, my new correcting device in disk form. It is evident that there will be required several disks *a*, corresponding to the several velocities of the wind assumed; but I believe that a disk for each velocity from zero to forty miles per hour, varying by five miles per hour, will be found sufficient for all practical purposes. The deflection corrections are distinguished in this form by difference in the color from that in which the range corrections are entered, and the deflection corrections are entered in one-hundredths of a degree, while the range corrections are in yards.

To illustrate the operation, the same data will be assumed as in explaining Fig. 2—to wit, a wind-azimuth of one hundred and ten degrees and a gun-azimuth of one hundred and fifty degrees. Bring the point or index Q of disk *a* into register with the "110" division of disk *b*. Then with the disks in this relative position bring the "150" division of disk *b* into register with index *q* on the window-plate *e*. With the disks in this position and retaining them there bring the ruler *c* to the "150" division on the circle *d*. Then by means of thumb-nut 15 clamp the ruler *c* and both disks upon the pintle 16. At the window *e'* will now be found the corrections for the assumed gun-azimuth and wind-azimuth and velocity, and near the inner end of said window or opening *e'* appears the figure "40," which gives the angle between wind and gun. As the target changes position it is followed by the ruler *c*, the setting of this ruler being made by the aid of circle *d*, and as the ruler *c* swings it carries with it the disks *a* and *b*, clamped to it, and thereby brings to the opening the new set of corrections for the then position of the target and the new angle between wind and gun. (Only angle 40 is visible in Fig. 3; but it will be readily understood that the graduation of disk *a* is the same as in Fig. 2, but that these graduations are covered by the window-plate *e*.)

In Figs. 5 and 6 I have shown my new correcting device in cylindrical form. This form has the advantage that it permits of a more ready separation of the deflection corrections and the range corrections.

In Fig. 4 I have shown the rectification of the two cylinders *g* and *h* and of the graduated cup *v*. Upon the cylinder *g* are entered in the same horizontal line the deflection corrections (which are the algebraic sum of the corrections for drift and the corrections for the deviation effect of the cross component of the wind) for the same range. Thus in the upper horizontal line are given these deflection corrections for a range of three thousand yards. In the horizontal line next below are given those for a range of four thousand yards, and so on up to a range of twelve thousand yards, varying by a thousand yards. Again, these deflection corrections are arranged in vertical columns, the position of which is determined by the angle made by the direction-line of the wind with the plane of fire. This angle is indicated by the numeral at the head of the column, while the character of the wind is shown, according to my system of quadrant classification, by the wording at the top of the cylinder.

In the case of the lower cylinder *h* the range corrections are entered in horizontal rows, which, as in the case of the upper cylinder *g*, correspond to ranges varying by a thousand yards from three thousand yards to twelve thousand yards and in vertical columns corresponding to the angle made with the plane of fire by the direction-line of the wind.

The two cylinders *g* and *h* are, in fact, one cylinder, being, as shown in the figures, mechanically integral with each other; but the two cylinders may be mechanically separate and driven by the same shaft. The latter arrangement may be used with advantage in the case where the device is used at the gun, the cylinder carrying the range corrections being placed conveniently close to the elevating scale in yards of the gun, upon which the corrections may be laid off by shifting index or otherwise.

To the block *w* is adjustably secured by thumb-screw 20 the vertical graduated slide-way or frame *j*, formed with a central aperture or longitudinal slot *k*, at one side of which are marked off the divisions which indicate the range. Adapted to slide along the slot *k* are two windows *l* and *m*, secured to a rack *n*, in mesh with a pinion *o*, whereby the rack with its windows are moved up and down. The index *p* on the window *l* serves to enable the windows to be adjusted for the given range, and the two windows are so positioned relatively on the rack that when the index *p* indicates that the window *l* is over the horizontal row of deflection corrections for a given range the window *m* will then be over the horizontal row of range corrections for the same range. The base-plate *r* is provided with screw-holes *s s*, by which it is adapted to be secured to the plotting-ruler *c*, and is provided with a spindle *t*, which projects upwardly through the end plates of the cylinder and the free end of which is screw-threaded to engage the thumb-screw or securing-nut *u*. Centered on the spindle *t* is a cylindrical cup *v*, the cylindrical wall of which is graduated in azimuth, as shown. The block *w* is provided with screw-holes *x x*, by which it is adapted to be secured to the plotting-board *i*.

From what has already been said with respect to my new correcting device in disk form it will be understood that for any particular gun and muzzle velocity there will be provided several cylinders *g h*, and it is my plan to provide a cylinder for wind velocities from zero to forty miles per hour, varying by five miles per hour, or nine cylinders in all; but it is obvious that the number of cylinders may be more or less than this number and that the limits (zero and forty miles per hour) may be varied without departing from the principle of my invention. Again, it is equally obvious that the length of the cylinder may be increased or diminished, and a greater or less number of series of corrections may be inserted thereon. Thus the corrections for every hundred yards of range may, if desired, be tabulated on the cylinder without departing from the substance of my invention; but I regard my provision of a cylinder (or disk) for every five miles per hour velocity sufficient for all practical purposes, for the maximum error in selecting a cylinder would be about two miles per hour velocity, and this is considered within the error of determination of wind velocities under present conditions and is also within the error of setting of the gun or of the sights. As for the ranges, the windows *l* and *m* are so arranged that two or more numbers are always exposed, which admits of easy interpolation for ranges between the even thousand and the next five-hundred-yard division. Similarly, interpolation may be made for angles intermediate of those indicated by the divisions, which latter read to the even ten degrees; but the number nearest the center of the window would always be used, and this interpolation would not ordinarily be necessary.

My new correcting device in its cylindrical form is assembled and operated as follows: Select a cylinder corresponding to the caliber and muzzle velocity of the particular gun and as close to the wind velocity existing at the time as the number of cylinders permits. Thus if the wind is blowing with a velocity of seventeen miles per hour use a cylinder bearing the corrections computed for a wind velocity of fifteen miles per hour. As above explained, the error introduced is not material and may be avoided altogether by having cylinders for every mile per hour velocity of wind within the limits taken. Put the cup *v* on the cylinder *g h* and turn it until the index *y* points to the azimuth of the wind, (taken as in the case of the disk form to be one hundred and ten degrees.) Thread the cylinder and cup in this relative position on the spindle *t*. Turn the ruler *c* (secured to the base-plate *r*) until it indicates on its own azimuth-circle *d* any even-degree azimuth—say one hundred and fifty degrees. Now turn the cup *v* and the cylinder until the division "150°" on the cup *v* comes into the vertical plane through the center or axis of the slot *k* in the slideway *j*—that is, into the vertical axis of the windows *l* and *m*. By means of the thumb-screw *u* clamp the ruler *c*, cup *v*, and the cylinder in the relative positions now existing. The successive positions of the target are plotted now by any of the methods in common use by either the vertical-base or horizontal-base range and position finder. As soon as the position of the target is located upon the chart swing the ruler *c* over so that its reading edge passes through the position so plotted and read from the ruler the range, as usually is done. By turning the pinion *o* adjust the rack *n* so that the index *p* on the window *l* is set on the division or graduation on the slideway *j* corresponding to that range or until the index *p* indicates the range as closely as possible. The deflection corrections may now be read through the upper window *l* and the range corrections through the lower window *m*. In both cases the number nearest the center of the window is taken. The character of the wind and the angle it makes with the plane of fire may be read from the top portion of the cylinder, and the azimuth of the target will be indicated upon the cup *v* at the bottom of the slot *k*; but, as stated above, the cup *v* is for the purpose of setting the instrument, and the azimuth of the target is found in the usual manner. For the purpose of distinction the range corrections may be given in one color and the deflection corrections in a different color. The cylinder may be of brass or other suitable material.

As the successive positions of the target are plotted the above operation is repeated, the gunnery corrections for each position being read off from the cylinder. Thus my new correcting device is speedy and automatic in operation.

Again, my new device is adapted to any system of deflections, as minutes of arc or hundredths of a degree, as at present used in the United States service. It is also adapted to any deflection-scale on the sight.

The graduations on my new correcting devive would correspond, of course, to the particular form of scale used.

While I have described my new correcting device in connection with its use when combined with the plotting-ruler, yet it is evident to all skilled in the art that other means than said ruler may be provided to give the cylinder rotation without departing from the spirit of my invention. All that is required is that the cylinder (or disk) of my device shall be made to rotate with an angular motion equal to that of the gun or of an arm pointing to the point for which the corrections are made.

In Fig. 7 I have shown my new correcting device mounted at the gun. The vertical shaft 2 is mounted rotatably in the rotary gun-mount 3 and is provided with a pinion 4, which meshes with the rack 5 upon the fixed base-ring 6. It is provided at its upper end with a pinion 7, which engages the spur-gear 8, fast to the base-plate *r* of the cylinder *h* of my device. As the gun-mount 3 is traversed to follow the target the pinion 4, in mesh with the rack 5, drives the shaft 2, and thereby the spur-gear 8. The ratio of the gearing is such that the angular motion of the gun in azimuth is equal to the angular motion of the gear 8, and therefore of the cylinder or disk attached thereto. The cylinder is mounted conveniently in front of the gunner, where it may be readily read by him. With a gun equipped in this manner much of the confusion and congestion now found in the plotting-room is avoided. Such an arrangement is particularly adapted to rapid-fire guns, a spur-gear being mounted upon the pedestal and connected by suitable mechanism with the correcting device, as will be readily understood. Hence my new correcting device may be in the form of a disk, cylinder, cone, or the like, it may be vertical, horizontal, or inclined, and it may be in the plotting-room, at the gun, or other position, the only essential requirement being that the rotatable member shall turn with an angular motion equal to that of the gun or of an arm directed to point for which corrections are required.

While my correcting device is strictly correct only when used on the gun center, as described, (either at the gun or at the plotted position thereof,) it may nevertheless be used without substantial error on any other center about which a swinging arm rotates, provided such center be not too far from the true gun position, real or plotted. For instance, the point on the plotting-board which represents the range-finder station may be taken as such center without appreciable error. It may be added that the direct attachment to the ruler, as described, without the use of gears has certain advantages over other forms of the device as applied to the plotting-board—as, for example, where the cylinder is mounted in a horizontal position, which requires the use of bevel-gears. In the case of the so-called "shifting center," in which one ruler is used to give, by polar coördinates, the position of a point on a chart from two different points—as, for example, of a target from the range-finder and from the gun itself—the ruler being on a pivot or center which slides in a slot and is shifted from one position to the other, the vertical cylinder or disk simply rides on the ruler and the corrections are read when it is at the plotted gun position.

While I have so far explained the use of my new device only for the purpose of obtaining deflection corrections and range corrections for wind, it is obvious that by extending the cup *v* or by providing a second cylinder geared at its base to rotate with an angular motion equal to that of the cup (or gun) the device may be used to obtain the range and azimuth differences for a gun not the directing-gun. In this case the cup may be a part of the gun-carriage itself—as, for example, the dust-guard 10, which turns with an angular motion equal to that of the gun itself. These range differences and azimuth differences are the corrections for range and azimuth, respectively, due to difference in position of one point from another given point—for example, the difference in position of a gun which is not the directing-gun from the directing-gun itself. Each of these corrections depends on the range and azimuth combined of the target from the directing-gun. The azimuth difference may be taken, then, as the angle made at the target by lines drawn from the target through the position of the directing-gun and the position of the gun for which the differences are required. Heretofore these differences have been obtained from a different chart by setting the ruler at the plotted position of the directing-gun to the range and azimuth of that gun for the target. If the target holds the same range, but varies in azimuth for the directing-gun, both the range difference and azimuth difference for any other gun will change. Similarly, if the target holds the same azimuth from the directing-gun, but varies the range therefrom, both differences change for the other guns. In my new device these differences are marked upon the cup *v* extended, or upon a second cylinder in gear therewith, or upon the dust-guard of the gun, if desired. In the cylindrical form of my device with the extended cup (marked *v'* in Figs. 8 and 9) the azimuth of the directing-gun appears at the bottom of slot *k* as the swinging member, ruler, or gun rotates in following the target. This has been described already. In a vertical column on the cup above the azimuth are arranged the range and azimuth differences for that gun-azimuth each in the horizontal row corresponding to the range for which it has been calculated.

In Figs. 8 and 9 the azimuth differences are shown on that part of cup *v'* which is marked *g'*, while the range differences appear on the lower part *h'* of said cup. The azimuth differences, like the deflection corrections of Figs. 3, 4, and 5, are given in one-hundredths of a degree, while the range differences, like the range corrections of said figures, are given in yards.

It will be understood that only a few differences and corrections are given by way of illustration in the drawings and that the actual structure would be complete in this respect. The differences and corrections given are those for the twelve-inch breech-loading rifle, and since this gun has a field of fire of only between one hundred and fifty and two hundred and thirty degrees the differences are confined to these azimuths in Figs. 8 and 9. Manifestly no setting is required for this use other than to see that the cup gives the correct gun-azimuth when the ruler or gun is set for that azimuth. Then the range and azimuth differences are read by bringing a reading-window to the proper range—that of the target from the directing-gun. Where the dust-guard of the gun for which the differences are required is used, that gun is set to the azimuth of the directing-gun, and the differences are then read off from the dust-guard.

Another important use of my new device is automatically to solve the angle between the direction-line of the wind and the plane of fire. In explaining Fig. 2 I have shown how this is done, and as in the cylindrical form of my new device the cup v corresponds to the outer disk of Fig. 2 and the cylinder g h to the inner disk of that figure the cylindrical form also solves the same angle automatically. By inspection of Fig. 4 it will be seen that this angle will appear at the top of the slot or aperture k.

The reading-window in my device may be placed at any azimuth so long as it is radial and is always opposite field of fire and so does not interfere with the ruler. Hence my new device is adapted to any field of fire, an important advantage.

It is obvious that the reading-window may be mounted to rotate with an angular motion equal to that of the swinging member which follows the point for which gunnery corrections are required, while the cylinder may be fixed. All that is necessary is relative angular motion between the cylinder and reading-window.

My new device solves, therefore, the angle between wind and gun. It gives automatically the gunnery corrections for effects of the wind or for changes in azimuth of a point with reference to a given point and range and azimuth differences or corrections for changes in azimuth of a point (as the target) with reference to two other given points, (as with reference to a directing-gun and a gun for which the corrections or differences are required.)

What I claim is—

1. In a device of the class described, the combination of a member adapted to swing about a center and point in the direction of the point for which gunnery corrections are required; means for setting said member to a given azimuth and a rotary device mounted to travel with an angular motion equal to that of said member and having visible characters indicating gunnery corrections dependent on the azimuth of said point from a given point.

2. In a device of the class described, the combination of a member adapted to swing about a center and point in the direction of a point for which gunnery corrections are required; means for setting said member to a given azimuth; a rotary device mounted to travel with an angular motion equal to that of said member and having visible characters indicating gunnery corrections dependent on the azimuth of said point from a given point; and means for setting said rotary device.

3. In a device of the class described, the combination of a member adapted to swing about a center and point in the direction of a point for which gunnery corrections are required; a rotary device mounted to travel with an angular motion equal to that of said member and having visible characters indicating gunnery corrections dependent on the azimuth of said point from a given point; and means for selecting from said rotary device said corrections corresponding to any given azimuth of said point.

4. In a device of the class described, the combination of a member adapted to swing about a center and point in the direction of a point for which gunnery corrections are desired; means for setting said member to a given azimuth and a rotary device mounted to travel with an angular motion equal to that of said member and having visible characters indicating gunnery corrections dependent on the azimuth and range of said point from a given point.

5. In a device of the class described, the combination of a member adapted to swing about a center and point in the direction of a point for which gunnery corrections are desired; means for setting said member to a given azimuth; a rotary device mounted to travel with an angular motion equal to that of said member and having visible characters indicating gunnery corrections dependent on the azimuth and range of said point from a given point; and means for selecting from said rotary device said corrections corresponding to any given range and azimuth of said point.

6. In combination, a member graduated from zero to three hundred and sixty degrees; and a second member graduated from zero to ninety degrees in both directions from zeros diametrically opposite; said members being mounted free to rotate in azimuth relatively to each other so that the graduations of the second member may be brought in line with the graduations of the first-named member.

7. In combination in a device of the class described, a member graduated from zero to three hundred and sixty degrees; a second member graduated from zero to ninety degrees in both directions from zeros diametrically opposite; said members being mounted free to rotate in azimuth relatively to each other so that the graduations of the second member may be brought in line with the graduations of the first-named member; and an index for laying off azimuths upon said first-named member.

8. In combination in a device of the class described, a member graduated from zero to three hundred and sixty degrees; a second member graduated from zero to ninety degrees in both directions from zeros diametrically opposite; said second member being mounted rotatably so that its graduations may be brought in line with the graduations of the first-named member; and a rotary element by which said members are turned with an angular motion equal to its own.

9. In combination in a device of the class described, a member graduated from zero to ninety degrees in both directions from zeros diametrically opposite; a second member graduated from zero to three hundred and sixty degrees; said first-named member being mounted rotatably so that its graduations may be brought in line with the graduations of said second member; a rotary element by which said members are turned with an angular motion equal to its own; and means for setting.

10. In combination in a device of the class described, a plotting-chart; an arm pivoted to swing over said chart; means for setting said arm to a given azimuth; a device having visible characters indicating gunnery corrections dependent upon the range and azimuth of a point from a given point and driven by said arm with an angular motion equal to the change in azimuth of the point from the given point; and means for selecting from said device said corrections corresponding to any azimuth of said point from the given point.

11. In combination in a device of the class described, a plotting-chart; an arm pivoted to swing over said chart; means for setting said arm to a given azimuth; a device having visible characters indicating gunnery corrections dependent upon the range and azimuth of a point from a given point and driven by said arm with an angular motion equal to the change in azimuth of the point from the given point; and means for setting.

12. In combination in a device of the class described, a swinging member adapted to follow the changes in azimuth of a point which changes its position; means for setting said member to a given azimuth and means driven by said member to bring to reading position gunnery corrections necessitated by the change in position of said point.

13. As a new article of manufacture, a device having inscribed in columns gunnery corrections due to a difference in range, and in rows gunnery corrections due to a difference in azimuth of a point from a given point.

14. As a new article of manufacture, a device graduated in azimuth, and having inscribed upon it gunnery corrections due to change in range and azimuth of the target.

15. In combination, a reading device; a cylinder having inscribed upon it range and azimuth differences; and means for producing relative angular motion between said cylinder and said device, said means being mounted to rotate with an angular motion equal to the change of azimuth of the target.

16. In a device of the class described, the combination of a member adapted to swing about a center and point in the direction of a point for which gunnery corrections are desired; means for setting said member to a given azimuth; a rotary device mounted to travel with an angular motion equal to that of said member and having visible characters indicating gunnery corrections dependent on the azimuth and range of said point from a given point; and means for setting.

17. In combination in a device of the class described, a member graduated in azimuth, and a second member graduated in quadrants from zeros diametrically opposite; said second member being mounted free to rotate in azimuth so that its graduations may be brought in line with the graduations of the first-named member.

18. In combination in a device of the class described, a member graduated in azimuth; a second member graduated in quadrants from zeros diametrically opposite; said second member being mounted free to rotate in azimuth so that its graduations may be brought in line with the graduations of the first-named member; and an index for laying off azimuths upon said first-named member.

19. In combination in a device of the class described, a member graduated in azimuth; a second member graduated in quadrants from zeros diametrically opposite; said second member being mounted rotatably so that its graduations may be brought in line with the graduations of the first-named member; and a rotary element by which relative angular motion equal to its own is produced between said members and a reading device; and said reading device.

20. In combination in a device of the class described, a member graduated in azimuth; a second member graduated in quadrants from zeros diametrically opposite; said first-named member being so mounted that its graduations may be brought in line with those of the second member; a rotary element by which said members are turned with an angular motion equal to its own; and means for setting.

21. In combination in a device of the class described, a member graduated in azimuth; a second member graduated in quadrants from zeros diametrically opposite; said members being so mounted as to permit their graduations to be brought in line; a rotary element by which a relative angular motion between said members and a reading device is produced; said reading device; and a plotting-board.

22. In combination, a swinging member adapted to follow the changes in azimuth of the target from the gun position; means for setting said member to a given azimuth and means

by which the angle between the direction-line of the wind and the plane of fire is brought to reading position.

23. In combination, a swinging member adapted to follow the changes in azimuth of the target from the gun position; means for setting said member to a given azimuth and means by which the angle between the direction-line of the wind and the plane of fire, and the gun-azimuth are brought to reading position.

24. In combination, a member graduated in quadrants from zeros diametrically opposite and having inscribed upon it gunnery corrections; a second member graduated in azimuth and adjustable relatively to said other member; a reading device; and a swinging member adapted to follow the target in azimuth and to bring to reading position the angle between the direction-line of the wind and the plane of fire, and the gunnery corrections for said angle.

25. As a new article of manufacture, a device graduated in a complete circumference and having inscribed in columns corresponding to said graduations gunnery corrections dependent upon difference in range for the given angle, and in rows gunnery corrections dependent upon difference in azimuth for the given range.

26. In combination, a member graduated in azimuth; and a second member graduated from zero to ninety degress from zeros diametrically opposite; said members being mounted rotatable relatively to each other about a common center.

27. In combination, a member graduated in azimuth; a second member graduated from zero to ninety degrees from zeros diametrically opposite; said members being mounted rotatable relatively to each other about a common center for adjustment; and a device for rotating said members after adjustment.

In testimony whereof I hereunto set my hand, in the presence of two witnesses, at said Fort Revere, this 19th day of March, 1904.

ELMER W. HUBBARD.

Witnesses:
GORDON ROBINSON,
WILLIAM BRUNS.