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NOTES ON THE CONSTRUCTION AND USE OF AN ARTILLERY RULER



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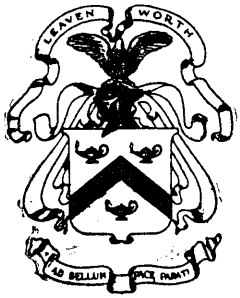
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eneral.

WAR DEPARTMENT,
WASHINGTON, D. C., *23d February, 1918.*

The following notes on "An Artillery Ruler" are published for the information of all concerned.

[062.1 A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

JOHN BIDDLE,
Major General, Acting Chief of Staff.

OFFICIAL:

H. P. McCAIN,
The Adjutant General.

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PURPOSE OF THE RULER.

The Artillery Ruler is designed to be used on contoured maps for studying the following problems connected with artillery fire and the choice of battery positions. It is a great labor saver. By its use any of the following problems can be solved at a glance:

1st. To determine whether a battery can shoot out from a given position.

2nd. To determine whether a battery can shoot into a hostile position.

3rd. To determine the best locations for battery positions.

4th. To determine the least range for a given battery position.

5th. To determine the dead space in the sector of a given battery.

MAPS.

Scale of Maps.

The Artillery Ruler is designed for use in studying contoured maps. It is necessary that the range scale on the ruler should read ranges direct to the scale of the map. For our maps on a scale of three inches to a mile, 1/21120, a range scale reading to 6500 yards makes a ruler about a foot in length. For French maps to a scale of 1/20000, which is approximately that of our three-inch maps, a ruler should be constructed to read ranges in hundreds of meters. It will be seen from the above method of construction that the ruler can be used only on maps of the scale for which it has been designed.

GUNS.

Range Tables of Gun Employed.

The ruler bears two range scales on its face. Opposite the hundreds of yards on one scale are the corresponding angles of departure in mils for the gun employed. Opposite the hundreds of yards on the second scale are the corresponding angles of fall in mils for the same gun. It is thus seen that besides being designed for maps of a given scale, the ruler is also constructed for use with one particular calibre of gun.

These facts are mentioned, not because they cause any difficulty in the use of the ruler for the purpose for which it is designed,

but in order to prevent mistakes that would result from using the ruler on a map of a different scale, or in connection with a battery firing a different calibre of gun than that for which the particular ruler is constructed.

CONSTRUCTION OF THE RULER.

Computation of Range Scales.

This is a simple mathematical computation for the purpose of ascertaining the proper lengths on the scale to read ranges direct from the map by use of the ruler. For our maps, scale three inches to a mile, 1/21120, compute the length of scale to measure 1000 yards on the map. After this has been done, multiples of this length, or subdivisions of it, will give the lengths for indicating distances by hundreds of yards from 0 to 6500 or 7000 yards. For a high-power gun it will be necessary to carry the scale to the extreme range of the gun. The figures given in this article are for our three-inch field piece.

Computations are given, so as to serve as a model form in constructing a ruler for use with maps of a different scale, or for use with a different calibre of gun.

Length of scale for 1000 yards on 3-inch map is equal to

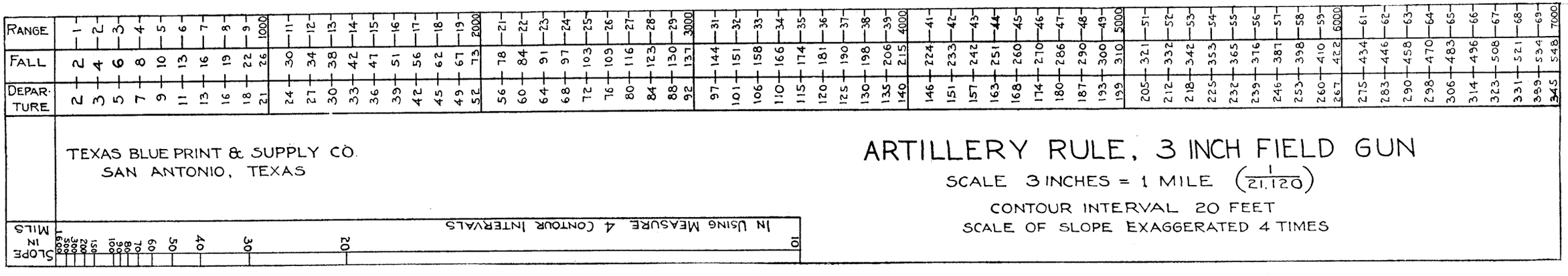
$$\frac{1000 \times 36}{21120} = 1.7 \text{ inches.}$$

Length of scale for 1000 meters, or 1 Km. on French map of scale 1/20000, is 5 cm.

To obtain subdivisions reading to hundreds, divide above lengths of scale into ten equal parts. For the French scale this gives 0.5 cm. per 100 meters. For the scale of three inches to the mile, it is convenient to perform the division into ten equal parts graphically. By using these subdivisions in connection with the multiples of 1000, a range scale can be laid off which will read ranges in hundreds of units up to the maximum range of the gun employed.

For convenience in using the ruler, lay off these scales along the two opposite edges on one face of the ruler.

From the range tables for the calibre gun employed, select the angle of elevation in mils corresponding to each range, and mark down a scale inside one range scale. Label it "Angle Elevation," and record opposite each graduation for range the corresponding angle of elevation.



ARTILLERY RULE, 3 INCH FIELD GUN

SCALE 3 INCHES = 1 MILE $\left(\frac{1}{21,120}\right)$

CONTOUR INTERVAL 20 FEET

SCALE OF SLOPE EXAGGERATED 4 TIMES

From the column "Angle of Fall" select the numbers giving the angle of fall in mils at each range. Opposite the divisions of the second range scale record these angles, and label this scale "Fall."

Ranges can be read directly from the map on either edge of the ruler. Opposite any range can be seen at a glance the corresponding "Angle of Elevation" and "Angle of Fall" for that range, these angles being given in mils.

SLOPES.

Scale of Slopes.

In order to make use of the ruler, it is now necessary to have marked on its face a scale of slopes, by which the slope, as indicated on the contoured map, can be read directly from the map by laying the ruler on the desired locality.

This scale of slopes is the important feature of the ruler. It is at once apparent that when a scale of slopes has been constructed by which the slope of the ground in any desired locality can be read directly from the contoured map in mils, comparison between this number of mils and the various angles of departure and fall opposite the range scales on the ruler is a mere matter of inspection. Computations are unnecessary and any of the five classes of problems listed at the first of this article can be solved at a glance.

CONSTRUCTION OF THE SCALE OF SLOPES.

To construct a scale of slopes for the particular map employed, compute the horizontal equivalents of the vertical contour interval for the different angles of slope.

It will be sufficient to compute the horizontal equivalents for the following angles of slope:

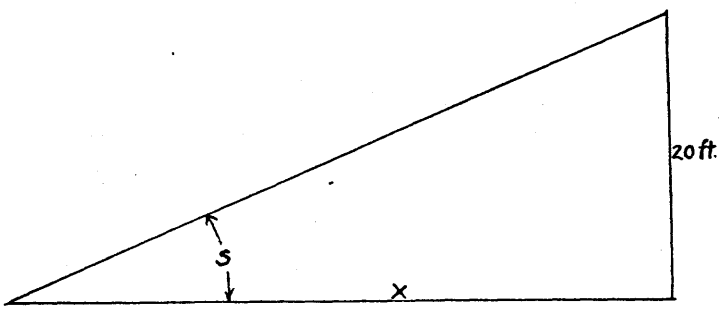
10 mils	60 mils
20 mils	70 mils
30 mils	80 mils
40 mils	90 mils
50 mils	
100 mils	
150 mils	
200 mils	
300 mils	
500 mils	
1600 mils	

1600 mils is included in the above list because its horizontal equivalent is zero; in other words, it marks the vertical. The other angles have been selected so as not to cause confusion and difficulty in reading the scale. It will be remembered that the steeper the slope, the smaller the horizontal equivalent of a given vertical contour interval. Accordingly where these divisions on the scale would be small, only certain ones can be indicated, and the intervening ones must be read by interpolation by eye. It will be found possible, with a scale reading the above graduations, to interpolate readily for the intervening ones.

EXAGGERATING THE SCALE OF HORIZONTAL EQUIVALENTS.

If the scale of horizontal equivalents is constructed to scale the divisions will be so small and so close together that its use will be difficult and mistakes and confusion will result. By means of the following device, the scale of horizontal equivalents can be exaggerated four times and still used by direct application on the contoured map. With the exaggerated scale instead of measuring the slope by applying the ruler to one contour interval as shown on the map, apply it to four intervals, and read the angle of slope in mils.

COMPUTING HORIZONTAL EQUIVALENTS.



Given an angle of slope, (s)
Vertical interval 20 ft.
Scale of map 1/21120 Exaggerated scale 1/5280.
To compute horizontal equivalent (x)

Formula. $\tan(s) = 20/x$.

$x = 20/\tan(s) = 20 \cot(s)$.

Value of horizontal equivalent in inches to the exaggerated scale,

$$x = \frac{240 \cot (s)}{5280}$$

For French maps with contour interval of 5 meters, to obtain value of (x) in centimeters to exaggerated scale of 1/5000, use following formula:

$$x = \frac{\cot (s)}{10}$$

Values of horizontal equivalent to exaggerated scale 1/5280 for contour interval of 20 feet.

Angle of slope in mils.	Horizontal equivalent in inches.
10	5.96
20	2.33
30	1.55
40	1.16
50	0.935
60	0.771
70	0.660
80	0.577
90	0.513
100	0.463
150	0.306
200	0.229
300	0.150
500	0.085

ARRANGING THE SCALE OF HORIZONTAL EQUIVALENTS.

The scale for horizontal equivalents as computed above is about six inches long. By placing it on the opposite face of the ruler from that bearing the ranges, the ruler is not prolonged an inconvenient distance. In fact when it is considered that slopes under 30 mils are less than one and a half degrees, and are accordingly so nearly flat as to need no consideration in firing problems, the necessary length of space devoted to horizontal equivalents need be only about two inches even on the exaggerated scale. When placed on the same side of ruler as range scales, the entire length of ruler need be only about 15 inches.

The graduations on this scale are arranged as follows: The horizontal equivalent of 1600 mils slope is zero. Use therefor 1600 mils as a starting point. Mark this graduation on the scale and label it 1600. From this same point as origin, lay off the horizontal equivalent, considering of course angles less than 1600 mils. Starting from the origin, lay off the horizontal equivalent for slope of 500 mils. Going back and starting again at the origin, lay off the horizontal equivalent for a slope of three hundred mils. As can be seen from the computations, this will extend beyond the graduation for 500 mils. In similar manner lay off the horizontal equivalent for each angle of slope, remembeing each time to start to measure from the origin in laying off the distance.

When the scale of horizontal equivalents has been laid off and its graduations marked, the ruler is ready for use.

USE OF RULER IN MEASURING RANGE ON ANGLE OF SLOPE.

As can be seen from the process of construction, the Artillery Ruler is designed to measure either of these directly from the map. In measuring angle of slope, it is necessary to measure the slope as given by *four* contour intervals, because of the fourfold exaggeration of this scale. This is done by applying the origin at one extremity of the slope, and measuring on the scale to read (or estimate by eye) the graduation opposite the *fifth* contour line. Placing the origin on one contour line and measuring to the *fifth* contour line includes *four* contour intervals.

USE OF THE ARTILLERY RULER.

The Artillery Ruler is especially useful in the study of contoured maps. It solves from the maps all the problems of fire that can be solved by the old form of Battery Commander's Slide Rule, and many more, because it bears a scale for angle of fall in addition to angle of departure.

All results can be seen as a matter of simple inspection, thus doing away with the labor of mathematical calculations. It enables an officer to tell at a glance whether his battery, if located in a certain position, can fire upon designated targets. Not only this, but by studying the relative merits of several positions, it enables him to determine from the map what localities offer

advantages as battery positions against certain targets. This enables him to reduce the amount of time necessary to spend in reconnaissance on the ground. It also prevents the possibility of locating a battery where the conditions of terrain interfere with fire on the targets desired. This kind of information is of value to an officer when it comes to a question of deciding on his battery positions. The moral support of knowing with certainty that the least range for a given position is well short of the ranges at which fire will be conducted gives a comfortable assurance when it comes to a question of deciding on the location of battery positions. If there is going to be any question of difficulty in firing from a position, the ruler will reveal the fact, provided of course that the information on the map is accurate.

FIRING OUT OF A GIVEN POSITION.

In these days when the concealment and protection of defilade are sought in locating battery positions, it is an important thing to make certain that a battery can fire out of a given position and reach its targets. It is necessary to have this information before work is started on the construction of gun pits, emplacements and shelters. For it would be manifestly worse than a waste of effort to construct a battery position, and then to discover, on attempting to fire, that guns from this position could not fire out of this position or fire into the enemy position at the actual ranges required.

For firing out of a given position, use the ruler in the following manner: Measure the range from the position to the designated target. Opposite this range read the angle of elevation. To this angle add the angle of site of the target as shown by the difference in contours on the map. (The angle of site may be obtained by reducing the difference in level to yards, and by dividing the yards by 1/1000 of the range, giving the approximate angle of site in mils.) The combined result of angle of site and angle of elevation at the given range, is the angle at which the piece will be laid. Now compare this angle with the angle of slope of the protecting crest in front of the battery. If it is greater than the angle of slope, the guns will clear the crest.

In measuring the angle of slope, take the following precautions, which are on the side of safety: First consider the slope uniformly steep and measure the slope of the steepest portion. It may be necessary in doing this to disregard the contour inter-

vals where the slope changes to a more gentle one, and dot in by pencil points spaced at the same intervals as the contours on the steeper portion. It is self-evident that if the guns will shoot out from behind a hill uniformly as steep as the steepest portion, they will have no difficulty in shooting out from behind the hill where part of the slope is reduced in steepness.

In a case where the covering crest is some distance in front of the guns, and it is necessary to take into consideration the amount of drop in the trajectory by the time the projectile reaches the crest. Read the amount of this drop in mils opposite the range to the crest reading on angle of elevation scale. Add this amount to the angle of slope. In other words, the gun has to be laid this much higher than the top of the crest in order to clear the crest, due to the drop of the projectile during flight. Compare the angle thus obtained with the elevation given to the gun. If the elevation given to the gun is greater than the combined result of slope and drop, the trajectory will clear the crest.

In cases where the crest is some distance away, and the ruler does not give the true slope from battery to top of crest, if it is not possible to estimate an average portion of the slope for this work, it will be necessary to compute angle of site of crest in the same manner as computing angle of site of target by dividing difference of elevation in yards by 1/1000 of range to crest. With practice, an average slope can be selected and then measured by using the ruler. Precautions for safety can be observed by taking care to select this average a little steeper than the actual mean slope.

FIRING INTO A GIVEN POSITION.

To determine whether or not a battery can fire into a given hostile position, measure the range from the battery to this hostile position. If within the range of the gun, and included within the field of fire, read opposite the range the angle of fall. Compare this angle of fall with the angle of slope protecting the target. If the angle of fall is greater than the angle of slope, the projectiles can search behind the crest and reach the target. If the angle of slope is the greater, the space behind the hill is dead space for this particular battery.

TO DETERMINE THE BEST LOCATION FOR BATTERY POSITIONS.

Locate on the map the various enemy positions upon which the battery will be required to fire. Place a maximum limit on the range. For the three-inch field gun, for example, say that the battery position must be so located that the range to any target shall not exceed 6000 yards. This gives a certain area within which the battery must be located.

Study the terrain in this area, hunting for covering crests behind which to conceal the battery position. This article is not intended to cover the tactical features of the selection and location of a battery position. Questions of trajectory and possibilities of fire only are considered. It is assumed that after determining the possibilities of fire from each of the tentative locations, that one will be selected which not only affords the necessary possibilities of fire, but which possesses the advantage from the tactical point of view.

Within the area limited as above, there are usually a number of alternative positions, some of which afford better fields of fire than others. By use of the Artillery Ruler an officer is enabled to make a quick comparison of the possibilities of fire from each position. The questions of least range and of dead space also enter into the question of possibility of fire from a certain position.

LEAST RANGE.

Given a battery position concealed behind a covering crest, it is necessary to know with certainty the least range at which the battery can clear the crest. If the crest is far enough in front of the battery for the question of drop to enter into consideration, refer to the scale of "Angle Elevation" on the ruler and read the amount of drop opposite the range to the crest. Expressed differently, it is necessary to give the piece this added elevation to clear the crest.

Measure the angle of slope (or, as explained heretofore, the angle of site of the crest in certain exceptional cases), and to this add the extra elevation necessary to compensate for drop.

Look on the ruler, and opposite this resulting angle read the least range that will clear the crest, assuming that the target is on the same level as the guns.

Lay off this least range on the map, and ascertain whether this is the case or not. If not, and the targets at this range are on

a different level than the guns, compute the angle of site. The least range as given above is then only a first approximation, and the actual least range is determined within more accurate limits as follows:

In setting off firing data on the quadrant, elevation will be given to the piece by setting both angle of site and range elevation on the quadrant.

The combined angle as obtained above by adding slope and compensation for drop is equal, therefore, to the sum of angle of site of target and elevation for least range.

Hence, after obtaining the first approximation of least range and having computed the angle of site of the terrain at this range, deduct this angle of site from the combined angle mentioned above. (By a process of algebraic subtraction.) The remainder will now be the part of the angle giving the elevation for least range. Opposite this angle read on the "Angle Elevation Scale" the second approximation for least range. Unless slopes in the vicinity of this range are very steep, so as to give considerable differences in angles of sites for small difference in range, it will not be necessary to carry the process of approximation beyond the above stage.

It is necessary to obtain the least range for a number of directions within the sector of fire.

In choosing a battery position, part of our light batteries should be able to bring fire to bear well within our own first line trenches. For these batteries the least range is an important consideration influencing choice of position.

DEAD SPACE.

The space in the sector of fire and short of the least range is considered as dead space for all artillery purposes. It may also be that behind certain hills and steep slopes there exists dead space that cannot be reached by the battery. To determine if this is the case, select by inspection such steep slopes in the sector of fire, and use the ruler to ascertain whether the battery can fire into these positions. For reference, it is customary to prepare for each battery position occupied, a sketch showing field of fire, least range, and dead space, on a transparent sheet which can be used on the firing map when desired.