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CAMPBELL'S RANGE INDICATOR.

A Paper contributed by Captain JOHN R. CAMPBELL, Hants Militia Artillery.

NEXT to efficient ordnance for the defence of our coasts, few things are more important than a good "range-finder," or (speaking in more general terms), some easy, rapid, and at the same time *sufficiently exact* method of ascertaining the distance between our guns and the enemy's ship. Nothing can be more unsatisfactory than the common process of searching this out by means of *trial shots*, as they are called, that is, by judging the distance by the eye for the first round, and correcting the elevation given to each of the following rounds by the *apparent* error as shown by the graze of the one before, until at last we hit. Against a ship in motion this system is almost absurd; one might frequently go on bungling until she was out of all range, or, worse than that, until her crew by a well-directed fire had succeeded in dismounting our most powerful gun. It must be remembered, too, that each round with the present gigantic weapons occupies several minutes and involves the cost of a very expensive projectile, besides the wear-and-tear of the gun. Yet, curiously enough, until very recently the question of "range-finders" was hardly dreamt of; at any rate it never seems to have seriously engaged the attention of our scientific military departments. Now there are several plans before the notice of the War authorities, and before many years, no doubt other new ones will appear, or improvements on the present instruments be suggested.*

It is not my intention to offer any opinion regarding the respective merits of the different range-finders we have heard of lately; indeed, I do not feel myself competent to attempt such a task were I inclined to do so. The object of the present paper is simply to describe my own designs for an instrument of this sort, suitable for coast batteries, involving very little expense, simple of application, and which will indicate with *considerable* accuracy the range of a vessel under way—not as the result of a single observation, but by a continuous process, showing it for every point of her course.

* See a paper by the author entitled "Calculation of Range for the service of Artillery," in vol. viii, page 431, of the Journal. (In that article at page 431, lines 15 and 16 from the top, the sign - ought to be + in the first fraction, and the + in the second ought to be -).

Suppose X to be the highest point on the works of a battery overlooking the sea, from which observations can conveniently be made, YH the water level at any particular height of tide, and Y the position of an enemy's ship. Join XY and draw XZ and ZH, horizontal and vertical lines, through X.

Now I assume the height HX of a flat stone at X, on which (during the time the battery is in action) the instrument stands, above the sea-level, to be always known to a yard. The height of tide is easily shown by a rough scale painted on some post, pier, or rock at the point V, or in the immediate neighbourhood of the fort; besides which, in critical times, a register of tides might be kept. Call this known height h ; put angle ZXY (which is = angle HXY) = θ and XY (the range) = R.

Then we have $R = h \operatorname{cosecant} \theta$

an equation giving us the proper value of R for any particular one of θ .

Now the object of my range-indicator is to measure this angle θ —let us call it the *angle of dip*—recording the result, not in degrees and minutes, but in yards of range corresponding to the height of tide at the time of observation. This is effected by the motion of a telescope mounted theodolite fashion, the range answering to any position of its axis below a horizontal line being read off on a high multiple of the arc described by the extremity of its axis. The telescope, by means of a toothed arc gearing with an endless screw (or in large instruments it may be a pinion) gives motion to a circular disc, causing it to make one exact revolution while it moves through an angle of dip of 3 degrees—for very few coast batteries are more required, but the principle is the same whatever limit we assign to θ . On the surface of this disc the range is shown in a manner I shall presently describe.

Fig. 1 (see plate) is a side elevation of the arrangement, and Fig. 2 a plan. The framing (brass) mainly consists of two inverted V-shaped cheeks, AA (in the elevation) being one of them, between which the telescope, T, is supported in plumper-blocks, t . These cheeks are erected on a circular plate, E, which rests and is pivoted on another plate F, the latter being in a piece with the triangular base or pedestal. For the sake of portability, the upper part of the instrument can be lifted out of the socket formed in the base. L is a spirit-level carried on the revolving plate E, and w, w, w , three levelling screws by means of which the instrument is brought into adjustment. The telescope—a powerful one about 16 inches in length and furnished with the usual cross-wires—has attached to its side a short toothed arc R, whose centre is at t , in gear with the endless screw S, the shaft of which is borne on a projecting branch, BB, of the cheek AA. On this shaft is fixed a circular disc of zinc, D, 2 feet in diameter, and the radius (6 inches) and pitch of tooth of the arc are such that D makes exactly one revolution for a motion of the telescope (from the horizontal position) through 3 degrees. The manner of mounting the screw with its disc is shown more plainly in Fig. 3, which is an end elevation of this part of the arrangement drawn to twice the scale used in the other figures. The same letters, however, refer to the same parts in all. S is the screw

Fig. 1

File 3.

Fig. 4.

Fig. 2

CAMPBELL'S RANGE INDICATOR.

Fig. 5.

Scale $\frac{1}{8}$ 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 inches

passing through a plummer-block, p ; v a boss on its shaft to keep it in position, while the lower end rests on a screw, e , held in a small step, q , by means of which it is prevented from working loose. Both plummer-block and step are fixed to a plate, PP , and this is clamped by three bolts to another plate forming part of the projection BB . The bolts pass through short horizontal slots in the latter plate to allow of a small amount of primary adjustment by the maker before it leaves his hands. The toothed arc, R , is similarly clamped to a piece, f , projecting from the side of the telescope. The disc rests on a circular table a (virtually forming a portion of the screw shaft), and is secured in its proper position by a bolt, b , with a capstan-headed nut below. This bolt passes through a hole in the table and a slot in the disc, thus permitting of the latter's adjustment.* KZ (best seen in Fig. 2) is a fixed scale, formed of a strip of cardboard and held in position by having its end clamped between two plates, M (the upper one being hinged on to the lower, and the whole secured by a screw passing through a hole in the strip). The plates, M , are carried on a branch, C , of the framing, and in order to stiffen the arrangement there is a bar, C' , connecting the two ends of the instrument, and supporting a plate, m , over which a portion of the disc (liable to be pressed down by the fingers of the operator) passes. Screwed into the disc, and projecting below it, is a movable stop, g ; this, by coming in contact with the bar, limits the motion of the disc to somewhat less than a complete revolution, thus preventing the screw, S , from running out of gear with the toothed arc.

I now come to an important feature of the apparatus, viz., the surface of the disc. This is painted white, or coated with paper, and has a curve described on it in the following manner. A large number of radii are drawn, and on each, measured from d , the centre, is marked off (to a convenient scale) the range the instrument placed at a certain height, h , ought to indicate, supposing that radius brought into a position coinciding with the edge, kl , of the fixed scale, which itself is in line with d . Practically, it is easiest to begin by dividing the surface of the disc into 36 angular parts, each of which will correspond to 5 minutes of dip. A number of points, $1 \ 2 \ 3 \dots r$, will thus be obtained lying in a spiral curve. This curve is then carefully traced by a black or red line, the radii, except that marked dZ , which corresponding to $\theta = 0$, and $\theta = 3^\circ$, being afterwards obliterated. The disc is in its proper position on the screw shaft when this *zero* radius is found to coincide with the edge of the scale, the axis of the telescope having first (by means of the spirit level, L') been rendered horizontal.

It will be easily seen that the polar equation to the curve is—

$$R' = h \operatorname{cosecant} \frac{\theta'}{120}$$

where d is the pole, R' the radius vector, and θ' the angle Zdr . dZ produced is an asymptote to the curve.

* An opening is formed in the plate, P , in order that the position of the toothed arc may be regulated without dismantling the screw. In all the figures some minor details—small screws, &c.—are omitted.

Supposing now the divisions on the scale kk to correspond with the unit of measure employed in describing the curve, it is evident that as the disc revolves during a change of position of the vessel on whose water-line the axis of the telescope is directed, a *near approximation* to her range will constantly be shown on the scale at r , the point of intersection of its edge, kk , with the curve. In Fig. 2 the instrument is arranged for a height of 20 yards, and the ultimate divisions, or *units*,* of the scale may correspond to distances in the range of 20 yards each. The same curve will, however, serve for *any* height (between very considerable limits) simply by changing the fixed scale; for since, supposing θ to be constant, the range is proportional to h , we have only to make the unit of division inversely proportional to the height—taking any scale already constructed for a known height as a *datum* for our new one—and the result is obtained. Thus, having a scale as in Fig. 2, correct for 20 yards, if we wish to apply the same curve to a position 27 yards above sea level, we must make the divisions in our new scale $\frac{20}{27}$ times the length of those (signifying the same quantity of range) in the other. A scale can be marked out by any artillery Officer in less than an hour. The process, a very simple one, is this. An old scale, kk (Fig. 4) being its edge, is pinned on to a drawing board, and the position, d , of its zero found. A slip of cardboard for the new scale is then attached to the board, with its edge, $k'k'$, in line with d and making any angle $k'dk$ with kk . Suppose the old scale is for a height h and we require the new one for h' , any two distances, dx , dy , are marked off on the edges of the old and new scales respectively, such that—

$$dx : dy :: h' : h$$

Then, joining xy , and through the divisions of kk , drawing lines parallel to xy , these lines evidently divide the edge $k'k'$ in the manner required, *i.e.*, into a scale correct for the height, h' ; d will be the zero, and the same figures must be attached to the divisions as those found opposite the divisions on kk , from which they are severally derived.

Every fort ought to possess five or more scales referring to as many different heights of tide, since an error of a yard or two in h produces a considerable one in the observation of a long range, or indeed of a comparatively short one if measured from a low position. For distances over 3,000 yards it is as well to add 1 yard, and for the less common ones, exceeding 4,500 yards, 2 yards, to h in constituting scales, to allow (roughly) for the curvature of the earth.

In order to find a scale suitable to the tide level at any particular time, it is not always necessary to consult any measure marked on a post or pier—a buoy, or half sunken rock, the exact distance of which is known, will answer the same purpose; for, having directed the axis of the telescope to the water line on this object, we have merely to choose that scale which gives this distance correctly.

Fig. 5 is a plan of the “range-indicator” under a slightly different form, but one that, simple as it at first sight appears, I consider inferior in

These divisions are too minute to be inserted in the figure.

more than one respect to the arrangement I have described. Here the disc, instead of having a curve described on its surface, is divided by radii into angular spaces corresponding to every so many minutes of dip—one minute for the long ranges, two or three for the short. On each radius is written the range for several heights of tide the instrument ought to show when that radius is in line with a fixed pointer, I, clasped in a socket, M. The socket is supported on a branch of the framing in the same position as the plates M in Fig. 1, and the pointer, which can be advanced or drawn back, is clamped by a thumb-screw. The number of yards for different tide levels are arranged in zones; a few only are inserted in the figure. *dZ* is the zero radius. Of course an instrument on this plan must have its disc specially constructed for the height of fort above mean tide where it is applied. A plan of the parts below the disc, common to both forms of indicator, is shown in this figure by dotted lines.

In using the "range-indicator," it is best to employ two Non-commissioned Officers, although one will do. The duty of the first is to keep the intersection of the cross wires constantly on the lowest visible point of the object under fire, elevating or depressing the telescope by turning the disc; he also reports on the effect of shots. That of the second is to read off the range, and call it out (as often as it appears to change) to the Officer who is directing the firing.

The merits I venture to claim for the instrument are three, the first, however, only applying to the form with a curve on the disc:—

1st. The same instrument is applicable to all (or nearly all) heights, simply by using different scales.

2nd. The working of it requires no technical education, any intelligent gunner may be taught the use of it in an hour.

3rd. The range is *constantly* known (to a sufficient degree of accuracy), no matter how frequently or how rapidly it may vary; in fact, with this arrangement no time is lost by observations independent of one another, which, from the time they require, are often in the case of a moving ship, valueless before their results can be applied.*

I believe such an instrument might occasionally be useful for other purposes besides that of range finding, by the addition of a compass, H, mounted on the parallel plate E. This gives us the power of setting the cross wires on any point out at sea of which we know the direction and distance, and thus we are enabled to *watch* the position of a sunken torpedo.

* This range indicator appears to me especially applicable to forts surrounded by water, like those now building at Spithead, where, owing to the smallness of area, no trigonometrical measurement of range from a *horizontal* base is practicable.