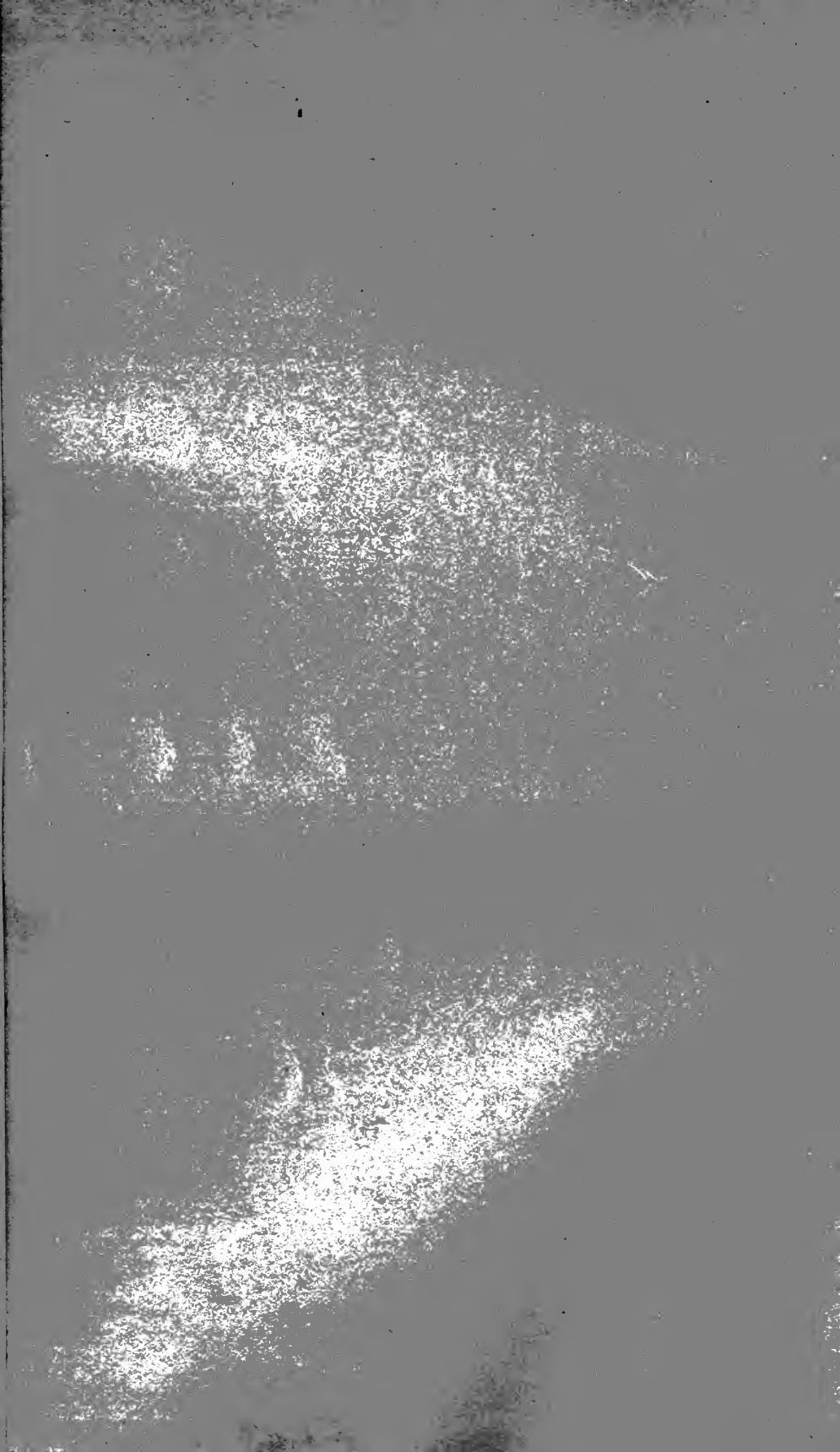

# MANUAL

OF

# FIELD RANGE-FINDING,

FOR

## OFFICERS AND NON-COMMISSIONED OFFICERS

OF

## HORSE AND FIELD ARTILLERY.



**1890.**



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# MANUAL OF FIELD RANGE-FINDING

FOR

# HORSE AND FIELD ARTILLERY.

## PART I.—GENERAL DIRECTIONS.

THE chief uses of Field Range-finding for Artillery is to determine the actual distance of the guns of a battery or batteries from the objects of their fire, the principal advantages thus conferred being:—

1. A saving of time under fire before the commencement of effective shooting.

2. A saving of ammunition in the ranging of the batteries.

Range-finding is also of great assistance in field reconnaissances, enabling exact information to be given as to the distances from the reconnoitring party, of positions held by the enemy, and also the distances of these one from another.

### RANGE-FINDING IN THE FIELD.

In all cases it will be desirable to ascertain the range before the coming of the battery into action, and with as little exposure as possible, in order to avoid premature exhibition of purpose to the enemy.

When time is abundant, accuracy should be ensured by the employment of long bases, of deliberate work and of verification by taking more than one observation to a particular point. This will generally be feasible on *the defensive*, and in reconnaissance preparatory to attack when the ranges should be taken to all points which may become important during the course of the operations. These ranges should be recorded on a rough but clear sketch, having the points numbered, and the numbers tabulated with their corresponding ranges.

When time is scant, the range-takers should attend closely on the commanding officer in readiness to find the range as soon as he can point out the intended position for action.

When the advance or retirement of a battery in prolongation of its line of fire is expected, the range of a point in the next probable position should be taken. This deducted from or added to the existing range will give that of the new position.

When a new position, not in prolongation of the line of fire has been decided on, the distance of this from the objective should be found (see Part II. Chap. IX), before the battery is required to move.

As ranges to moving objects cannot be taken except under special circumstances (see Part II, Chapter X), points in their probable path sufficiently advanced to allow time for the operation must be selected. If, it is impossible to take the range of the actual object required (such as troops or guns under cover), and a tree or any other conspicuous adjacent object has been taken instead, this should be distinctly notified to the officer in command, as observations of this nature cannot be implicitly relied upon, on account of the difficulty of correctly estimating by eye the comparative ranges of objects, though apparently equally distant.

Range-finding should be invariably conducted under the immediate supervision of an officer, who should see that it is carried out as much as possible under cover (see Part II, Chapter XIII), and that there is no mistake made in the identification of the object.

When observation of effect of fire is likely to be difficult, or the target is badly defined, it is often advisable to find the ranges of objects short of and beyond it; this will give limits between which the true range must lie on the principle of the brackets recommended in ranging by common shell.

The Range-finders in the Service for Horse and Field Artillery are: —

1. The Watkin Field Range-finder, see Part II.
2. The Watkin Field Telemeter, see Part III.

Their application is at present restricted to objects seen by daylight,* and as already stated, except under special circumstances, to the observation of stationary objects.

* By the aid of lamps fitted to the pickets, the range of lights at night can be readily found. The adoption of such lamps is now under consideration.

# PART II.—THE WATKIN FIELD RANGE-FINDER.

## CHAPTER I.

### The Range-finding Equipment of a Battery.

The range-finding equipment of a battery of Horse or Field Artillery, to which the Watkin Field Range-finder has been issued, consists of the following articles:—

1 Watkin Field Range-finder, large pattern, Class 1, in a leather case with a shoulder belt attached.* The instrument is invariably of the Mark IV pattern.
1 leather waist-belt.*
1 steel tape, Mark II, in a wind-up case in a leather pocket,
1 metallic cord, Mark II or III, carried in a leather pocket.
1 set of 3 tripod pickets with a linen flag each.
2 picket straps 3 feet 4 inches long, one for the A and B pickets, which are carried together, one for the C picket.
4 leather picket buckets, 2 large and 2 small.

In addition to the above, batteries are allowed a second instrument Class II, for drill purposes; this is usually of the Mark III pattern.

### Patterns of Instrument.

The Artillery patterns are described in the official vocabulary as:—Range-finders, Field Watkin *large*, to distinguish them from the two patterns of Infantry range-finders which resemble them in every respect except *size*, and are described as *small*.

There are two patterns of the large, or Artillery, range-finders now in the Service, viz.:—Mark IV, which is the ordinary Service pattern, and Mark III, which is issued to batteries for drill only, and does not form part of their Service equipment.

Marks III and IV differ in manufacturing details only. The Mark III has a solid base, whereas the Mark IV has an open frame-work screwed to a false bottom. The Mark III may be further recognised by having the guide collar regulated by a capstan screw instead of by the automatic split-spring adopted in the Mark IV. Mark III instruments, when in good order, are as reliable as Mark IV, but those now in use are nearly all much the worse for wear, and consequently not good enough for accurate work.

* New cases are fitted with 2-inch shoulder-belts, and 2-inch waist-belts are issued for use with these. Some old cases are, however, fitted with 1½-inch shoulder belts, and waist-belts Mark II, 1½-inches wide, are supplied to correspond with these.

For the regulations relating to classification of instruments and their issue to batteries, see Appendix C, p. 56.

## The Mark IV Instrument. (Plates I and II.)

The instrument is double reflecting, on the principle of the common sextant, but is so constructed that the distant object is seen by direct vision, and the near one by reflection.

When closed it forms a rectangular box $10\frac{1}{2}$ inches long, 4 inches wide, and $1\frac{3}{4}$ inches deep.

It weighs about $4\frac{1}{2}$lb.

The parts of the instrument are as follows:

The metal case.
The cylinder.
The cylinder guide collar.
The cylinder band.
The base bar and sliding collar.
The base bar spring.
The steel bar.
The steel bar spring.
The index glass.
The short arm.
The horizon glass.
The rack and pinion.
The rack knob and spring slide.
The regulator.
The regulator blocks.
The adjusting key.
The telescope.
The two eyeholes *with* sliding shutters, one for each eyehole.

### *The Case and its Fittings.*

The case consists of a ribbed frame, a false bottom and bottom plate, and a top or cover.

The cover is hinged so that when the instrument is in use one half may be thrown back, thus admitting light and giving access to the cylinder and base bar.

In the cover is carried the adjusting key and the telescope.

There are two eyeholes fitted with sliding shutters, so that the instrument can be used with or without the telescope.

The case is marked—*on the top* with the name, and number of the instrument, and with the maker's name; *on the base* with a ing to show where the head of the picket is to be when the nstrument rests upon it; *at the eyeholes* with the words "Range —Right Angle," to mark the end eyehole, and with the word *Base* to mark the side one;—*over the rack knob* with the words "Range and Right Angle—Base," to show the proper position of the spring slide.

*The Cylinder.*

The cylinder consists of a metal barrel, with a steel pointed screw rigidly fixed in it. The screw works in a split spring guide collar, its point bearing upon a steel block at the end of the base bar.

The cylinder has engraved upon it spirally a scale of ranges from 450*† to 5,000 yards; these are read by means of an arrow-head upon a fixed band which partly surrounds the barrel. The cylinder has a zero mark to show when it is fully screwed up.

*The Base Bar.*

The base bar is of gun metal, and has a scale of bases engraved on it from 60 to 130 yards‡; the scale is read by means of a line cut on the sliding collar.

The bar is compelled to move with the cylinder, being pushed forward by it in one direction, and constrained by the base bar spring to follow it in the other.

*The Steel Bar.*

The steel bar conforms to the movement of the base bar (in accordance with the setting of the sliding collar), being pushed forward by it in one direction, and constrained by the steel bar spring to follow it in the other.

*The Index Glass.*

The index glass, which is entirely silvered, is fixed in a frame at the pivot end of the steel bar. This glass has necessarily a movement dependent upon that of the steel bar.

*The Horizon Glass and Short Arm.*

The horizon glass is a half-silvered glass in a metal frame fixed to the short arm.

It has two positions—

First, when the regulator is pressed against the side block K (Plates I and II); it is then at 45° inclination to the index glass.

Second, when the regulator is pressed against the centre block L; it is then parallel to the index glass.

The horizon glass is shifted from one position to the other by the rack and pinion, actuated by the rack knob. Back lash is avoided by a bent spring under this knob.

*The Regulator and Regulator Blocks.*

The regulator is a small screw of hardened steel carried at the end of the short arm, from which it projects in both directions; the arm then plays between the steel regulator blocks.§ The

* Available for any other unit.

† In some instruments the scale begins at 500.

‡ Some instruments read to more than 130, and some to a little under it.

§ The regulator, if it works loose, can be tightened by a slight turn of the capstan crew on the short arm.

position of this screw can be slightly altered by the adjusting key without any alteration in the total angular traverse of the short arm carrying the horizon glass.

Thus if the short arm be locked in position, so that the regulator bears against the block L (Plates I and II), then by screwing or unscrewing the regulator, the horizon glass can be brought exactly parallel to the index glass, and by this method the instrument can be tested and adjusted.

### *The Sliding Collar.*

The sliding collar can be set in any position on the base bar from the 60 graduation to the extreme end. Its function is to communicate a motion to the steel bar from the base bar; this motion being proportional to the length of base to which the collar is set.

When the cylinder is at zero the steel bar and base bar are absolutely parallel, and the movement of the sliding collar along the base bar imparts no movement to the index glass.

In every other position of the cylinder the steel and base bars are not parallel, and the inclination of the index glass, for a given position of the cylinder, will then vary with the position of the sliding collar on the base bar.

Thus the amount of motion of the cylinder to give a definite movement to the index glass depends on the position of the sliding collar on the base bar; and the instrument is so arranged that by setting this collar to the proper graduation for the base used, the one scale of yards on the cylinder will give the range (within the limits of the graduations) without any calculation whatever.

### *The Sliding Shutters.*

The shutters have the eyeholes in them, and must be always closed when the telescope is not used.

The importance of the small eyehole is very great, for an observation taken with the shutters open cannot be depended on.

### *The Telescope.*

The telescope magnifies objects to about four times the natural size. It is focussed by pulling out or pressing in the eye piece.

For use, it fits into the eyeholes, the shutters being withdrawn.

When not in use, it is carried in a socket on the lid of the instrument.

In the Mark IV, this socket has a cross slot which fits in a small projection on the telescope.

In the Mark III the socket holds the telescope by a simple spring.

## The Steel Tape.

The steel tape is a riband of steel 20 feet long, with a loop at one end for fixing to a button on the A picket, the other end being fastened to the interior of a case into which the whole riband can be wound. There is a raised mark on the tape indicating a length of 6 yards.

The tape is employed to test the length of the metallic cord.

## The Metallic Cord.

The cord Mark III is composed of a silk line 18 feet 9½ inches long, covered with copper wire.

One end is fixed to a wooden shuttle on which the cord is wound, the other end is furnished with an S hook which enables the cord to be attached to the button of the A picket.

A length of exactly 6 yards is marked off by a single knot on the cord on the outside of the hole in the shuttle, the measurement being from this knot to the outside bend of the hook.

In the Mark II pattern, which is liable at times to kink, the cord is covered with brass instead of copper wire, and the S hook is weaker than in the Mark III.

The Mark I, now obsolete, was fitted with a ring instead of a hook.

The shuttle should be painted on each side half white and half black.

## The Leather Pockets for Tape and Cord.

The Mark II pockets for the tape and cord have a loop on the back, through which the waist-belt passes; they are closed by a buckle and strap. That for the cord is square, the other is rounded off. Mark I pockets should be altered to pattern locally.

## The Tripod Pickets.

The tripod pickets are of ash,* each in four pieces—the head and the three legs—any one of which may be easily replaced on service by battery artificers.

The head is attached to the legs by a joint of thick leather.

The legs, which are furnished with steel points, fold together so that the picket may be carried like a lance.

Each picket weighs about 3lb. 5 oz., and is 5 feet 6 inches long when folded.

One of the pickets (called the A picket) is fitted with a moveable crosshead and with a brass button to take the S hook of

* The earlier patterns of picket now obsolete were—
One picket of tubular steel with iron points, furnished with white enamel leather discs having black crosses on them.
Two pickets of male bamboo shod with steel furnished with leather discs as above.

the metallic cord. This picket carries a flag with a black cross on a white ground, and takes one of the picket-straps. It has a small strap on one leg to go round the B picket when carried by No. 2 mounted.

The other two pickets are identical, except that one (the B picket) carries a flag with a single black vertical line on a white ground, while the other (the C picket) has a flag like the A picket, and takes the second picket-strap,

### The Picket Buckets.

The Mark IV buckets are of brown leather. They are in sets of 2, one for each stirrup, so that the picket may be carried on either side of the rider, as may be found convenient. The large buckets take two pickets each, the small ones one picket only. Each bucket is fitted with a loop, through which the stirrup leather is passed, and with a strap for attachment to the stirrup iron.

The buckets receive the lower ends of the tripod pickets, the upper ends being slung by a strap to the arm of the rider.

Buckets Marks I, II, and III are obsolete.

## CHAPTER II.

### Method of Carrying the Equipment by a Mounted Party.

A MOUNTED range-finding party consists of No. 1 the range-taker, No. 2 the assistant, No. 3 the horse-holder.

The equipment is carried by Nos. 1 and 2 as follows:—

No. 1 carries the instrument in the case strapped over the left shoulder so that it may rest behind his right elbow just clear of the hip. The instrument is kept from jolting by the waist-belt, which is passed through the loop of the leather case and buckled in front. On the left side of the waist-belt are carried the metallic cord and steel tape in their leather pockets, through the loops of which the waist-belt is passed before it is buckled. The steel tape is put on to the front (about half-way between the seam and the buttons of the jacket or tunic), the cord is put on close behind it.

No. 1 also carries the C picket. It rests in one of the buckets (small size) which are attached to the stirrups. A strap is passed round the picket, under one of the small straps of the flag, and then round the arm. The picket is thus carried like a lance.

No. 2 carries the A and B pickets in a similar manner to the way No. 1 carries the C picket, but they are drawn together at the top by a loop on the picket strap, and strapped together at bottom by the little strap on the A picket.

The buckets should be put on to the front of the stirrups so that they may be on the outside of the feet when mounted.

#### *Formation.*

The party ride in line; No. 1 on the near side, No. 2 on the off side of the horse-holder.

#### *Dismounting.*

At the command from No. 1, *Halt—Dismount,* No. 1 dismounts first. To do so, he takes up his picket and passes it from right to left across the saddle, point downwards under his left hand. He then dismounts in the usual way and giving his horse to No. 3, goes round by the front and takes the two pickets from No. 2.

No. 2 then dismounts in the usual way, and giving his horse over to No. 3 receives back his pickets from No. 1.

Nos. 1 and 2 proceed to the front on foot, and the horse-holder takes the horses under cover according to directions from No. 1.

*Mounting.*

At a signal from No. 1 the horse-holder rides up with the horses, that of No. 1 on the near, that of No. 2 on the off side.

At the command from No. 1, *Mount*, No. 2 mounts first and then receives his two pickets from No. 1, who, after giving them to him, goes round by the front to his own horse, and mounts with his picket held under the left hand point downwards.

When mounted, he takes up the picket in his right hand, and lifting it across the saddle, places it in its bucket.

## CHAPTER III.

### Use of the Instrument.

The principal application of the field range-finder in artillery operations is to solve practically, without calculation* or actual measurements, the following problem :—

*To find the distance to any visible point, from the ground occupied by the range-finding party.*

This is technically termed "taking a range."

The physical conditions necessary in order to take a range with the Watkin range-finder from any point P to any object O (fig. 1), are that a position may be found to the right or left of P from which both O and P are visible, and at which a point Q may be marked such that either the angle O P Q or the angle O Q P shall be a right angle.

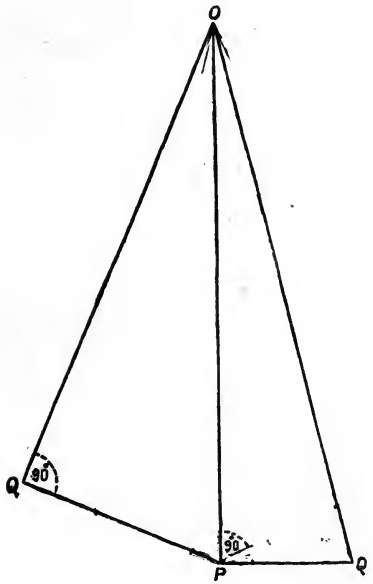


Fig. 1.

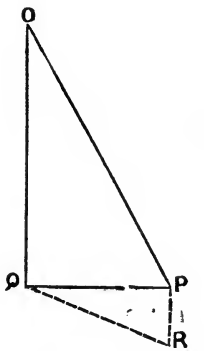


Fig. 2.

* There are certain cases when, although the limits of the instrument are exceeded, it is still possible to find the correct range. In these exceptional cases a simple calculation is required. (*See* Chapter VIII.)

In practice the mode of proceeding is usually as follows :—

The object being O (figs. 2 and 3) a picket is placed at P, and the range-taker, by means of the instrument, finds the right angle point Q and places a second picket there.

He then, standing at Q, reads with the instrument the base P Q by means of a sub-base P R, which is marked by a picket R, at right angles to P Q.

After this, setting the base so found on the base bar of the instrument, he proceeds to P, and by an observation at that point reads off the range O P on the graduated cylinder.

Three things, therefore, have to be done by means of the instrument—

1. To fix the right angle.
2. To find the base.
3. To take the range.

It is best to consider 1 and 3 first.

*Step 1.—To fix the right angle.*

The cylinder must be turned to zero and the rack knob pushed to "Range—Right-angle" (this will set the mirror at 45°), and the observer must look through the end eyehole marked for right angle and range. The sliding collar should be at the stop.

Let the observer's position be Q′ or Q″ (fig. 3) to the left of the picket P, and O the object the distance to which is required.

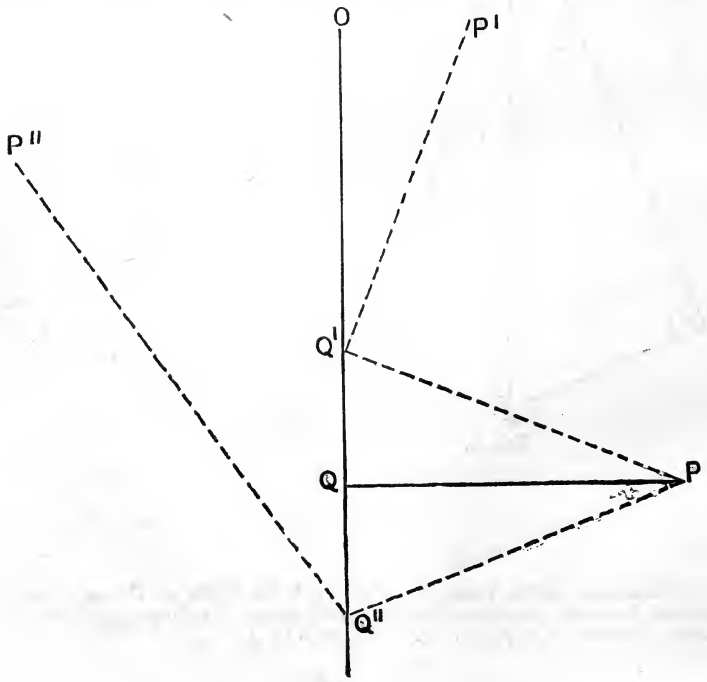


FIG. 3.

From this position, looking at O through the unsilvered portion of the horizon glass, the observer will see the image of the picket P reflected in the silvered portion of the glass towards P′ or P″ at right angles to P Q′ or P Q″ (figs. 4 and 5).

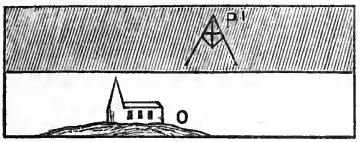


FIG. 4.

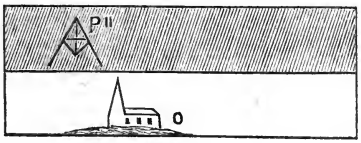


FIG. 5.

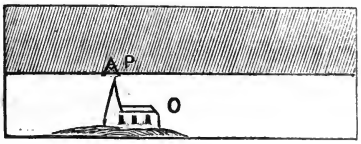


FIG. 6.

Then, by advancing or retiring as may be necessary he will be able to reach a point Q at which the object O and the reflected image of P coincide in the glass (fig. 6).

This will fix the right angle.

*Step III.—To take the range.*

Assuming that the right angle has been fixed and marked by a picket Q (fig. 7), and that the length of the base P Q has been ascertained (by step 2, which remains to be described), it is desired to take the range to O.

First the base P Q must be marked on the base arm by means of the sliding collar, and then the instrument, being in other respects set as for finding the right angle, must be taken to the picket P, and placed upon it with the ring which is marked on the case exactly over the picket head.

The observer using the end eyehole marked "Range—Right angle" will now see the image Q′ of the picket Q reflected at right angles to P Q in a direction S to the right of O (figs. 7 and 8).

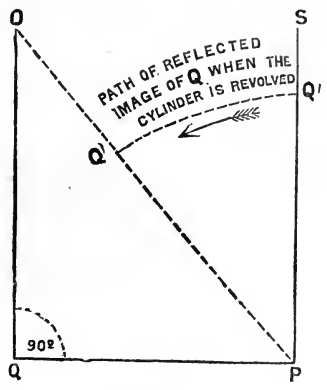


FIG. 7.

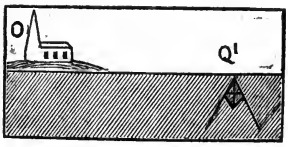


FIG. 8.

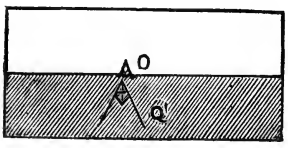


FIG. 9.

He must now revolve the cylinder (thus causing Q′ to move towards O) until the object O seen direct and the reflected image Q′ exactly coincide (figs. 7 and 9); when this has been done, the reading O on the cylinder will be the required range.

*What has been described as steps* 1 *and* 3 *amounts to this:—*

*Two right angles inwards are made; first* O Q P *at* Q, *and then* Q P S *at* P (*fig.* 7), *in doing which the instrument is used like a common sextant, the mirrors being inclined to one another at* 45°.

*After this, the instrument remaining in its last position,* P, *the right angle at that point is altered by revolving the cylinder so that* Q′ (*the image of* Q) *is no longer reflected at right angles* Q P S, *but at the smaller angle* Q P O.

*Now the longer the range is, the less does the angle* Q P O *differ from the right angle* Q P S, *and therefore the fewer are the turns which it is necessary to give to the cylinder to make* Q′ *move from* S *and coincide with* O.

*From the above it is easy to see how by engraving a scale on the cylinder, such scale can be made to record the actual range, that is, the particular value of* O P *in every instance.*

*So far, however, it may not appear how the reading on the cylinder is applicable to every range independent of the length of the base, for it is evident that if* P Q (*fig.* 7) *were shorter, the angle* O P Q *would be greater and vice versâ, although the length of* Q O *remained unaltered. This difficulty is met by the use of the base bar, which enables the movement given to the index glass by each turn of the cylinder to be increased or diminished according to the position of the sliding collar. By this contrivance it is arranged that in proportion as the base is longer for any given range, the greater is the movement of the index glass corresponding to any given number of turns of the cylinder, and therefore* (*fig.* 7) *the greater the resulting deviation of the reflected image* Q′ *from the right angle* O P S. *Thus within certain limits the necessary compensation is effected to enable the one scale in the cylinder to be made use of whatever the length of base may be.*

*Step II.—To find the base.*

Following the lettering of figures 3 and 7, Q is the right angle picket in position with reference to the range picket P (fig. 10). The base to be found is P Q.

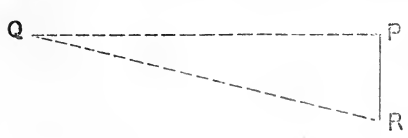


Fig. 10.

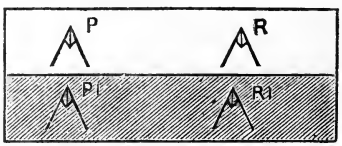


Fig. 11.

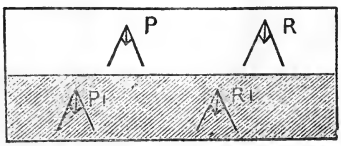


Fig. 12.

From P at right angles to P Q a sub-base P R (which is usually the length of the metallic cord, *i.e.*, 6 yards) is marked by a picket R.

The cylinder must be turned to zero, the rack knob pushed to *Base* (thereby setting the mirrors parallel), and the length of the sub-base recorded on the base bar.

The observer should now stand at Q facing Q R, holding the instrument immediately over the picket Q, and should look through the side eyehole marked *Base*, when he will see the pickets P and R with their reflected images immediately under their natural ones in the horizon glass (fig. 11).

If he now commences to revolve the cylinder the images seen by reflection will travel to the left (fig. 12), and he will finally be able to make the reflected image of R coincide with the natural image of P. In this position the reading on the cylinder scale will be the distance P Q required.

*The principle involved in the operation just described is the same as that already investigated when considering step* 3.

*As long as the cylinder is at zero, the glasses are parallel, and the natural and reflected images coincide, but when the cylinder is revolved the index glass is displaced and the reflected images are thrown to one side, to an extent proportional to the number of turns given to the cylinder.*

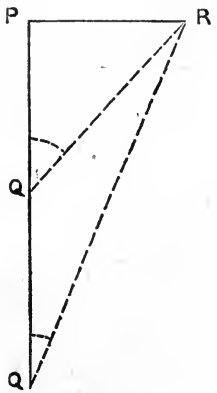


FIG. 13.

*The sub-base* P R, *fig.* 13, *being fixed at* 6 *yards,* the smaller* P Q *is, the greater is the required movement of the index glass, and the amount of this movement, as registered by the scale on the cylinder, is a measure of the distance* P Q.

* If a sub-base other than 6 yards is made use of, the compensating action of the base bar comes into play; for example, if P R be 12 yards, the base bar is set to 12 instead of 6, and the movement of the cylinder is regulated accordingly. (*See* p. 15, Explanation, Step III.)

## Reading the Scales.

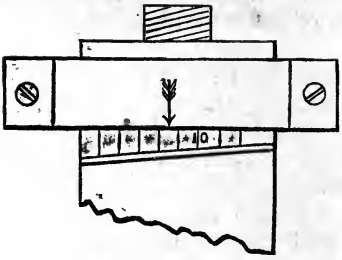

Fig. 14.

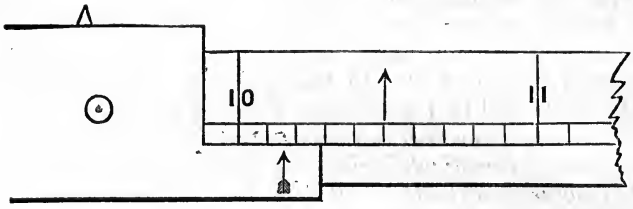


Fig. 15.

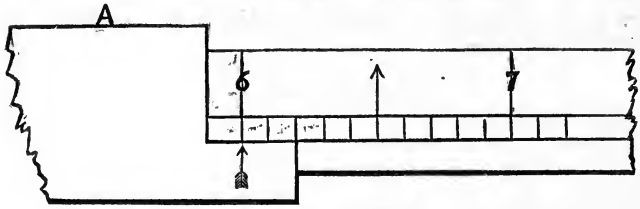


Fig. 16.

1. The scale on the base bar serves two purposes—
   1. For marking a sub-base.
   2. For marking a base.

For a *sub-base* the numbered divisions read yards, and the sub-divisions are not made use of; thus fig. 16 shows how the usual sub-base of 6 yards is set.

For a *base* the numbered divisions really *mean* tens of yards, and the sub-divisions yards, but in practice the numbered divisions are treated for convenience as reading hundreds of yards, and the sub-divisions as tens of yards.

2. The cylinder scale serves two purposes—
   1. For reading a *range.*
   2. For reading a *base.*

Up to 2,000 yards the scale is graduated for every 10 yards; from that to 3,000 yards for every 25 yards, and from 3,000 to the end of the scale for every 50 yards.

The numbers read from right to left.

*In reading a range* the numbers from 450 to 990 give the actual range in yards, while those from 10 to 50 (that is, for the remainder of the scale) express hundreds of yards. Thus the

arrow-head pointing to 850 would indicate a range of 850 yards, and when pointing to 23 it would indicate a range of 2,300 yards.

*In reading a base* the actual distance is the reading on the cylinder divided by 10; but, as already explained, in practice a base is read as if it were a range, and set on the base bar without calculation (treating the numbered divisions of the base bar as hundreds of yards).

Thus, if the arrow-head points as in fig. 14 it would indicate a range of 1,015 yards. If a base were being read the figures would really mean 101½ yards, but they would be read in practice as 1,015 and set on the base bar as in fig. 15.

Again, if a base happened to be 60 yards it would be read on the cylinder as 600 and marked on the base bar as shown in fig. 16.

---

## CHAPTER IV.

### Correcting the Adjustment of the Instrument (commonly called Adjusting the Instrument.)

Some experience is necessary to know when the adjustment is imperfect, and a practised hand and eye are needed to correct it properly; it should therefore never be attempted by any one who has not been trained for the purpose.

A good instrument will seldom require the adjustment corrected, but it should invariably be tested before commencing a day's work, and again, if possible, after riding long distances, or over very rough ground.

There are two adjustments—

1. The *horizontal* or ordinary adjustment, the correction of which, when necessary, is a part of the range-taker's everyday duty.
2. The *vertical* adjustment, which is rarely imperfect, and the correction of which, except on active service, should be considered an instrument-maker's repair.

To test the adjustment, open the lid, set the cylinder to *zero*, the rack knob to *base*, and the sliding collar to the stop (that is to 6 on the scale).

If in proper adjustment the index and horizon glasses are now parallel, and by looking through the side eyehole at any sharply defined vertical line at from 200 to 300 yards distance, it will appear in the upper and lower part of the horizon glass as a single unbroken line (fig. 17). If the line be broken (fig. 18) when the instrument is held level to the object, the horizontal adjustment requires correction.

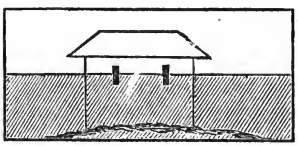

Fig. 17.

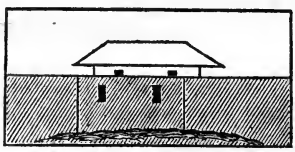

Fig. 18.

The best objects to look at are the sides of buildings, poles, sign-posts, or corners of walls, but the stems of trees can be made use of, and on an emergency a picket folded and held upright will answer the purpose.

To correct the horizontal adjustment, unscrew the adjusting key, apply it to the square shoulder of the regulator, and turn it towards the lower portion of the line until the two come together.

After this shift the rack knob from base to right angle, and back again twice, and look again to see if the adjustment remains correct;* if it does so, nothing further is required.

* It is desirable to get a small piece of pointed steel made to fit the capstan screw of the jaws which hold the regulator, and to tighten these jaws occasionally. If they work loose, the instrument will get out of adjustment very quickly. A very gentle pressure should be applied, however.

To connect the vertical adjustment, a small screw-driver is required.

First put the instrument in exact horizontal adjustment, then look at some well-defined object as before, only let it be one which has some point on it which can be distinctly recognised. Bring this point to the dividing line in the horizon glass. Give a very slight turn to the cylinder and note if the two images as they separate appear on a level. If not, and one is below the other as in fig. 19, the vertical adjustment needs correction.

Apply the screw-driver to the small screw just above the horizon glass. If the reflected image is too low turn from left to right *when facing the screw*, and vice versâ.

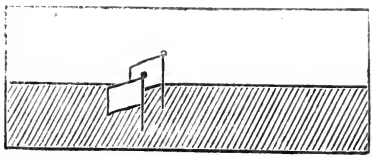

Fig. 19—incorrect.

## CHAPTER V.

### Care of Instruments and Equipment.

*Care of Instruments.*

If properly cared for, an instrument should remain in good order for several years. Constant wear will in time cause a falling off in accuracy, but the process is a very gradual one, and can never account for an instrument becoming suddenly unfit for use.

Range-finders should never be exposed to rough treatment. Like hunting watches they will bear a considerable amount of fair wear and tear, but are put entirely out of order by ill-usage.

The following points are of importance:—

1. Service instruments (as distinguished from those appropriated for instruction) should never be handled by persons untrained in the proper way of using them.
2. On no account should any of the small screws be taken out or interfered with; the adjustment and the occasional tightening of the regulator is all that should be attempted by range-takers.
3. An instrument should always be carried by the range-taker, never on a limber or wagon. It should never be sent with baggage unless packed in a separate box, as glass is packed, with some soft material round it to form an elastic cushion.
4. In barracks or camp, and on the march in wet weather, the cylinder screw and all the steel parts should be slightly oiled with mineral oil to prevent rust.
5. Before use, the oil should invariably be removed. This should also always be done before a march in dry dusty weather.
6. The mirrors should be wiped occasionally with a piece of clean chamois leather or soft linen.
7. In moving the rack knob from "base" to "range," and *vice versâ*, care should be taken not to do it with a violent jerk, but by a firm pressure to ensure actual contact with the blocks. A slight click only should be heard.

*Care of Equipment.*

1. The leather parts of the equipment require the same treatment as saddlery. Special precautions must be taken in tropical climates to prevent its perishing.
2. The tripod flags when soiled, should be taken off and washed.

3. The metallic cord should be kept as dry as possible, and always wound up after use. It should not be trodden on, nor should it be knotted (except at the end outside the shuttle).

   A good cord may be known by its being perfectly flexible, where a bad one will easily kink, and soon split.

4. The steel tape should be wiped dry, and carefully wound up after use. If damp it will rust, and if twisted it will easily break. The handle must never be reversed. The tape should not be used for measuring sub-bases, but only for testing the cord. It should be oiled occasionally.

## CHAPTER VI.

### Preliminary or Position Drills.

This part of the subject can only be acquired by practice under a competent instructor, who will show how each operation is performed by going through the various movements himself.

For reference, however, the various positions are here described.

### Planting Pickets.

*The A picket* is planted with the flag to the left.

*To plant a C picket* (fig. 20).

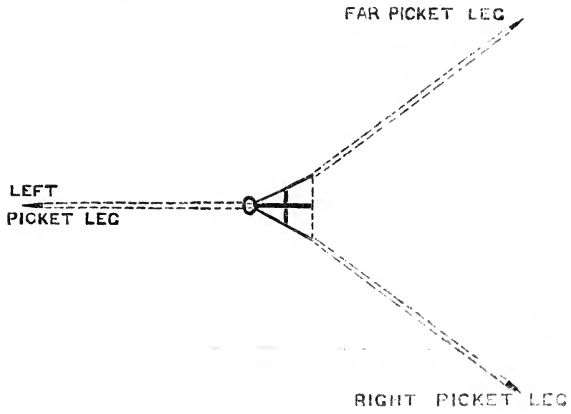


Fig. 20.

The picket is held about the middle point in the right hand, the instrument reversed being held up to the eye just over the right foot, which is slightly advanced.

The picket is turned with the flag to the right, the two near picket legs being held in the whole hand, with the exception of the forefinger, which is circled round the far picket leg.

To plant the picket, the right foot is held quite steady and the weight of the body thrown upon it.

1. The far picket leg is thrown to the right front.
2. The left picket leg being released by the hand is caught by the left foot and extended straight to the left, while at the same time the right picket leg is drawn by the right hand to the right rear, and the picket thus extended so that its head is exactly over the right foot and the flag pointing to the right.

A slight adjustment by the right hand sets the picket in correct position.

After being thus planted the picket ought not to need moving more than an inch or two when the instrument is placed upon it. Any such movement is performed by the right hand applied to one picket leg at a time.

*To plant a B picket and lay out a 6-yard sub-base.*

The A and C pickets being planted, No. 2 turns the crosshead of the A picket on to the C picket, and then with the metallic cord in his right hand and the B picket in his left, looks over the line of the crosshead which is at right angles to *the base*, and takes up *a line for the sub-base.*

He then proceeds as follows:—

1. Hooks the S hook of the cord to the button of the A picket.
2. Extends the cord in the correct line, letting it run loosely through the *right* hand till fully extended, but not drawing it taut.
3. Still holding the cord slackly, takes the two near legs of the B picket (flag towards the C picket) and throws out the far leg to the front, at the same time placing the others in position, the right leg straight to the right, the left one to the left rear.
4. Changes the shuttle to the left hand.
5. Extends the cord to full length, and with the other hand adjusts the head of the B picket to the exact end of the cord, keeping it in the correct line.
6. Drops the shuttle, steps up to the A picket, lifts the hook of the cord carefully from the button of the picket, and then winds up the cord.

## Position of the Hands in using the Instrument.

### *Fixing the Right Angle.*

*First Position.*—(Before planting the picket.) The instrument open and reversed is held in the left hand, with the thumb (pointing upwards) on the left, the forefinger doubled under the adjusting key, and the other fingers (pointing towards the observer) on the right. The thumb must hold the body of the instrument so that it may not tip forward, and at the same time the hollow of the hand must be kept away from the sharp edges of the cover.

*Second Position.*—(Verification after planting the picket.) This position is the first position with the forefinger still under the adjusting key resting on the head of the picket, while the little finger is extended outwards to clear the picket head.

*Finding the Base.*

The instrument is held in both hands with the middle or base eyehole in use.

On the left the forefinger (outermost) and thumb (innermost) of the left hand grasp the base, and on the right the forefinger and thumb of the right hand are appplied to the cylinder, while the remaining fingers support the instrument.

The instrument should not touch the picket, for fear of disturbing the right angle, but should be held immediately over it, to insure which the little finger of the left hand may be allowed just to feel the picket head.

*Taking the Range.*

The instrument is placed on the picket with the ring upon the base resting on the picket head. The thumb and forefinger of the right hand turn the cylinder while the middle finger underneath steadies the movement.

The left hand is circled round the picket head, the forefinger and thumb extended so that the instrument may rest partly upon them.

POSITIONS OF THE BODY.

When using the instrument before planting the C picket, the body should be upright with the right foot slightly advanced. When the instrument rests on the A or C picket the body should be thrown forward on the left leg, with bent knee and toes to the front, the right leg being extended backwards and kept straight with the toes to the right.*

Exceptional heights of picket often require exceptional positions, such, for example, as kneeling when the head of the picket is very low down.

* Never separate the legs and bend both knees, as the position arrived at in that way is very unsteady.

## CHAPTER VII.

### Service Drill.

The range-finding party consists of No. 1 the range-taker, and No. 2 the assistant.

These having dismounted, and left their horses in charge of the horse-holder, advance in Indian file under the command of an officer, who, if necessary, first reconnoitres the position, and who points out the object to both numbers.

No. 1 carries the instrument and the rest of the equipment, except two pickets (the A and the B) carried by No. 2.

If time admits of it, No. 1 will, before advancing, test the metallic cord and look to the adjustment of the instrument, assisted by No. 2.

Having reached the spot chosen for commencing to take the range, No. 1 estimates the distance, and the length of base required, and directs No. 2 to plant the A picket; this done, he ascertains that it is correctly placed, and that the *object* is visible from the head of the picket when planted.

He then takes the metallic cord from its pocket and hands it to No. 2. If the sub-base is to be 12 yards, No. 1 assists No. 2 in laying it out.

The A and B pickets are planted with their flags to the left.

### Duties of No. 1. (Figs. 3 to 9, pp. 14, 15.)

No. 1 takes the instrument from its case, opens it,* and holding it in his left hand upside down, with the C picket in his right, stands on the left of the A picket facing the object. The cylinder should be at zero, the sliding collar as far from the cylinder end of the base bar as it will go, and the rack knob pushed to *Right angle.* Looking over his left shoulder he takes up a guide point a little to the front of his exact left, fig. 21, and then keeping his eye on the precise point of the object he intends observing, he doubles at a quiet pace† towards the guide point till he has covered sufficient distance for his base.‡

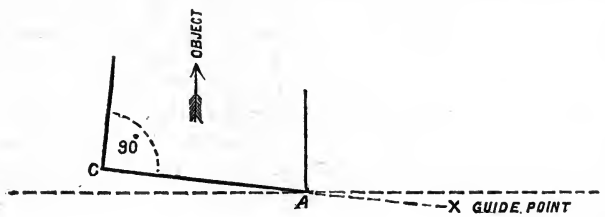


Fig. 21.

* When the ground is very uneven, or the distance to be traversed considerable, it is best not to do this till the other end of the base is reached.

† About 70 paces go to 100 yards at the proper "double."

‡ It is sometimes necessary to take the guide point on the other side of the A picket, a little to the right rear of No. 1, who afterwards lines himself on this and the A picket.

No. 1 then halts, and facing the object applies his eye to the right-angle eyehole of the instrument (the C picket remaining in his right hand sloped so as not to impede the view), and by reflecting the A picket on the object *fixes the right angle*, advancing or retiring as may be necessary in order to do so. If the A picket appears to the right of the object he retires, if to the left he advances. (Rule, *Right retire.*)

Having approximately fixed the right angle point, No. 1 plants the C picket, and placing the instrument upon it verifies the observation, pushing the picket forward or drawing it back slightly as may be necessary to obtain exact coincidence.

Having firmly planted the C picket at the right angle, No. 1 now faces the A picket, turns the instrument lid uppermost, sets the rack knob to *base*, and reads the base by turning the cylinder* until the B or right-hand picket of the sub-base is reflected on to the A or left-hand picket. This he does holding the instrument immediately over the C picket, but *not resting on it.*

Having found the base, he sets it on the base bar, and pushes the rack knob back to *range.*

No. 1 then doubles back to the A picket, and resting the instrument lid uppermost upon it takes the range by turning the cylinder until the C picket is reflected on to the object.

It should be remarked that the taking up of a guide point is not absolutely necessary, but is of great assistance when the base is long, to save loss of time in advancing and retiring.

## Duties of No. 2.

No. 2, as soon as the A picket has been planted, places himself on the left of it, facing in the direction towards which No. 1 is to run. He holds the B picket in his left hand and the cord in his right.

As soon as No. 1 commences to plant his C picket, No. 2 turns the crosshead of the A picket upon No. 1, and then looking over the other line of the cross, lays out the sub-base, planting the B picket with the flag towards No. 1.

He then returns to his position at the A picket, and keeps his eye on No. 1, ready at a signal from him to stand behind the picket if required. If No. 1 takes up his C picket and moves his position, No. 2 will lower the B picket, and lay out a fresh sub-base as soon as the C picket is planted again.

As soon as No. 1 leaves the C picket, No. 2 will lower the B picket, and, leaving it on the ground, will double out to the C picket and stand by it, placing himself behind it, if signalled to do so.

On a signal from No. 1 that he has taken the range, No. 2 will bring in the C picket.

* In practice, to avoid fatiguing the eye, it is convenient to begin by setting the cylinder to the point which indicates the approximate base.

If at any time, by accident, either A, B, or C picket is shifted while No. 1 is at the other end of the base or crossing, No. 2 will at once lower that picket, and not set it up again until No. 1 indicates by a signal that he understands what has occurred.

### Variations in the Drill for Casualities.

The variations which are recognised in the drill are those necessary to meet the following casualties:—

#### 1. Diminished Numbers with Complete Equipment.

(*a*) *No. 1 disabled.*—No. 2, if qualified, becomes No. 1 and works alone. No. 3 carries one picket when mounted.

(*b*) *No. 2 disabled.*—No. 1 works alone, and No. 3 carries one picket.

(*c*) *No. 3 disabled.*—No. 2 remains with the horses, and No. 1 works alone.

*No. 1 working alone, in the above three cases.*

When No. 1 works alone he has to lay out the sub-base for himself as follows:—

Having planted the A picket he lines himself with it and the object at cord's length, and then, if the range is estimated to be under 3,000 yards, takes a side pace in the direction of the C picket (that is, to the right or left according as the base is to be to the right or left). The side pace so taken must be in length according to the estimated range, as follows, for a sub-base of 6 yards:—

| | |
|---|---|
| Estimated Range 1,000 yards .. | pace of 18 inches. |
| ,, 2,000 ,, .. | half pace of 9 inches. |

#### 2. Full Numbers with Equipment Incomplete.

(*a*) *B or C picket wanting.*—The A picket is planted as usual, and the remaining picket is used as a C picket; No. 2 marks the end of the sub-base by holding the shuttle at arm's length towards the A picket.

(*b*) *The A picket wanting.*—One of the remaining pickets must be placed for the A picket, and the other be used as a C picket. No. 2 must mark out the sub-base as in (*a*), but he will have to hook the cord to the leather ring of the flag, and must get the direction of the sub-base as described for No. 1 working alone. No. 1 will therefore be required, if the object admits of a doubt, to put No. 2 in position before leaving the A picket to fix the right angle.

(*c*) *Two pickets wanting.*—The one remaining picket is used in this case as an A picket.

No. 2 gives the base as in (*a*) or (*b*).

No. 1, if he cannot mark the right angle point with a sword or other substitute for a picket, proceeds as follows:—

Having fixed the right angle he finds the base as usual, and then summoning No. 2 to him causes him to stand in exactly the position he has himself occupied when fixing the right angle, and thus supply the place of a C picket while the range is being taken.*

(*d*) *The cord lost.*—Lay out the sub-base with the tape.

(*e*) *Cord and tape lost.*—Where the ground admits of it, the base is found at once by pacing; but if this cannot be done, a sub-base of any length from 6 to 12 yards is put out and measured by pacing, and this sub-base is set on the base bar.

The pacing should be done more than once, and the mean taken.

N.B.—*Much care is needed to obtain good results in the last two cases.*

3. Diminished Numbers with Equipment Incomplete.

The following is the only case for which special directions can be given:—

*No.* 1 *working alone with only two pickets.*

No. 1 plants one picket as an A picket (A, fig. 22); then having fixed the right angle C and planted the other picket as a C picket, he obtains the base A C thus:—Stretching the cord from the C picket in line with the object O he stands so that

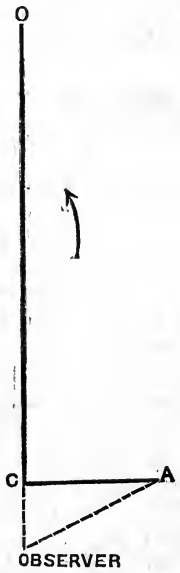


Fig. 22.

* A good way to make sure that No. 2 stands on the exact spot is for No. 1 to make a half turn on one foot so as to mark the ground, and for No. 2 to place his heel in the place thus marked.

his eye may be just the distance of the cord from the C picket, and in this position he reflects A picket upon the object by turning the cylinder (sliding collar set 6). This will give the base A C.

### Twelve-yard Sub-base.

*To lay out a* 12-*yard sub-base,* the three pickets are used and No. 1 superintends.

First, a six-yard sub-base is laid out in the usual way from the A picket; and the C picket is placed to mark the end of it.

Then a second length of 6 yards is laid out from the C picket in exact line with the A and C pickets, and the B picket is planted to mark the end of it.

The C picket is then taken away.

N.B.—No. 1, working alone, can not lay out a 12-yard sub-base unless he has three pickets.

# CHAPTER VIII.

## APPLICATION OF THE DRILL.

### SECTION I.—SERVICE RANGE-FINDING.

FOR ordinary artillery ranges taken from fairly favourable ground, no calculation whatever is required.

Actually the scales on the base bar and cylinder admit of finding ranges without calculation from 450 to 5,000 yards with bases from 60 to 130 yards, and sub-bases of either 6 or 12 yards; but though possible up to 5,000 yards, range-finding without calculation should generally be restricted to ranges under 3,500 yards.

The telescope should be used for distances of 3,000 yards or upwards.

TABLE FOR RANGE-FINDING WITHOUT CALCULATION, SHOWING APPROXIMATE LENGTH OF BASE DESIRABLE AND THE MAXIMUM TIME ADMISSIBLE FOR QUICK WORK ON FLAT GROUND.

| Range. | Base with sub-base 6 yards. | Time, counting from the moment the A picket is planted. |
|---|---|---|
| yards. | yards. | min. sec. |
| 500 to 1,000 | 60 | 2 0 |
| 1,500 | 75 | 2 15 |
| 2,000 to 2,500 | 100 | 3 0 |
| Beyond 2,500 | 120 to 130 | 3 30 to 4 30 |

### SECTION II.—EXCEPTIONAL RANGE-FINDING.

As before stated, there are certain cases in range-finding in which some simple calculation must be resorted to. These cases are—

1. When the only base available is under 60 yards.*
2. When the base is over 130 yards, either because a shorter base cannot be got, or because the range being very long a longer base than 130 yards is desirable for the sake of accuracy.

Calculation is also required in certain range-finding problems.

The principle which governs all cases of calculation is that the scales on the base bar and cylinder do not necessarily refer to yards, but will answer for any linear unit it is found convenient to work in, as for example metres.

It is usual to work in half yards, and double yards.

*Half yards* for bases under 60 and not less than 30 yards long, with ranges not exceeding 2,500.

* A base *under 60 yards* should never be taken, if one between 60 and 120 yards is available.

***Double yards*** for bases over 130 yards (120 in Mark III), with ranges not exceeding 10,000 yards.

*Working in half yards.*

For this the sub-base of 6 *yards* is treated as 12 half yards, and is accordingly set as *twelve* on the base bar.

The working is otherwise exactly as usual, but the range finally obtained is read in half yards, and must therefore be halved for the distance in yards.

Example—

Sub-base of 6 yards is set 12 on the base bar.
Base reads 700, and is set on the base bar.
Range reads 1,900 (half yards).

$$\frac{1,900}{2} = 950 \text{ yards.}$$

*Working in double yards.*

A sub-base of either 6 yards or 12 yards may be used.

(*a*) When the sub-base is 6 yards it is set 6, the base is read as usual in yards and divided by 2 to get it in double yards.

This base (in double yards) is then set on the base bar. The range finally is read in double yards, and must therefore be doubled for the distance in yards.

Example—

Sub-base, 6.
Base reads .. .. 160/0 yards.
Divide by 2 .. 80/0 double yards.
Sliding collar set to 8.
Range reads 2,300.
$2,300 \times 2 = 4,600$ = distance required in yards.

*The above case* (*a*) *is the only one in which a calculation is required before setting the base.*

(*b*) When the sub-base is 12 yards.

In this case the sub-base is treated as 6 double yards, and set accordingly at 6 on the base bar.

The rest of the working is as usual. The range finally obtained is read in double yards, and must be multiplied by 2 for the distance in yards.

Example—

Sub-base 12 yards is set 6 on the base bar.
Base reads 900 and is set 9 on the base bar.
Range reads 2,100 (double yards).
$2,100 \times 2 = 4,200$ yards.

TABLE FOR WORKING IN DOUBLE YARDS. SHOWING SUITABLE LENGTHS OF BASE AND SUB-BASE, AND APPROXIMATE TIME REQUIRED ON FLAT GROUND.

| Range. | Base. | Sub-base. | Time. |
|---|---|---|---|
| yards. | yards. | yards. | ′ ″ |
| 3,500 | 140 | 6 | 5 0 |
| 4,000 | 160 | 6 or 12 | 5 30 |
| 4,500 | 180 | 12 | |
| 5,000 | 200 | 12 | 6 0 |
| 6,000 to 8,000 | 240 | 12 | 7 0 |

The following is convenient to remember:—

Working in half yards halve the reading on the cylinder.

„ double „ double „ „ „

Hence the rule—

"Half—halve," "Double—double."

# CHAPTER IX.

## APPLICATION OF THE DRILL—CONTINUED.*

### SECTION I.—TO FIND THE RANGE BETWEEN TWO DISTANT VISIBLE POINTS.

THIS will enable the officer commanding a battery, before advancing to a new position, to obtain some of the ranges he will probably require on arriving there.

It will also be possible, by the assistance of a signalling party, to furnish batteries with their ranges from a central position of observation, if time permit, and circumstances render such a proceeding desirable.

Let A be the point of observation, P and Q the distant points (figs. 23 and 24).

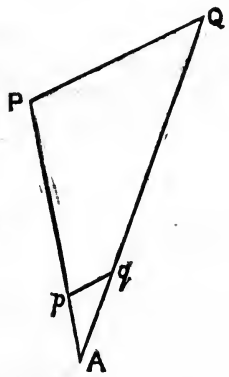


FIG. 23.

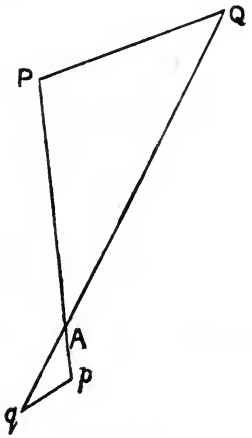


FIG. 24.

First take the two ranges A P, A Q, then lay out straight lines A $p$, A $q$, in the lines A P, A Q, respectively, either towards P and Q (fig. 23) or from them (fig. 24), making A $p$ a convenient proportion of A P, and A $q$ the same proportion of A Q.

Measure $p$ $q$ which will be the same proportional of P Q.

This will give the desired range P Q.

For example—

Let A P = 2,000 yards.
A Q = 2,500 yards.

$$\text{Make A } p = \frac{\text{A P}}{100} = 20 \text{ yards.}$$

$$\text{A } q = \frac{\text{A Q}}{100} = 25 \text{ yards.}$$

* To understand this chapter, a practical acquaintance with the instrument is necessary.

Measure $p$ $q$,—say it measures 21 yards.

$$21 \times 100 = 2{,}100 = \text{P Q}.$$

In practice, No. 1 should pace the line A $p$, and, having planted a picket at $p$ should pace the line A $q$ and then the line $p$ $q$.

Calculation may be avoided thus:—No. 1 when pacing A $p$, A $q$, will take *two* paces for every hundred yards, and then when pacing $p$ $q$ count a hundred yards for every second pace, and so obtain $p$ $q$ at once in hundreds of yards, an odd pace being 50 yards.

No. 2 should assist in keeping correct line. If No. 1 is pacing towards P or Q, No. 2 should stand behind the A picket and direct No. 1, when necessary, by the words "Right" or "Left" (meaning keep more to the right or left). If No. 1 is pacing away from P or Q, No. 2 should run out some little distance, and give No. 1 a point to advance on. If No. 2 is disabled, No. 1 must get the line by aid of the crosshead of the A picket.

To keep the exact line is very important. The length of pace is of no consequence provided it is uniform. For greater accuracy it is as well to pace the lines twice (once each way).

On no account should No. 1 pace one line and No. 2 the other. No two men pace alike.

## Section II.—To find the distance apart of two visible points situated near together.

This problem is chiefly useful for reconnaissance when it may be desired to know approximately the length of an enemy's shelter-trenches or the distances apart of their gun-pits.*

First take the range, which is assumed to be nearly the same for both points, and leave it on the cylinder; then set the instrument as for finding a base, and without disturbing the cylinder, move the sliding collar along the base bar until the right hand point is reflected on to the left hand one.

The reading so obtained on the base bar is the distance required; 6 on the bar being read as 60 yards, 7 as 70, and so on.

For lengths under 60 yards the working must be in half yards or quarter yards.

Greater lengths than 120 yards might be read off by working in double yards, but the problem is not to be depended upon for lengths over 120 yards because the ranges to the two points are in such cases likely to differ materially.†

* By holding the instrument vertically the height of buildings, &c., can be taken in this way also.

† The principles applied in the problem will be readily understood by any one well acquainted with the method of *finding a base* of which this is the exact converse, except that the scales are here read as for *a range and base*, instead of as for *a base and sub-base*.

SECTION III.—TO CORRECT THE ERROR IN RANGE RESULTING FROM HAVING SET A WRONG BASE ON THE BASE BAR.

Let the true base be B.
The base set by mistake *b*.
The resulting incorrect range R.
Then—

| False base. | | True base. | | False range. | | |
|---|---|---|---|---|---|---|
| *b* | : | B | :: | R | : | True range. |

$$\therefore \text{ True range} = \frac{B \times R}{b}$$

That is—Divide the false range by the false base, and multiply by the true base.

*From the above it will be seen how to get the longest range possible with any given base, under* 60 *yards.*

*For example, suppose the range to be nearly* 5,000 *yards and the longest base available to be* 58 *yards.*

*Set the base* 60 *and read the apparent range, say* 4,980.

$$\textit{The true range} = \frac{4{,}980 \times 58}{60} = 83 \times 58 = 4{,}814,$$

*a distance which could not have been measured in half yards.*

SECTION IV.—TO FIND THE APPROXIMATE TRUE RANGE WITH AN INSTRUMENT WHICH IS BELIEVED TO READ TOO SHORT OR TOO LONG.

First take the range with an actual base of any convenient length, then take it with an actual base of double that length.

Compare the two ranges. If they do not differ, it may be assumed that the reading is the true range, but if they do differ, take the difference between them, then if the reading with the longer base is the longer reading add the difference to it; if it is the shorter reading deduct the difference from it.

The result will be the true range.

The foregoing process is only true when the instrument is in fair order, other than in reading short or long. In particular the parallelism must be correct.

Example 1—
Base 90 yards—Reading 1,700.
Base 180 yards (set in double yards)—Reading 1,800.
Difference 100.
1,800 + 100 = 1,900 true range.

Example 2—
Base 64 yards—Reading 1,800.
Base 128 yards—Reading 1,700.
Difference 100.
1,700 − 100 = 1,600 true range.

**Rule to remember**—*The longer the base the truer the range.*

## CHAPTER X.

### Range-finding to Moving Objects.

The Watkin Field Range-finder is not generally suitable for the observation of moving objects, but by uniting the range-finding parties of two batteries, the ranges of captive balloons and of objects moving slowly, can be found with ease and rapidity, especially the men and guns of batteries in action, which though not stationary are in movement only within the limits of the position occupied.

### To Find the Range of a Moving Object.

Party.—Two certificated range-takers and one assistant.
Equipment.—Two Class I range-finders.
One metallic cord.
*N.B. Pickets are not required.*

*Duties.*

The officer in command having pointed out the object, No. 1 with his range-finder will take up a covenient position on the ground and will remain stationary.

No. 2 (the range-taker of the second battery), will run out with his range-finder a suitable base, and will roughly right-angle himself on the head of No. 1 and the object.

No. 3 (the assistant) will accompany No. 2, and as soon as the former has right-angled himself, will hold out the six-yard cord in line with No. 2 and the object, No. 2 holding the hook, and No. 3 the shuttle. The two men should close their hands and hold out the cord towards each other at arm's length.

Directly the cord is extended, No. 1 will read off the base in the usual manner, by reflecting the hand of No. 2 on to the hand of No. 1.

This done, he will hold up his hand as a signal, when No. 2 will drop his end of the cord (which No. 3 will wind up).

No. 1 will set the base he has read on the base bar, and by holding up both arms, give a signal to No. 2 that he is ready. The two (No. 1 and No. 2) will then simultaneously reflect each other on to the object, the point reflected by each being about 2 inches in front of the face of the other as seen when the range-finder is held up to the eye.

In this operation No. 1 must keep perfectly steady, merely turning the cylinder. No. 2 must move his body backwards or forwards to preserve the coincidence at right angles. If necessary he will take one or more full paces forward or back, keeping, however, carefully to his distance from No. 1.

Should the movement of the object under observation be so great that he is compelled to shift his ground considerably, he will (with No. 3) exhibit a fresh sub-base, on seeing which No. 1

will correct his heading of the base and the two will proceed as before.

A reading of the range should be taken every 30 seconds, and if the object is moving regularly in any given direction, the increase or decrease of the range per half minute should be noted, so that an allowance may be made at the battery in fuze and elevation.

No. 2 in working should stand invariably with the left leg forward and bent, and the right leg straight in rear. He must learn to move his body steadily and follow the movement of the object, taking a fresh pace when necessary.

### Instruction in Range-finding to Moving Objects.

Careful training is required. The first exercises should be with stationary objects, of ascertained distance, the ranges being found as if they were moving.

It is of assistance for the range-takers to wear white gloves or to wrap some white material round the hands. If No. 1 when reading keeps the thumb of his left hand just behind the rack knob of the instrument, it will be the proper point for No. 2 to reflect. Similarly if No. 2 puts the thumb of his right hand on to his range-finder just below the back of the rack knob (taking care not to impede the reflections), he will give a correct point to No. 1.

When the two numbers can take the range of stationary objects correctly, they should be exercised on a man or horse moving directly out or in, first at a walk, afterwards at a trot, and finally when they are thoroughly proficient in this, they should practice on men, horses, or wagons, crossing their front at various paces and distances, the hardest exercise of all being cavalry crossing the front at short ranges.

To test the accuracy of observation on objects moving in or out, range-finding cards, Plates III, IV, V, should be used. The moving party should be directed to keep an even pace and to pass certain fixed points, the distances to which are known only to the instructor. Readings should be called for at uneven intervals of time, and noted by dots in the proper squares. If the readings have been correct the line joining the dots on the card will be regular and the ranges will also be checked by the fixed points.

A reference to the Plates will show the use of the cards.

When testing the work of trained men in right-angling on the moving object, an excellent exercise is to cause a mounted man to walk or trot in a semi-circle marked out by pickets, at a distance known only to the instructor, and for the latter to act as No. 1, keeping the cylinder set at the true range. He will then see how far the No. 2 can follow the movements of the object.

## CHAPTER XI.

### To test a Watkin Range-finder without special appliances where there are no accurately measured test ranges.

The following tests should be applied by an efficient range-taker*:—

I. *General examination.*—See that the case has not been dented, that the works are neither rusty nor clogged with oil, and that none of the parts are broken or deficient. In particular, ascertain if the steel bar spring and base bar spring both work properly (this can be done by running out the cylinder, and then trying the resistance of each bar with the finger), and see that the rack knob can be moved backwards and forwards without a violent jerk, and is at the same time firm enough not to shift when the instrument is shaken.

II. *Adjustment.*—Put the instrument in adjustment, and see that it is not affected by shaking, or by the movement of the rack knob (see page 20).

III. *Parallelism.*—After adjustment push the sliding collar slowly along the base bar, and note if at any point the adjustment is thrown out. If this occurs it shows that the steel bar and base bar are not truly parallel when the cylinder is at zero. If the fault is at one point only, it indicates the evidence of a bend or dent, but if the alteration is gradual as the collar moves away from the point at which the adjustment was made, the fault is probably due to wear in the point of the collar or in the point of the cylinder screw.

IV. *Graduation.*—With a base of about 100 yards, take a range of about 2,000 yards. Then, without moving the pickets repeat the observation of the same range with the sliding collar set at every large division of the base bar in succession, and from the readings so obtained calculate the true range in each case (Chap. IX, Section III). The ranges when worked out should differ very slightly one from the other.

Assuming the parallelism to be correct, any error detected by this test must be attributed to defective graduation of the cylinder or base bar.

V. *Accuracy.*—Test the right angle as follows:—

Take a range of about 1,200 yards on flat ground: first with a base of about 60 yards, then from the same spot with a base of 90 yards, and again with a base of about 120 yards. Note the values obtained. Do the same with two or three other ranges, not exceeding 2,000 yards. If the values closely agree in each set, the right angle may be accepted as correct, but if there occurs in every set a progressive increase or diminution in the reading as the base is increased, it proves that the instrumental right angle is not a true one (see Chapter IX., Section IV).

* To test an instrument thoroughly is a day's work.

The readings must be repeated at every point several times, and the *average* reading only accepted. A fresh sub-base should be set out each time, and the base read again for every reading of the range.

*Condemnation of Instruments.*

No precise rule can be laid down as to the defects which render an instrument entirely unserviceable, but it is plain that a range-finder could be of little use if under Test IV, the variation in the average readings of ordinary ranges amounted to 50 yards or similarly if under Test V the difference in the readings with two bases, one double the other, were to average 50 yards.

For the limits of instrumental error usually allowed, see page 42.

## CHAPTER XII.

### Errors in Range-finding.

The errors made in range-finding are of two kinds—

1. Instrumental or index error, that is, error due to faults in the particular instrument used.
2. Personal error, that is, error due to inaccuracy of working on the part of the range-taker or his assistant.

No instrument can possibly be made absolutely perfect, and no observer, however skilful, can work without liability to a certain amount of inaccuracy.

It is therefore important to know what proportion of error is unavoidable, and what not.

#### *Instrumental Error.*

The total instrumental error may be approximately obtained by taking the mean of a number of observations of some accurately known ranges.

More than one series should be taken, however, before an opinion is hazarded. (See page 41.)

The error of a new instrument should not exceed 1 per cent. of the range when the base used is $\frac{1}{20}$th of the range, and the sub-base is about $\frac{1}{20}$th of the base.

The error of an instrument in use as part of a service equipment should not exceed 2 per cent. of the range under the above-named conditions. If it gets to be more than that, the instrument should be returned to store for repair.

Instructional instruments may be allowed a greater margin of error.

#### *Personal Error.*

Personal error is quite independent of instrumental error, and would be as great with an absolutely perfect as with an imperfect instrument. Personal error is commonly due to—

1. Inaccuracy in making coincidences.
2. Inaccuracy in laying out the sub-base.
3. Inaccuracy in holding the instrument exactly in the proper position over the picket when verifying an observation.

(1) *Inaccuracy in making coincidences.*

The power of the human eye is limited, and may be generally taken as incapable of appreciating a difference of less than one minute* of angle *with the naked eye*, or of about 30 seconds with the telescope belonging to the range-finder.†

* One minute of angle is the difference caused by observing one instead of the other edge of a tree one foot thick, at about 1,200 yards distance.

† Theoretically a greater accuracy than this is obtainable with the telescope, but in practice a portion of the advantage is lost.

The shorter the base is in proportion to the range, and the sub-base in proportion to the base, the greater is the error in the range caused by inaccuracy in making coincidences.

Hence it is very important always to take as long a base as possible.

(2) *Inaccuracy in laying out the sub-base.*

Every inch error in the 6-yard sub-base makes an error of $\frac{1}{216}$th of the range, that is to say, about half-a-yard per 100 yards of the range.

If the sub-base is laid out too short, then the range read is too long, and *vice versâ.*

The error in range caused by the sub-base being too short or too long is half as great with a 12-yard sub-base, as it is with one of 6 yards.

The error in laying out a 6-yard sub-base should never exceed 1 inch if the cord is properly measured.

If the sub-base is of the correct length, but laid out in a wrong direction, it will have the same effect as if it were of incorrect length, see fig. 25, where A B is the sub-base correctly

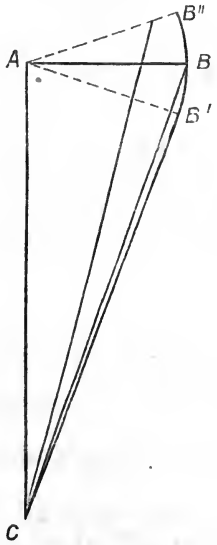


Fig. 25.

laid out, and A B′, A B′′ are the same lengths laid out in a wrong direction with regard to the base A C.*

(3) *Inaccuracy in holding the instrument over the picket.*

Any inaccuracy in the position of the instrument when

* It will be seen by the figure that an error in direction away from C is of greater consequence than towards it; also that the error of range is in both cases one of *excess.*

making a coincidence will cause the angles measured to be incorrect, and this error will be greater in proportion as the base is short, both absolutely and as compared with the range.

With a range of 1,000 yards and base of 100 yards the error caused by holding the instrument one inch too far forward or back at either the A or C picket would be about 2·8 yards; with the same base the error at 3,000 yards would be 24·8 yards; while with a base of 60 yards and a range 3,000 yards the error would be 67·9 yards.

A slight variation in the position of the instrument when *reading the base* is, however, of little consequence; hence it is not necessary to rest the instrument on the picket in this operation.

The limits of personal error which may be considered unavoidable are found by experience to be—

1 per cent. of the range.. For distances under 3,000 yards, taken without the telescope, with base about $\frac{1}{20}$th of the range.

1½ per cent. of the range.. For distances from 3,000 to 5,000 yards, taken with the telescope, the base being about $\frac{1}{30}$th of the range.

The *average* error of a good range-taker should not, however, exceed 1 per cent.

## Causes of Absolute Failures.

An error of 7 per cent. or more in a range may be considered an absolute failure, as contrasted with mere *inaccuracy*, however great.

The following are the most common causes of absolute failures:—

1. The instrument being very much out of adjustment or in a damaged condition.
2. The cylinder not being at zero when the right angle is taken.
3. The rack knob not being pushed home to Range or Base.
4. The cord being of wrong length.
5. A wrong base being set on the base bar.
6. The A picket being moved after the C picket has been placed (an awkward No. 2 will often do this in laying out the base).
7. The C picket being moved by No. 1 when reading the base, or by No. 2 when he has crossed over to it.
8. The eye being directed on different objects or different parts of the same object from the opposite ends of the base.

Of these the first seven occur only from want of training or gross carelessness, but there are cases where the object is so

ill-defined, as, for example, lines of shelter-trenches in certain lights, that even an experienced range-taker may find it difficult to be quite sure he is observing the same point from the A and C pickets respectively.

It sometimes happens also that a natural object, such as a tree or bush, appears to be in an entirely different position with regard to other objects when seen from different ends of a long base, so that a mistake may easily be made.

Thus from A (fig. 26), $a^3$ the middle of the five trees $a\,a\,a\,a\,a$, will seem the tree immediately on the left of the wood W, while from C the tree $a^5$ will appear to be the one in the position noted.

In hilly country, where the relative distances of objects are not easily recognised, the eye is readily deceived in this manner.

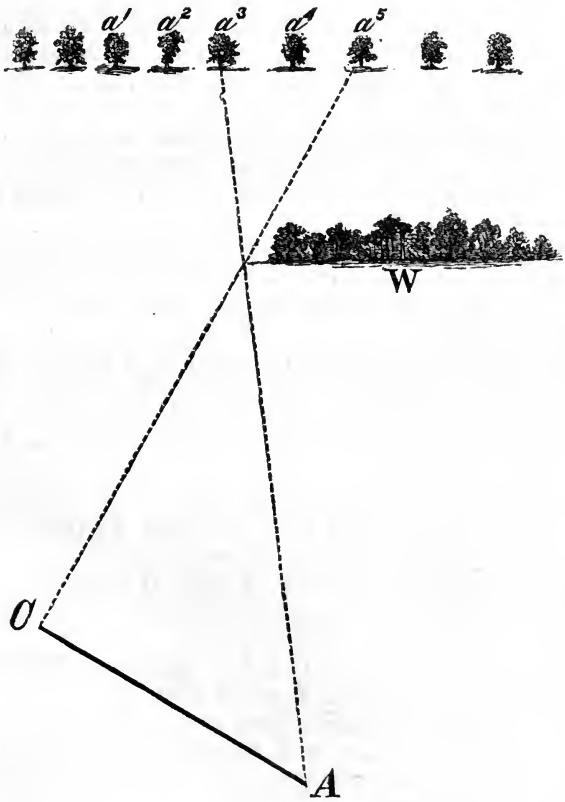


Fig. 26.

The only way to avoid such mistakes is to keep the object in view the whole time while running over the base, and if any doubt arises, to take the range twice over and compare results.

## CHAPTER XIII.

### Range-finding under Cover.

In the field it will be often necessary for range-takers, while at work, to keep themselves hidden from the enemy's view. This will be generally the case when they are sent on ahead to take ranges from or very near the ground which their batteries are going to occupy. To be able to do this it is necessary to constantly practice range-finding *under cover*, a mode of working which requires much experience, and cannot be learned mechanically.

The cover usually available is that of hedges, low walls, woods, and the slopes of open ground. Corn-fields, hop or vine plantations, and gorse scrub also afford good cover.

In every case the party on getting near the position must dismount and leave their horses where they will be safely hidden, and then advance with great caution, so that they may not be seen on their way to the ground on which they are going to work.

A hedge gives good cover when the pickets can be pushed close into it, so that objects in front can be seen through small openings, which, if not there already, can be easily cut without attracting attention.

A low wall will be similarly useful if it runs in the right direction, and the party are careful not to let their heads be seen as they move along it, only raising them above the top (*i.e.*, to the height of the picket) when halted and actually making an observation.

A wood may be utilized in two ways—

1. By working across the clearings, keeping men and pickets just inside the edges.
2. By working immediately in front of the trees.

The former is the best way of working for short ranges, the latter for longer ones.

At 1,500 yards and upwards it is extremely difficult to see men standing a yard or so in front of a wood.

Slopes of ground often afford excellent cover for range-finding, but it needs very well trained range-takers to make full use of them, as it is always a difficult matter to get cover at both ends of the base.

The more gradual the slopes are, either from the front or across the range, the better.

If the slopes are steep, and entire concealment is required, it is seldom possible to get a long base where the ground is quite open. In such cases, therefore, accuracy must be sacrificed to some extent.

When working on the reverse slope of a hill, it is important never to move straight from one end of the base to the other, but always to retire well under cover before crossing from picket to picket.

At 1,000 yards a man's head on the crest of a hill will never attract attention as long as it is not seen to move, but a moving object against the sky is noticed directly.

Range-finding under cover is a very useful exercise, apart from the question of the tactical advantages of entire concealment, because it teaches men how to avoid unnecessary exposure, and compels them to apply under difficulties every method of working they have before practised on easy ground.

## CHAPTER XIV.

### Duties of Range-takers.

The indispensable qualifications for the appointment of battery range-takers are good sight, good riding, and the possession of a certificate from the School of Range-Finding.

A non-commissioned officer apppointed range-taker should not, however, rest satisfied with his previous acquirements, but should lose no opportunity of improving himself in accuracy and rapidity of work, and especially in getting a quick eye to country. He should make himself a good judge of distance, and capable of giving a fair description of the country he has ridden over, and should constantly practice himself in selecting a position for a battery and in taking the ranges to the various points likely to be of importance as seen from the position itself or from neighbouring ground. He should frequently exercise himself and his assistant in taking ranges under cover, and in the applications of the drill given in Chapter IX.

On taking over an equipment he should carefully examine every article, and report any defect or deficiency to the officer commanding the battery. This examination should include the testing of the instruments. (See Chapter X.)

Having once taken over an equipment, the range-taker must remember that he is responsible for its condition, to which he should pay the greatest attention, noting particularly any deterioration in the instrument. For this purpose he should take a few *test ranges* every week, when in permanent quarters, from some convenient spot from which the same objects can always be seen. These ranges, together with the length of base used, he should keep a record of, and their comparison will show whether there is any change in the average reading of the instruments.

In a campaign, *test ranges* will seldom be available, but the instrument should be tested as often as possible by taking a range three or four times over with different lengths of base (see page 41).

On the march the instrument should never pass out of the range-taker's possession. In camp it should be in charge of the guard, or hung up in the commanding officer's office tent.

Next to the instrument, the article needing most attention is *the cord.* If in constant use, it will wear out quickly, and a new one will be required. Both cord and tape ought to be taken great care of; the former should be tested daily.

Practice *for accuracy of work* is absolutely necessary winter and summer. In two or three months without

practice, a range-taker will, as a rule, lose quite 1 per cent. of accuracy, and after six or eight months he will at first be unable to take ranges at all.

The best way of practising for accuracy is to select several points in line, or nearly so, which can be seen one from the other, and then to take the ranges from each of these points to all the other points. Each distance will thus be taken twice over, and the totals will check the work.

A battery range-taker must be prepared at any time to give elementary instruction in range-finding (see Appendix C, Section IV), and should always see that two or three non-commissioned officers or men in the battery are sufficiently trained to act as No. 2.

## CHAPTER XV.

### Hints to Range-takers.

1. Never be in a hurry. Better take the real range in six minutes than the wrong one in two. Quickness comes from practice, not from haste.

2. Do not gallop unless it is absolutely necessary to do so.

3. Never show yourself and horse against the sky.

4. Look carefully over the equipment before going out, and on coming in.

5. Test the cord once a day.

6. Wipe the range-finder before going out, and oil it slightly when you come in.

7. See that the range-finder is in adjustment before going out. If you suspect it when you get to the ground, examine it again. If you can get nothing better, adjust it on the legs of a tripod at about 200 yards distance.

8. Before you use the adjusting key, be quite sure it is needed.

9. As you hold the instrument to the eye, turn the adjusting key towards the lower image. Thus if you look at a pole and its lower half seems to be to the left of the upper half, turn the key towards your left shoulder.

10. The sub-base should be about a twentieth of the base, and the base should be about a twentieth of the range, unless you use the telescope. You may, however, work up to ranges of about thirty times the base, and get good results.

11. If you want a base over 160 yards, always have a sub-base of 12 yards.

12. Don't forget what you are working in—"yards," "double yards," or "half yards."

13. If your No. 2 does not do his work well, set out your base yourself.

14. Keep a little book and pencil for your calculations, but practice doing them in your head.

15. Taking ranges under cover on a hill-side, look at the ground well before you begin. Set one picket as far *forward* as it will go without exposure, and the other as far *back* as it will go, without losing sight of the object. If proper positions for the pickets cannot be found between these limits by moving one a little back, the other a little forward, you must try a different base.

16. On hilly ground you must take the best base you can, for you cannot always get one of the exact length you would like.

17. Remember you always take ranges to a *point*, therefore pick out one you are sure to know from both ends of your base.

18. Taking shelter-trenches, it is not safe to observe the apparent end on either side. You may see more of the trench when you move. The best way is to pick out a spot of ground darker or lighter than the rest, and observe that.

19. Taking woods, pick out a particular tree you will know by its shape or colour; don't trust to its being the left or right tree in the wood.

20. When you want the distance to the crest of a hill, and you select a tree for your object, *be sure you see the trunk*; otherwise you may find you have been observing the top of a high tree on *another hill across a ravine*, and so getting much too long a range.

21. In a high wind remove the flags.

22. When accompanying the battery, work on the flank or behind the line of limbers, never for choice between limbers and guns.

Don't forget to add or deduct the distance you are from the guns before reporting the *range*.

23. If you know that the instrument has a permanent error of so much per cent., short or long, do not forget to report the circumstance when giving in the *range*.

24. Remember that the exact permanent error per cent. is to be allowed for only when the base is $\frac{1}{20}$th of the range. Longer bases in proportion to the range give less error, and shorter bases more error.

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## CHAPTER XVI.

### THEORY OF THE INSTRUMENT.*

*The Mirrors.*

LET E be the eye looking through the unsilvered part of the horizon glass F at the object O. Let A be the picket, the reflection of which falls first on the index glass N at the angle $\beta$, and from it passes off at the angle $\beta'$, and falls upon the horizon glass (silvered portion) at the angle $\eta$, and from it again to the eye at the angle $\eta'$. Let $\theta$ be the angle at which the mirrors are to each other, and $\alpha$ the angle between the object and the picket.

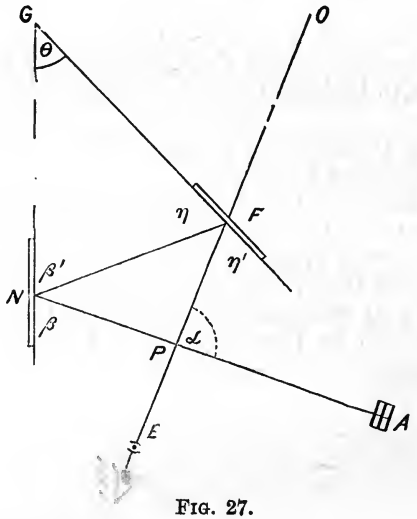



FIG. 27.

By the optical law—

Angle of incidence = angle of reflection.

$$\beta = \beta'$$
$$\eta = \eta'.$$

Now by Euclid the exterior angle = the two interior opposite angles.

Therefore—

$$\eta' + \text{P F N} = \theta + \beta' = \theta + \beta$$
$$\beta + \text{F N P} = \theta + \eta = \theta + \eta'.$$

Adding—

$$\beta + \eta' + \text{P F N} + \text{F N P} = 2\theta + \beta + \eta'.$$

That is—

$$\text{P F N} + \text{F N P} = 2\theta.$$

But—

$$\text{the angle } \alpha = \text{P F N} + \text{F N P}.$$

Therefore—

$$\alpha = 2\theta.$$

If then $\theta = 45°$, $\alpha = 90°$.

* See also Chapter III.

*The Range-finding Triangle.*

The conditions required for solving the range-finding triangle O A C are that we should know the base A C and the angle A O C, the angle A C O being always a right angle. But inasmuch as we are unable to get at the point O to measure the angle, we must find a line A D at right angles to A C, and measure the angle D A O, which is equal to the angle A O C. This is done in taking the range with the instrument.

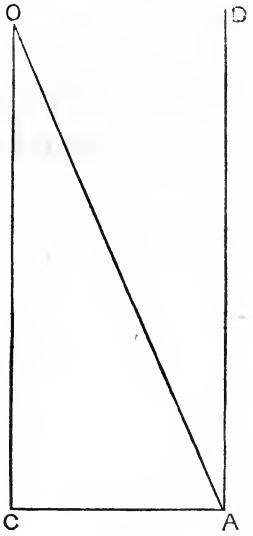





FIG. 28.

When the cylinder is set to zero (the mirrors being set at 45°) the picket C will be seen reflected in the direction D, at right angles to A C. On the cylinder being revolved the image moves to the left, and is brought to coincide with the object O. The inclination of the mirrors is a measure of the angle O A D, but, as explained in Chapter III, the position of the sliding collar alters the inclination of the mirrors, and, being set to the base, the cylinder gives the range due to that base.

*Measurement of the Base.*

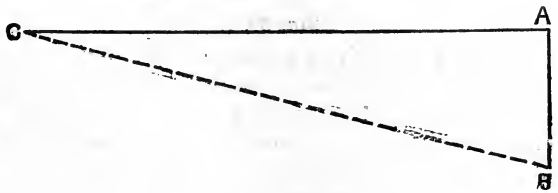



FIG. 29.

In measuring the base A C, Fig. 29, a small range-finding triangle, similar to O C A in the previous figures, is worked out. As we are, however, in this instance, at the station C, we can obtain the angle A C B, which A B subtends, by reflecting the picket B on

to A. If then the sliding collar be placed at the distance A B on the base scale, the cylinder will mark the distance A C. As A B is always 6 yards, the sliding collar is, for this operation, placed at the mark 6, representing 60 yards in the range-triangle. The results obtained are therefore ten times the true ones; thus the same scale on the cylinder does for both bases and ranges, if only in the former we divide by ten. It is advisable, however always to read this scale as for ranges, multiplying the base scale on the base bar by ten so as to avoid confusion. Thus a base of 110 yards would be read as 1,100 yards, and the sliding collar set to 11. If a tape of 10 yards were used, the same result for A C would be obtained by setting the sliding collar to the mark 10 before reflecting the image of B on to A.

*Object of the Sliding Collar.*

Suppose O an object, distant 1,000 yards, A C a base of 120 yards, and D C a base of 60 yards. The angle A O C will be double the angle D O C, and generally, if A C=$n$ D C, the angle A O C= $n$ times the angle D O C.

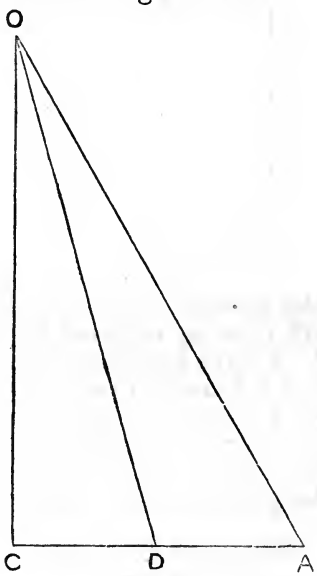



FIG. 30.

As there is only one given position of the cylinder and screw for any given range, some arrangement had to be devised by which the inclination of the mirrors might be altered, irrespective of the screw, so as to cause them to assume a greater inclination for a large base than for a small one.

This is arrived at by means of the arm W D (Plates I and II), with the sliding collar E bearing against the arm F G. As these two arms pivot at N and W, it is evident that the further the slide is away from W the greater will be the movement of the arm F G (and consequently of the mirror fixed to it), for any definite movement of the screw Y.

## Use of Instrument for Surveying, &c.

The following table of angles corresponding to ranges will be useful in taking angles between objects for surveying purposes :—

| Range. | Angle. | | Range. | Angle. | | Range. | Angle. | |
|---|---|---|---|---|---|---|---|---|
| yards. | deg. | min. | yards. | deg. | min. | yards. | deg. | min. |
| 5,000 | 1 | 9 | 2,100 | 2 | 44 | 1,200 | 4 | 45 |
| 4,500 | 1 | 16 | 2,000 | 2 | 52 | 1,150 | 4 | 58 |
| 4,000 | 1 | 26 | 1,950 | 2 | 56 | 1,100 | 5 | 11 |
| 3,500 | 1 | 39 | 1,900 | 3 | 1 | 1,050 | 5 | 27 |
| 3,400 | 1 | 41 | 1,850 | 3 | 6 | 1,000 | 5 | 43 |
| 3,300 | 1 | 44 | 1,800 | 3 | 11 | 950 | 6 | 1 |
| 3,200 | 1 | 47 | 1,750 | 3 | 16 | 900 | 6 | 20 |
| 3,100 | 1 | 51 | 1,700 | 3 | 22 | 850 | 6 | 42 |
| 3,000 | 1 | 55 | 1,650 | 3 | 29 | 800 | 7 | 7 |
| 2,900 | 1 | 59 | 1,600 | 3 | 35 | 750 | 7 | 35 |
| 2,800 | 2 | 3 | 1,550 | 3 | 42 | 700 | 8 | 8 |
| 2,700 | 2 | 7 | 1,500 | 3 | 49 | 650 | 8 | 45 |
| 2,600 | 2 | 12 | 1,450 | 3 | 57 | 600 | 9 | 28 |
| 2,500 | 2 | 18 | 1,400 | 4 | 5 | 550 | 10 | 18 |
| 2,400 | 2 | 23 | 1,350 | 4 | 15 | 500 | 11 | 19 |
| 2,300 | 2 | 29 | 1,300 | 4 | 24 | 450 | 12 | 32 |
| 2,200 | 2 | 36 | 1,250 | 4 | 35 | 400 | 14 | 2 |

The method of proceeding is as follows :—

Place the mirrors parallel, adjust the sliding collar to 10, look through the base eyehole and reflect the image of one object on to the other (as in taking the base) by turning the cylinder.

Note the range on the cylinder and take the corresponding angle from the table.

Thus, suppose the reading on the cylinder to be 1,000 yards the angle would be 5° 43′.

# PART III.—(PROVISIONAL).

## THE WATKIN FIELD TELEMETER.

### The Range-finding Equipment of a Battery.

The range-finding equipment of a battery of Horse or Field Artillery to which the field telemeter has been issued consists of:—

2 telemeters in leathern cases with telescopes complete.
2 leathern waist belts (as for the field range-finder).
1 steel tape, Mark II, in pocket (as for the field range-finder).
2 metallic cords, Mark III, in pocket (as for the field range-finder).
1 set of 3 tripod pickets with a linen flag each (as for the field range-finder).
4 leathern picket buckets, all small (as for the field range-finder).

An instrument is not issued specially for instruction.

### Patterns of Instruments.

There are two patterns, Mark I and Mark II, they are identical, except in material and weight.

Mark I is of gunmetal and weighs 3 lb. 13 ozs.

Mark II is partly of aluminium and weighs 2 lb. 15 oz.

### *The Instrument* (*see Plates VI to IX*).

The instrument is double reflecting like the field range-finder, the distant object being seen by direct vision, the near one by reflection. The parts are:—

The frame.
The cylinder.
The cylinder guide rod.
The cylinder band.
The compensating bar and spring.
The setting screw.
The screw guard.
The base bar, base bar spring and sliding collar.
The steel bar and spring.
The double index glass.
The horizon glass.
The right-angle pointer.
The right-angle and base eyehole with sliding shutter.
The range eyehole with sliding shutter.
The telescope.

*The Frame.*

The frame is fitted as in the Mark IV range-finder with a leathern bottom plate, having two recesses for the head of the picket corresponding to the range and right-angle eyeholes.

The frame is of hard gunmetal in the Mark I instrument and of aluminium in the Mark II.

It has on the cover the name and number of the instrument and the maker's name.

*The Cylinder, Cylinder Band, and Guide Rod.*

The cylinder consists of a metal barrel hollowed out and tapped to work on a screw guide rod. The cylinder has engraved upon it spirally a scale of ranges from 450 to 5,000 yards*; these are read by means of an arrow-head upon a fixed band which surrounds the barrel. The cylinder has a zero mark to show when it is fully screwed up.

*The Compensating Bar and Screw.*

The compensating bar and setting screw are on the right of the instrument: the bar is pushed forward by the screw in one direction and constrained by the bar spring to follow it in the other.

The screw which is just in rear of the cylinder is protected by a guard hinged to a metal frame.

The action of the compensating bar is to move the horizon glass within certain limits.

*The Steel Bar, the Base Bar and Sliding Collar.*

The above are for all purposes the same as in the field range-finder. The base bar is graduated to 140 (in some instruments to 145).

*The Double Index Glass.*

The index glasses which are entirely silvered are fixed in frames atright angles to one another at the pivot end of the steel bar.

*The Horizon Glass.*

The horizon glass is half silvered, and fixed in a metal frame in the compensating bar.

*The Right-angle Pointer.*

This is a metal pointer attached to the horizon glass. It travels over a brass plate, and when opposite a mark on the

* There are graduations on the cylinder beyond 5,000, but these are not to be depended on.

plate indicates the position of the horizon glass which gives the true right angle.*

*The Telescope.*

The telescope magnifies objects to about four times the natural size. It is focussed by screwing the eye-piece in and out. It is intended to be focussed once for all and carried ready for use in the pocket which is provided for it outside the leathern instrument case.

For use it fits into the eyeholes, the shutters being withdrawn.

*Tape and Cords.*

The tape and cords are the same as for the field range-finder. The cord shuttle is painted on both sides half black and half white.

*The Tripod Pickets.*

The tripod pickets are the same as for the Watkin Field Range-finder, but two only (the A and the B or C picket) are used in range-finding; the other is spare.

The flags should be painted on both sides, one side *black* with a white line, the other side *white* with a black line. The B and C pickets are exactly similar and interchangeable, as also their flags.

*The Picket Buckets.*

The set consists of four small buckets of the same pattern as for the field range-finder. The large buckets are not needed in the telemeter equipment as two pickets are never carried by one mounted man.

METHOD OF CARRYING THE EQUIPMENT BY A MOUNTED PARTY.

This is generally the same as for the field range-finder. The differences are:—

No. 1 and No, 2 both carry a telemeter and a metallic cord.
No. 1 carries the steel tape.
No. 1 and No. 2 each carry a picket.
No. 1 the right-angle picket (B or C)
No. 2 the range picket (A).
The spare picket is carried on a limber.

USE OF THE INSTRUMENT.

The physical conditions necessary in order to take a range with the telemeter are the same as for the range-finder (see Chapter III, Part II), but it is not necessary to make an exact right angle. A variation from the right angle is admissible to the extent caused by a movement forward (towards the object) or away from it of $\frac{1}{10}$ the base.† A deviation exceeding one

* Approximately only.
† Actually the setting screw allows considerably greater deviation.

or two paces, is, however, to be avoided, unless greater cover is thereby obtained, as it involves an error in range, this error increasing with the extent of the deviation and amounting to as much as $+1\frac{1}{2}$ per cent. at the extreme limits allowable, which are indicated by the travel of the right-angle pointer, and by the run of the setting screw.

As with the field range-finder, three things have to be done:

1. To fix the right angle (within certain limits of deviation).
2. To find the base.
3. To take the range.

*To fix the Right Angle.*

The cylinder must be set to zero, the right-angle pointer set as near as possible to right angle and the sliding collar to the stop on the base bar. The setting screw guard should be turned down. The observer using the right eyehole makes coincidence roughly and plants the right-angle picket (B or C) as for the field range-finder, then using the setting screw he completes the coincidence exactly (without moving the picket) and turns up the screw guard, which must not be touched again till the range has been found.*

*To find the Base.*

A sub-base having been marked by the assistant as in range-finding with the field range-finder (*Equipment incomplete, B picket wanting*), the observer makes coincidence between the reflection of the shuttle (which marks the end of the sub-base) and the object, by turning the cylinder, looking while so doing, through the right eyehole as before. The reading on the cylinder scale will be the base required.†

*To take the Range.*

The range is read through the left eyehole at the A picket in exactly the same way as with the field range-finder.

*Reading the Scales.*

The scales of the telemeter are read exactly as those of the field range-finder.

*Adjustments.*

The field telemeter requires no adjustment by the range-taker.

CARE OF INSTRUMENTS AND EQUIPMENTS.

The rules given in Chapter V, Part II, apply generally to the field telemeter.

* If the base bar has been bent, so that the parallelism is incorrect, it is well to readjust the right angle *after setting the base.*

† As usual in tenths of the unit in which the range is read.

## Position Drills.

The position drills are similar to, but much simpler, than those for the field range-finder.

### *Planting Pickets.*

The A (range) and C (right-angle) pickets are planted as described in Chapter VI, Part II, but the right-angle picket should be firmly driven at once as it has not got to be moved, the telemeter being adjusted to the picket, not *vice versâ* as in the case of the field range-finder.

The B picket is not used.

### *To lay out a 6-yard Sub-base.*

No. 2 turns the cross-head of the A picket on to the right-angle picket, and then looks over that line of the cross which is at right angles to the base, and takes up a line for the *sub-base.* He then—

1. Hooks the *S* of the cord to the button of the range picket.
2. Extends the cord in the correct line, paying it out carefully, and taking care not to disturb the picket.
3. Holds the shuttle upright at the level of the top of the picket and object under observation, keeping, however, the line taken up. (To do this he must sometimes raise the hand considerably, sometimes lower it.) The shuttle should be turned with the broad side towards the No. 1; that end uppermost the colour of which suits the background best.
4. On a signal from No. 1, No. 2 drops the shuttle, steps up to the picket, unhooks the cord and winds up.

### *Position of Hands.*

The position of the left hand is always as shown in Plate VII.

The right hand is applied to the cylinder or setting screw when required.

### *Positions of Body.*

The positions of body are the same as for the field range-finder.

## Service Drill.

The general detail is the same as for the field range-finder. No. 2, as well as No. 1, should, however, be a certificated range-taker.

No. 1 carries one instrument, one cord, one tape, and the right-angle picket.

No. 2 carries one instrument, one cord, and the range picket.

*Duties of No. 1.*

No. 1 finds the right angle roughly with the shutter open, and plants the right-angle picket securely. He then puts the telescope into the eyehole and completes coincidence by means of the setting screw. This done he turns up the screw guard, and runs the cylinder to what he thinks the base to be, and completes coincidence of base point and object, using the telescope, which he will not have needed to remove.

He will then cross to the A picket and take the range roughly, using the left eyehole with shutter open, then shift the telescope from right to left eyehole, and complete coincidence. The instrument must always rest with the picket head in the recess belonging to the eyehole in use.

*Duties of No. 2.*

No. 2, after giving the sub-base to No. 1, will cross to the right-angle picket.

As a rule he will take the range independently with his telemeter to confirm No. 1's reading, in which case No. 1 will give him a fresh sub-base.

If No. 2 does not repeat the taking of the range he will bring in the picket, but if he also takes the range, No. 1 will cross to the right-angle picket directly No. 2 has left it, and will bring it in on a sign that No. 2 has finished. On no account will No. 2 commence making his right angle till No. 1 has taken the range, and held up his hand to show that he has finished.

*12-yard Sub-base.*

This can only be laid out by joining the hook ends of the two cords, the officer or an extra man assisting by holding one shuttle to the head of the A picket.

## Application of the Drill.

*Service Range-finding.*

No calculation is required for ranges up to 5,000 yards, except when the ground is such that the only available base is under 60 yards or over 140 yards. The telescope must, however, be employed for all except short ranges.

When the range has to be taken in a different unit to yards (half or double yards) the mode of working is as given for the field range-finder (Part II, Chapter VIII, Section II.)

Table showing length of base required and time admissible on good ground with object well defined.

| Range. | Base. | Time. | |
|---|---|---|---|
| | | No. 1 only taking the range. | No. 1 and No. 2 taking the range with different instruments. |
| yds. | yds. | m. sec. | m. sec. |
| 500 to 1,500 | 70 | 2 0 | 3 0 |
| 2,000 to 2,500 | 100 | 2 30 | 4 0 |
| 3,000 to 4,000 | 110 to 130 | 3 15 | 5 0 |
| over 4,000 | 140 | 3 45 | 6 0 |

*To find the range between two distant visible points.*—The same as with the field range-finder. See Part II, Chapter IX.

*To correct the error resulting from having set a wrong base on the base bar.*—The same as with the field range-finder. See Part II, Chapter IX.

### Range-finding to Moving Objects.

A few minutes preparation is necessary to enable two telemeters to be worked together for a moving object on the principle explained in Part II, Chapter X.

For this reason, the method will be very seldom applicable except to finding the ranges of captive balloons.

For this purpose—

1. Both instruments must be set to the same right angle by actually making the same coincidence in reflecting one of the pickets on to a fixed object.
2. The base must be read by No. 2, No. 3 assisting No. 1 with the sub-base and No. 2 must send word to No. 1 what the length of base is.

The actual working in taking the range will be otherwise the same as with two field range-finders.

### *Testing a Telemeter.*

The easiest test of the telemeters in charge of Batteries will be a comparison between the readings of the two instruments.

The tests detailed in Part II, Chapter XI, generally apply, however, to the telemeter.

To test the parallelism, make a coincidence between picket and fixed object, as in fixing the right angle for range-finding;

then pass the sliding collar slowly along the base bar and notice if at any point the coincidence is altered. If it be altered the parallelism is proved faulty.

## Errors in Range-finding.

In addition to the causes of error enumerated in Chapter XII, pp. 44, 45, there is one which may occur with the telemeter but not with the field range-finder, namely, *error caused by laying out the base in a wrong direction up and down.*

This will have exactly the same effect as a similar error to right or left, and the resulting error of range will similarly be always one of *excess.*

The telemeter, as already stated, will read with a certain amount of error whenever the right angle is deviated from materially by using the setting screw over much.

The exact error in range, whichever way the deviation may be, will be that due to the difference between the base actually made and the base as it would have been had the right angle been adhered to. Thus, if a range be first taken with an exact right angle and base 100 yards, and then again the (approximate) right angle being made at a point either 20 yards forward or 20 yards back from the true position, then the new (incorrect) base will read 102, and the range will be 2 yards per 100 too long.

It will be seen from the above that the tendency of the errors likely to occur with the field telemeter are all in the direction of *excess*, hence a telemeter which reads 1 per cent. short is better than one which reads 1 per cent. long.

## Range-finding under Cover.

The field telemeter is particularly adapted for range-finding under cover, in consequence of the great choice of ground for the right-angle picket, given by the compensating horizon glass.

The rules given in Part II, Chapter XIII, generally apply to the field telemeter.

## Theory of the Instrument.

The general theory of the telemeter is the same as that of the field range-finder, see Part II, Chapter XVI.

The points of difference which require notice are:

1. The compensating action of the double index glasses.
2. The method of finding the base.

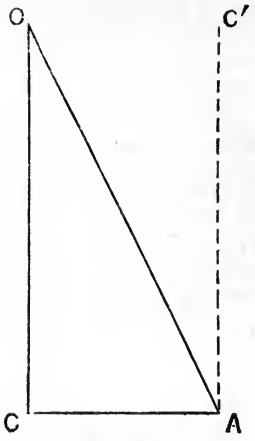



FIG. 31.

1. *The compensating action:* First consider the instrument as used when the right-angle pointer is set at zero. In this case both index glasses are at 45° to the horizon glass. Then if O be the object (fig. 31) and A C the base, and exact right angle, O C A is made by the use of the right eyehole, and (the cylinder being at zero) an exact right angle C A C′ is made by the use of the left eyehole, where C′ is the reflected image of the picket C.

Here the range A O, which is approximately equal to C O, is recorded by the instrument as A C, Cot A O C, and is therefore found correctly.

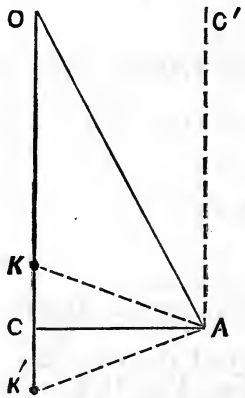



FIG. 32.

Next, suppose that for convenience the observer has left the exact right-angle position and advanced to K or retired to K′, Fig. 32, and has completed coincidence of A and O by use of the setting screw. The two index glasses are now no longer each at 45° to the horizon glass, but the increase in the angle on the one

side is exactly balanced by the decrease of the angle on the other, so that A O C remains unaltered. If, therefore, the true right angle base A C were set on the base bar, the range recorded by the instrument would be as before—A C Cot A O C. But instead of A C, the base set is A K or A K′, hence the range recorded is A K Cot A O C or A K′ Cot A O C, and the error introduced depends upon the difference between A K or A K′ and A C.

*Example.*—Let A C = 100 yards, Cot A O C = 10, then the true range, as recorded by telemeter, with pointer at zero, = A C Cot A O C = 100 × 10 = 1,000 yards; but if the C picket has been displaced to K or K′ and the setting screw made use of, then the range recorded will be A K Cot A O C or A K′ Cot A O C.

Let C K = C K′ = 10 yards, then A K = 100·5 yards ($\sqrt{\overline{AC}^2 + \overline{CK}^2}$), and the range recorded will be 1,005 yards, showing an error of ½ per cent.

N.B.—It will be noticed that the error caused by a deviation from the true right angle is always *plus*.

## Finding the Base.


Fig. 33.

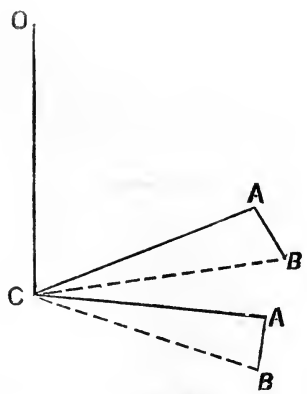



Fig. 34.



With the field range-finder, if A C is the base, Fig. 33, and A B the sub-base at right angles to A C, the base A C is measured from the point C by setting the horizon and index

glasses parallel and then moving the index glass (by turning the cylinder) until the reflection of B coincides with the image A seen directly. The base so read therefore = A B Cot A C B.

Now, with the telemeter, in order to measure A C from C (Fig. 34), the glasses are left in the position they occupied when forming the angle O C A (O being the object), until the cylinder is turned to bring the reflection of B upon O. This latter operation increases the angle A C O by the angle A C B, and, as before, the base is read = A B Cot A C B.

It is to be noted, however, that whereas in finding the base with the field range-finder, the triangle A C B may be in any plane, and therefore the sub-base A B at any angle to the vertical; with the telemeter it is necessary that A, B, C, O, be in one plane, hence the sub-base A B must be laid out so that the points B, A, O are all in one plane, otherwise the angle O C B will not be equal to O C A + A C B, but will be smaller, an error which will cause the base read to be greater than A C. This error, again, will always produce a plus error in the range found.

The above will explain the circumstance that the field telemeter, in the hands of beginners, almost invariably reads the range *too long*.

# PART IV.—APPENDICES.

## APPENDIX A.

## REGULATIONS IN FORCE 1ST SEPTEMBER, 1890, RELATING TO FIELD RANGE-FINDING IN THE ROYAL ARTILLERY.

N.B.—The Regulations reprinted in these Appendices were for the most part approved before the introduction of the field telemeter. They will, however, apply to range-finding with the telemeter until fresh regulations now in course of preparation are approved and promulgated.

### SECTION I.—SUPPLY OF WATKIN RANGE-FINDERS.*

The Watkin Field Range-finders in the service, of the large or Artillery pattern, will be classified as follows:—

*Class I.*—Mark IV instruments, which satisfy the standard conditions of accuracy, or can be made to do so by repair.

*Class II.*—Mark III instruments, or Mark IV disrated, which are retained for exercise and instruction.

A Watkin Range-finder, Class I, will be supplied, as part of their service equipment, to all horse and field batteries of the Royal Artillery.

All horse and field batteries will also be supplied for instructional purposes, with a Watkin Range-finder, Class II. These instructional instruments will not be taken by batteries proceeding on active service.

A battery proceeding to a foreign station (other than India) or on active service, will receive new range-finding equipment, the old equipment being returned to store.

The range-finders belonging to batteries at home will be inspected annually by the Instructor in Range-finding. The Instructor will communicate on this subject with the officers commanding batteries, who will send the instruments when required for inspection direct to him at Aldershot, except from Ireland, whence the instruments will be sent through the Senior Ordnance Store Officer in that country. The instruments will be returned in a similar manner to the battery if considered fit for service purposes.

Batteries serving abroad will put forward demands, as a rule, every two years, for the exchange of their range-finding equipment, for the purpose of being inspected by the Instructor in Range-finding. The old equipment will be sent home by the

* A.C., March, 1886, Clause 43.

local Ordnance Store Officer to the Commissary-General, Royal Arsenal, Woolwich.

A history sheet, in duplicate (one of which will be retained by the Instructor in Range-finding at Aldershot), will be supplied by the Ordnance Store Department with each instrument, filled in as far as possible before issue. The history sheets will subsequently be carried on to completion, as shown in the specimen form of history sheet. They will accompany the instruments to which they relate on all occasions of inspection or return to store.

# SPECIMEN FORM OF HISTORY SHEET.*

*Description*, Watkin Field Range-finder, large. *Number* 387. *Mark* IV. *Manufacturer*, Smith & Son.
*Inspection before acceptance.* *Date* 7.1.86. *Signature of Inspecting Officer*, * * *
Major, R.A.,
Instructor in Range-finding.

| Issues and Exchanges. | | | | Inspections. | | | | Repairs. | | Signature of Officer who makes the entry. |
|---|---|---|---|---|---|---|---|---|---|---|
| Date. | From | To | For | Date. | Occasion. | Remarks of Inspecting Officer. | Recommendation. | Date of completion. | By | |
| 4.2.86 | C.G.O. ... ... | A \| A, R.H.A.... | Service ... ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | ... | 6.12.86 | Annual ... ... | Good order ... ... ... ... | Service ... ... | ... | ... | |
| ... | ... | ... | ... | 5.1.87 | On report ... | Clip broken ... ... ... ... | Exchange for repairs | ... | ... | |
| 6.3.87 | A \| A, R.H.A.... | C.G.O. ... ... | Exchange ... ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | ... | ... | ... | ... | ... | 9.6.87 | Smith & Son ... | |
| ... | ... | ... | ... | 30.6.87 | After repair ... | Good order; 1 p.c. short ... ... | Service ... ... | ... | ... | |
| 5.8.87 | C.G.O. ... ... | 1 \| 4, R.A. ... | Service ... ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | ... | 5.11.88 | Annual ... ... | 2 p.c. short ... ... ... ... | Exchange for repairs | ... | ... | |
| 6.1.89 | 1 \| 4, R.A. ... | C.G.O. ... ... | Exchange ... ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | ... | ... | ... | ... | ... | 3.4.89 | Smith & Son ... | |
| ... | ... | ... | ... | 2.6.89 | After repair ... | Good order; about ¾ p.c. long ... | Service ... ... | ... | ... | |
| 7.10.90 | C.G.O. ... ... | K \| 2, R.A. ... | Service ... ... | ... | ... | ... | ... | ... | ... | |
| 6.6.1 | K \| 2, R.A. | C.G.O. ... ... | Exchange for embarkation for Cape | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | ... | 7.8.91 | On exchange ... | Good order ... ... ... ... | Service ... ... | ... | ... | |
| 10.9.91 | C.G.O. ... ... | S.O.S.O., Natal | Biennial exchange | ... | ... | ... | ... | ... | ... | |
| 4.2.92 | S.O.S.O. ... | M \| 1, R.A. ... | Service ... ... | ... | ... | ... | ... | ... | ... | |
| 6.1.94 | M \| 1, R.A. ... | S.O.S.O., Natal | Biennial | ... | ... | ... | ... | ... | ... | |
| 14.1.94 | S.O.S.O., Natal | C.G.O. ... ... | exchange | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | ... | 4.6.94 | Return to store | Much the worse for wear; right angle incorrect. | Repairs ... ... | ... | ... | |
| ... | ... | ... | ... | ... | ... | ... | ... | 3.7.94 | Smith & Son ... | |
| ... | ... | ... | ... | 16.8.94 | After repair ... | In fair order ... ... ... ... | Instruction ... | ... | ... | |
| 1.95 | C.G.O. ... ... | C \| B, R.H.A. ... | Instruction... ... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | ... | 1.11.95 | Annual ... ... | About 2 p.c. short ... ... ... | Instruction ... | ... | ... | |
| ... | ... | ... | ... | 2.12.96 | Annual ... ... | About 2½ p.c. short; parallelism imperfect. | Instruction ... | ... | ... | |
| 15.7.97 | C \| B, R.H.A. ... | G.O. ... ... | For special report... | ... | ... | ... | ... | ... | ... | |
| ... | ... | ... | ... | 8.8.97 | Special ... ... | Damaged by fall or blow ... ... | To be broken up... | ... | ... | |
| | | | | | | Struck off charge as | unserviceable and | past repair 1.12.97 | Authority 84/W/.... | |

Remaining entries will be made as follows:—
Issues to batteries, or to S.O.S.O. abroad, by C.G.O., also name of instrument-maker who executes repairs.
Returns to Store, by Officer returning the instrument.
Inspections by the Inspecting Officer.

* First line of heading will be filled in by C.G.O. Second line by Inspecting Officer.

An instrument when condemned, or sentenced to be repaired, or disrated to a lower class by the Instructor in Range-finding, will be returned to store for transmission to Woolwich. An instrument merely disrated may (if not required for instruction by the battery to which it belongs) be retained at Aldershot by the Senior Ordnance Store Officer, for issue to a battery there, for instructional purposes.

The Instructor in Range-finding will communicate direct with the Commissary-General of Ordnance, Royal Arsenal, Woolwich, whenever an instrument on battery charge is condemned, or sentenced to be repaired, or disrated.

When instruments on Ordnance Store charge require examination, the Instructor in Range-finding will receive an intimation from the Commissary-General of Ordnance, Royal Arsenal, Woolwich, with whom he will communicate as to the place and time of inspection.

When an instrument is returned to store, or sent to the Instructor in Range-finding for inspection, a report on its condition at the time will be made on a half-sheet of foolscap paper, signed by the officer commanding the battery and pinned to the history sheet. The report will consist of answers to questions in the following form:—

*Condition of Instrument, No.—, Mark—.*

Are the parts and fittings complete and in good order?
Is the right angle correct?
Is the horizontal adjustment easily upset by shaking?
Is the vertical adjustment correct?
Is the parallelism of the steel and base bars perfect?

The range-taker of the battery should be able to give information on these points.

*Addendum.**

With reference to Clause 43, A.C. 1886, the following order will regulate the course to be pursued by officers commanding with respect to the range-finding equipment of their batteries:—

1. When the Instructor in Range-finding notifies to a battery that he is prepared to receive the instruments for the annual inspection (which will take place, as a rule, during the winter months), the Officer Commanding will cause them to be slightly oiled, and then very carefully packed in their leather cases in a wooden box and forwarded to Aldershot. The box should be packed with tow, hay, or lumps of paper, allowing a slight play, so that if it should by accident be thrown down, the instruments may escape injury. If hay is used the instrument must be wrapped in paper, either inside or outside the leather cases. The box should be marked conspicuously "Glass, with care,"

* See Reg. Gen. Orders, March, 1886, No. 19.

and clearly shown on the cover the battery to which it belongs. Boxes should be closed by screws, not nailed down.

2. The Instructor in Range-finding should be informed by letter of dispatch of the instrument, and the history sheets should be forwarded to him at the same time, together with a statement of any deficiency noted, or any defects observed in the working of the instrument since the last inspection.

3. After the inspection is concluded the instruments will, if passed as satisfactory, be returned by the Instructor in Range-finding to the battery.

## Section II.—Range-finding in Batteries.*

All officers of Horse and Field Artillery are to make themselves thoroughly acquainted with the range-finding instruments, forming part of the equipment of their batteries, a detail of which will be found in *List of Changes in War Matériel*, para. 4571, November, 1884. (See also par. 4620—1884 and 4964—1886).

In every battery of Horse and Field Artillery one rank and file non-commissioned officer is to be appointed range-taker with extra duty pay at 6*d.* a-day, and one non-commissioned officer or gunner as assistant range-taker without extra pay. The range-taker's duties will include giving instruction when required.

The range-taker is to be appointed in the same manner as ordinary promotions are made in a battery, and, if he is at any time found to be inefficient, or not the best qualified non-commissioned officer for the appointment, serving in the battery, the officer commanding will take steps as follows:—

(*a*) If the range-taker has proved himself inefficient, he is to be removed from the appointment subject to the approval of the Lieutenant-Colonel Commanding the Division.

(*b*) If the commanding officer has reason to believe that the range-taker is not the best qualified non-commissioned officer for the appointment serving in the battery, a competitive examination in range-finding may be held, in accordance with the instructions for the classes at the School of Range-finding at Aldershot, hereafter detailed. Should the result of this examination show that the holder of the appointment possesses inferior qualifications, to any appreciable extent, to those of any other non-commissioned officer serving in the battery at the time, and holding a certificate from the school at Aldershot, the latter non-commissioned officer may, subject to the approval of the Lieutenant-Colonel

* See R. G. O., No. 14, 1885, paras. 1 to 14; also G. O. 138, Nov., 1886; and R. G. O. 108, Nov., 1887.

Commanding the Division, be appointed range-taker to the battery in place of the existing range-taker.

Except in cases of proved inefficiency as stated in (*a*), the range-taker of a battery is not to be removed from his appointment until he has held it for one year.

No non-commissioned officer is to be appointed range-taker to a battery at home who has not been through a course at Aldershot, and been reported qualified by the Instructor in Range-finding, but when batteries abroad have no qualified non-commissioned officer the position may be filled temporarily by any non-commissioned officer who can take ranges with not more than 5 per cent. of error, as proved by an examination in the presence of a Regimental Board, to be carried out in accordance with the instructions for preparatory classes hereafter detailed.

When the officer commanding a battery is unable to fill up the appointment from the rank and file non-commissioned officers under his command, he will report the vacancy through the Officer Commanding Royal Artillery in the District to Headquarters, stating in the case of batteries abroad whether a temporary appointment has been made or not.

In batteries abroad a non-commissioned officer who has been reduced to the ranks, or a serjeant, may, in the absence of any other qualified candidate, be employed as range-taker, but in the former case he will draw no extra-duty pay until he has been re-appointed a non-commissioned officer.

If the range-taker of a battery, returning from foreign service, has been temporarily appointed under the foregoing regulations, or under any special regulations in force in India, the officer commanding the battery is to report the fact without delay, in view to the range-taker being sent to join a class at the School of Range-finding at Aldershot, for a qualifying course of instruction and examination.

Non-commissioned officers who have qualified and are recommended for appointment as range-takers, are to be shown in the Monthly Qualification Return, Army Form B 92.

The range-taker and assistant range-taker will be exempt from such ordinary duties as will give them full time for practice. They are not to be appointed clerks, or employed in positions which interfere with their special duties as range-takers, unless they vacate the latter appointments for this purpose.

Besides practising by themselves they will be exercised once a fortnight, weather permitting, under the officers of the battery, who will note the results obtained (see Form I), and verify them by reference to the Ordnance Survey Maps, which have been issued to Districts for the purpose. A report that this has been done is to be rendered monthly to the Lieutenant-Colonel Commanding the Division. Officers commanding districts are responsible that these maps are returned to the District office before batteries leave their commands.

Range-finding is to be carried out, when practicable, at battery

drills, field days, manœuvres and route-marching, and invariably at battery practice, and may be usefully combined with judging distance.

Three or four of the horses in every battery should be trained so as to be accustomed to carry range-takers, as much time may be lost in mounting and dismounting, with the tripods, from unsteady horses.

Officers commanding batteries are held responsible that the instruments and range-finding equipment of their batteries are of correct pattern* and in working order. They should cause their range-takers to examine all new issues, and report to them before they are taken over.

The instruments should be in the immediate charge of the range-takers, and when not in use should be kept in a secure place. They are not to be handled by any unauthorized person nor used except in the presence of an officer or one of the range-takers.

A report on the range-finding of each battery will be made in the confidential report, Army Form B 224. The number of non-commissioned officers in each battery qualified to be range-takers is also to be shown.

* Whatever mark of range-finder may be in possession of a battery it is to be used on the occasions detailed, but officers commanding batteries are responsible that there is no delay in demanding the authorized service equipment if it has not been already supplied.

## FORM I.

Form of recording Ranges taken at Drill.

Place_____

Date_____

| Name of observer. | State of the weather. | Number and mark of instrument. | Object observed. | Observed range. | True range, stating how determined.* | Length of base. | Time. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

Signature of Officer, if present.

* In verifying by Ordnance Map, the scale on the map itself must be used, not a graduated ruler, because the paper is liable to stretch and shrink.

FORM II.

## RANGE-FINDING CERTIFICATE.

*

R. A.

Attended a course of instruction at the School of Range-finding, Aldershot, from to

and passed a† Examination,

obtaining a decimal of

He is qualified to act as Battery Range-taker with the Watkin Range-finder, and to instruct in the use of the instrument.

Instructor in Range-finding.

Date

Commanding R.A., Aldershot.

Date

* Regimental Number, Rank, Name, Battery, and Brigade.
† "Good," or "Very good."

## Section III.—Classes at the School of Range-finding, Aldershot.*

A School of Range-finding having been established at Aldershot the system of drill and instruction in field range-finding throughout the regiment will be in strict accordance with that authorized there.

There will be occasional classes for officers as well as for non-commissioned officers.

Non-commissioned officers selected for the classes at Aldershot must be under the rank of serjeant, and be certified by their respective commanding officers to be good riders, and not shortsighted. They should, if possible, have gone through a preparatory course of instruction, as hereafter detailed. Preference should be given to any who have learned signalling.

The course for non-commissioned officers will last about eight weeks. An examination will be held at the end of the course, and certificates (see Form II) awarded to those who pass, according to the credits assigned, by the Instructor in Range-finding.

The following are the regulations for examination of classes of non-commissioned officers:—

(*a*) The examination will be divided into three sections, A, B, and C, and 100 marks will be given as full credits, viz.:—

Section A, 40 marks } Range-finding without calculation.

Section B, 40 marks } Range-finding where calculation is necessary.

Section C, 20 marks { General knowledge of the subject, and capacity for teaching it. Examination of the instrument.

(*b*) In Sections A and B the examination will consist of two ranges in each (four in all), taken independently by each member of the class, one range in each section being that of a natural object such as a tree or bush.

The mean of ranges taken by the Instructor and Assistant Instructors, verified when possible by the Ordnance Map, will be deemed to be the true range in every case.

The table (Form III) shows how the marks are to be allotted.

(*c*) In Section C the credits will be given as follows:—

10 marks by the Instructor from the experience he has of each man's capabilities.

10 marks for replies to *vivâ voce* questions at the examination.

(*d*) To obtain a certificate a total of 75 marks must be obtained. A total of 75 marks and over will be recorded as "good," 90 marks and over as "very good."

* R.G.O., No. 14, 1885. Paragraphs 15 to 19.

# FORM III.

## Table showing Method of giving Marks at Examinations for Range-takers' Certificates.

| | Range about | Base not less than | Time allowed. | Marks per range. | Deduction of Marks for overtime. | Deduction of Marks for inaccuracy either over or under true range.† | | | | | | | | | | | | | | | | | | | Remarks and Directions. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Nil. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | |
| | yds. | yds. | min. sec. | | | | | | | | | | | | | | | | | | | | | | |
| Section A, Marks 40. No calculation. | 1,000 | 60 | 2 | 20 | 1 Mark for every 15 seconds or fraction of 15 seconds overtime. | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 | 110 | 1. The sub-base will be laid out under the superintendence of the examiner. |
| | 1,500 | 70 | 2 15 | | | 15 | 22 | 30 | 37 | 45 | 52 | 60 | 67 | 75 | 82 | 90 | 97 | 105 | 112 | 120 | 127 | 135 | 142 | 150 | 157 | 165 | |
| | 2,000 | 80 | 2 30 | | | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 | 210 | 220 | |
| | 2,500 | 90 | 2 45 | | | 25 | 37 | 50 | 62 | 75 | 87 | 100 | 112 | 125 | 137 | 150 | 162 | 175 | 187 | 200 | 212 | 225 | 237 | 250 | 262 | 275 | |
| | 3,000 | 100 | 3 0 | | | 30 | 45 | 60 | 75 | 90 | 105 | 120 | 135 | 150 | 165 | 180 | 195 | 210 | 225 | 240 | 255 | 270 | 285 | 300 | 315 | 330 | |
| | 3,500 | 110 | 3 30 | | | 35 | 52 | 70 | 87 | 105 | 122 | 140 | 157 | 175 | 192 | 210 | 227 | 245 | 262 | 280 | 297 | 315 | 332 | 350 | 367 | 385 | 2. The time allowed and the approximate length of base required will be stated before the words "Take the range." |
| Section B, Marks 40. Calculation necessary. | 1,000 | not more than 40 | 2 0 | 20 | 1 Mark for every 30 seconds or fraction of 30 seconds overtime. | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 | 110 | |
| | 4,000* | not less than 160 | 5 30 | | | 40 | 60 | 80 | 100 | 120 | 140 | 160 | 180 | 200 | 220 | 240 | 260 | 280 | 300 | 320 | 340 | 360 | 380 | 400 | 420 | 440 | |
| | 4,500* | 180 | | | | 45 | 67 | 90 | 112 | 135 | 157 | 180 | 202 | 225 | 247 | 270 | 292 | 315 | 337 | 360 | 382 | 405 | 427 | 450 | 472 | 495 | |
| | 5,000* | 200 | 6 0 | | | 50 | 75 | 100 | 125 | 150 | 175 | 200 | 225 | 250 | 275 | 300 | 325 | 350 | 375 | 400 | 425 | 450 | 475 | 500 | 525 | 550 | |
| | 5,500* | 220 | 6 30 | | | 55 | 82 | 110 | 137 | 165 | 192 | 220 | 247 | 275 | 302 | 330 | 357 | 385 | 412 | 440 | 467 | 495 | 522 | 550 | 577 | 605 | |
| | 6,000* | 240 | 7 0 | | | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 330 | 360 | 390 | 420 | 450 | 480 | 510 | 540 | 570 | 600 | 630 | 660 | |
| Section . Marks 20. | | | | | | | | | | | | | | | | | | | | | | | | | |

* Using telescope.

† The figures in the heading show the marks to be deducted corresponding to the error in yards given in the columns below.

## Section IV.—Preparatory Classes.*

At all stations where there are range-takers available to give instruction, classes will be occasionally formed for elementary range-finding. They should be conducted so as to interfere as little as possible with the ordinary routine of duty, and should be assembled in mild weather only.

These classes are for the purpose of testing the capabilities of non-commissioned officers intended to be sent to the classes at Aldershot, and are intended as a preparation for more advanced instruction.

The number under one instructor should not exceed six.

About 12 attendances of three hours each will be sufficient, and they may be spread for convenience over six or eight weeks.

The whole of the instruction should be given out of doors, and be strictly confined to drill and practice in taking ranges up to 2,000 yards without calculation.

The adjustment of instruments will not form part of the course.

A record of each day's work will be kept, and any ranges taken will be noted in Form I. (See page 74.)

At the end of the course an examination will be held under an officer. It should be conducted according to the general rules laid down for the examination of classes at Aldershot (Form III, Section A),† but five ranges should be taken instead of two—20 marks being allowed for each. The ranges should not much exceed 1,500 yards. The objects should be well-defined, and the time allowed should be double that given in Form III.

Seventy-five marks (·75) should be obtained at these examinations as a general rule to qualify candidates for joining an Aldershot class.

At the examinations held abroad under paragraph 4, for the temporary appointment of range-taker, the rules laid down in paragraph 27 are to be observed, and 5 per cent. of error or a total of 60 marks (·6) will qualify for the appointment.

Range-finders forming part of the service equipment of batteries are never to be used for instruction, but instruments, Class II, are to be specially demanded for that purpose.

## Section V.

For the regulations relating to examination of officers in range-finding before promotion see orders issued with Army Orders, 1st March, 1889.

* R.G.O., No. 14, 1885, paragraphs 20 to 30.
† This refers to the Section of the Examination.

## APPENDIX B.

### Outline of a Course of Instruction for Preparatory Classes.

*Assembled in accordance with Regimental General Order* 14, 1885, *paragraphs* 20 *to* 30. (*See* Appendix C, Section III.)

The following is intended as a general guide only; Instructors must vary the detail according to the progress of the class.

1st attendance:—

(1) Instructor having put out a sub-base of 6 yards will exercise the class in *finding a base* of about 60 yards, first with shutter open, afterwards with shutter closed. They will at the same time learn how to read the cylinder.

(2) Those not occupied in the above, will be employed in ascertaining by trial, several times over, how many of their paces at the double go to 100 yards, also in learning to pace yards at *the quick march.*

2nd attendance:—

(1) Each man will be taught in succession *to lay a* 6-*yard sub-base* with reference to a C picket placed by the Instructor, and will afterwards learn how *to plant a C picket.*

(2) Those not occupied in the above, will be employed in *finding a base* set out by the Instructor with the sliding collar at a different point from the correct one. One of them will take down the readings in a note-book, and the Instructor will afterwards turn the readings into yards, and see what accuracy each man has attained to, the same instrument being used throughout.

3rd attendance:—

(1) Instructor having put out a C picket, and set the base himself, will exercise the class in taking an easy range (about 800 yards), first with shutters open, afterwards closed.

(2) Those not employed in the above will practice *picket drill.*

4th attendance:—

(1) First part of last lesson will be repeated with a longer range (shutter closed), and class will also be taught how to *fix a right angle,* and will each in succession do so, and plant a C picket with reference to an A

picket placed in position by the Instructor. The Instructor will follow each, and make those who fail repeat their observations.

(2) Those not employed as above will be exercised by taking a range, A and C pickets being placed by the Instructor, and an untrue base given to be set on the base bar. One of the class will write down the readings, and the Instructor, who knows the real base, will afterwards turn these readings into yards, and judge of each man's work.

5th attendance:—

The class being told off in squads of two will be taught how to take an easy range in slow time, the Instructor following each one's work.

6th attendance:—

Repeat yesterday's lesson in quicker time, with a range of about 1,200 yards.

7th, 8th, and 9th attendances:—

Range-finding with and without telescope on easy ground. Distances up to 2,000 yards. Bases 60 to 110 yards. No calculations.

10th, 11th, and 12th attendances:—

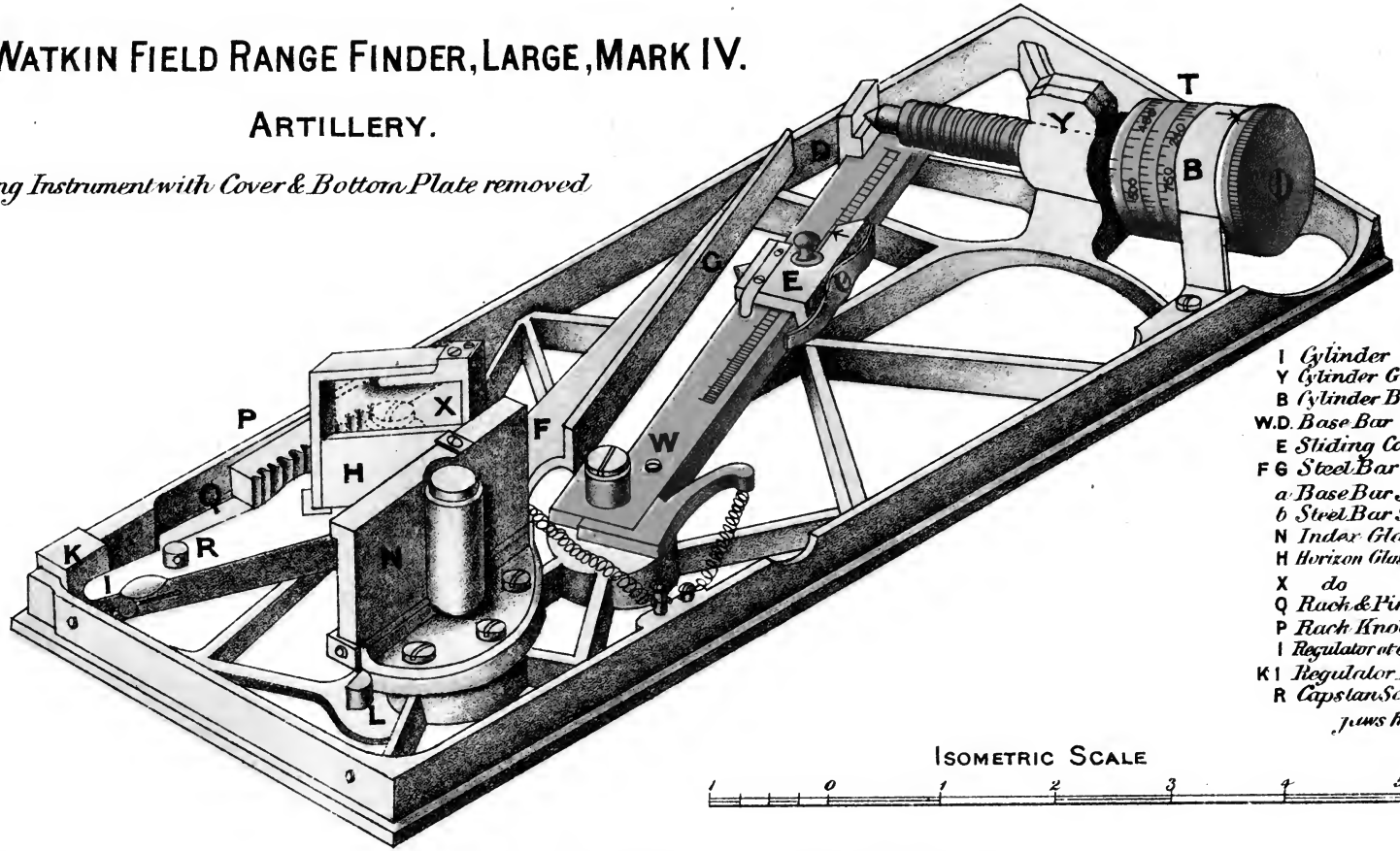
Range-finding on difficult ground, including steep slopes. Distances up to 3,000 yards. Bases 60 to 120 yards. No calculations.

The class *to measure cords every day* before beginning work. The Instructor must pay great attention to the positions of the hands at drill, and to the accuracy of the work, on no account insisting on quickness at the expense of accuracy.

# WATKIN FIELD RANGE FINDER, LARGE, MARK IV.

## ARTILLERY.

*Showing Instrument with Cover & Bottom Plate removed*




I *Cylinder*
Y *Cylinder Guide Collar*
B *Cylinder Band*
W.D. *Base Bar*
E *Sliding Collar*
F G *Steel Bar*
a *Base Bar Spring*
b *Steel Bar Spring*
N *Index Glass*
H *Horizon Glass Silvered Part*
X *do Open Part*
Q *Rack & Pinion*
P *Rack Knob*
I *Regulator at end of Short Arm*
K I *Regulator Blocks*
R *Capstan Screw to tighten jaws holding regulator*

ISOMETRIC SCALE

1 0 1 2 3 4 5 Inches

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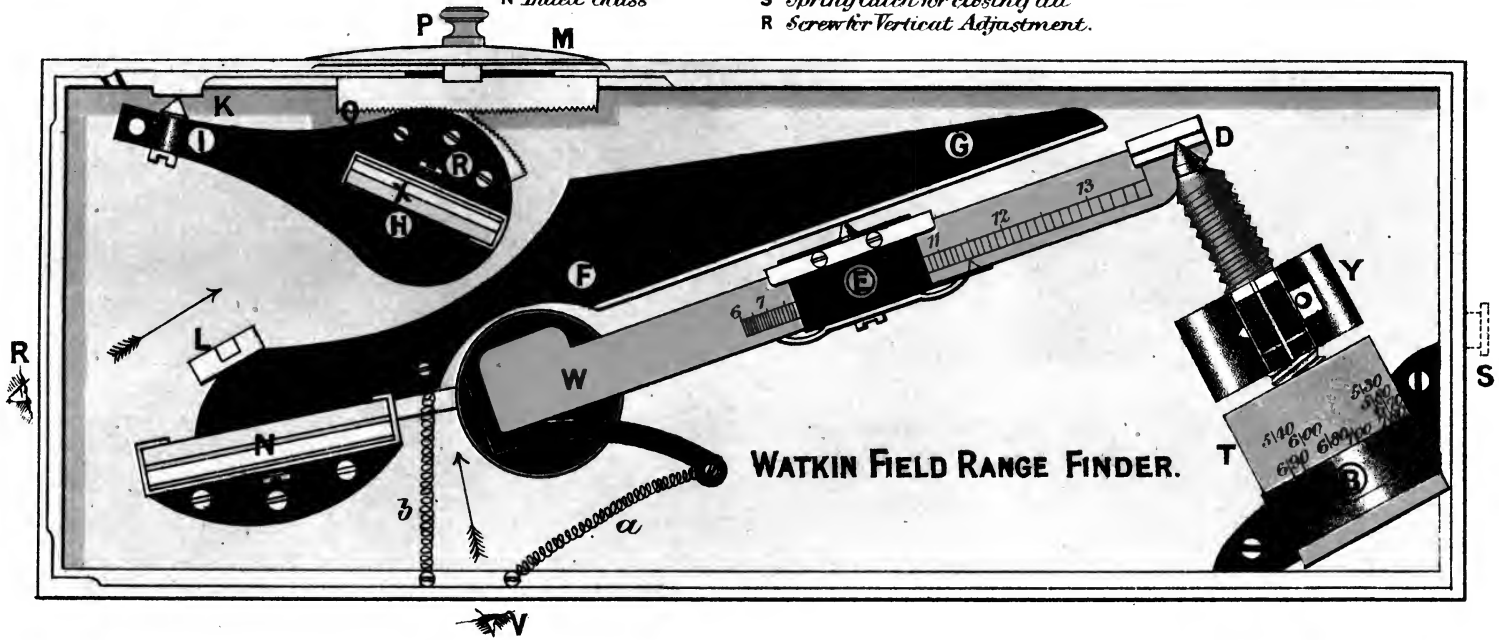
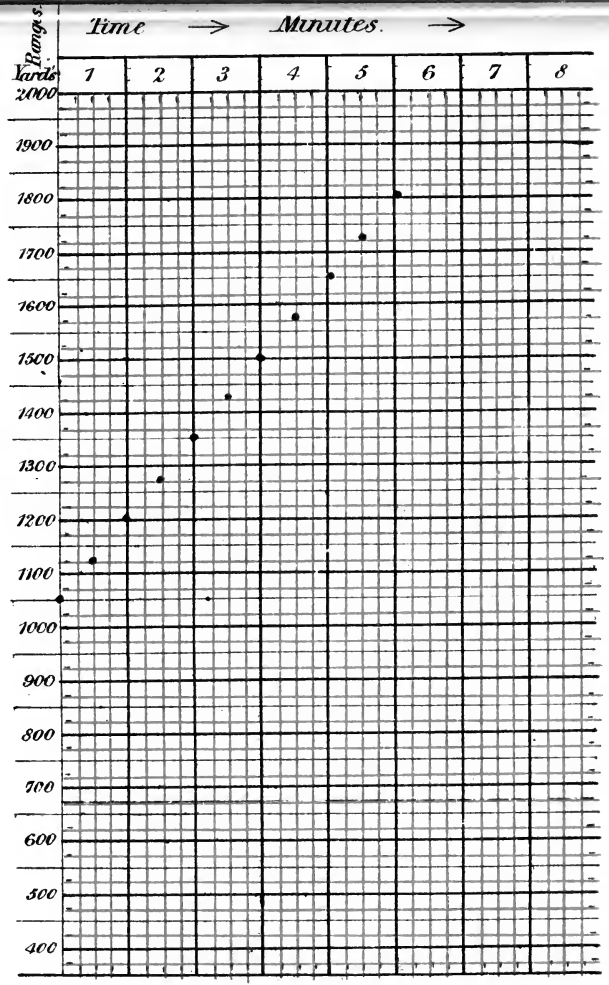
T Glinder
V Glinder Guide Collar
B Glinder Band
W.D Base Bar
E Sliding Collar
F.G Steel Bar
a Base Bar Spring
b Steel Bar Spring
N Index Glass
X. Horizon Glass
Q. Rack & Pinion
P. Rack Knob
M. Spring Slide
I. Regulator at end of short arm H
K.L Regulator Blocks
R End Eye hole (Range Right Angle)
V Side Eye hole (Base)
S Spring Catch for closing lid
R Screw for Vertical Adjustment.




*Plan of upper side of Instrument; lid and cover removed.*

Judd & Co Ltd Lith. 73 & 75. Farringdon Rd & Doctors' Commons 2011.1/91.



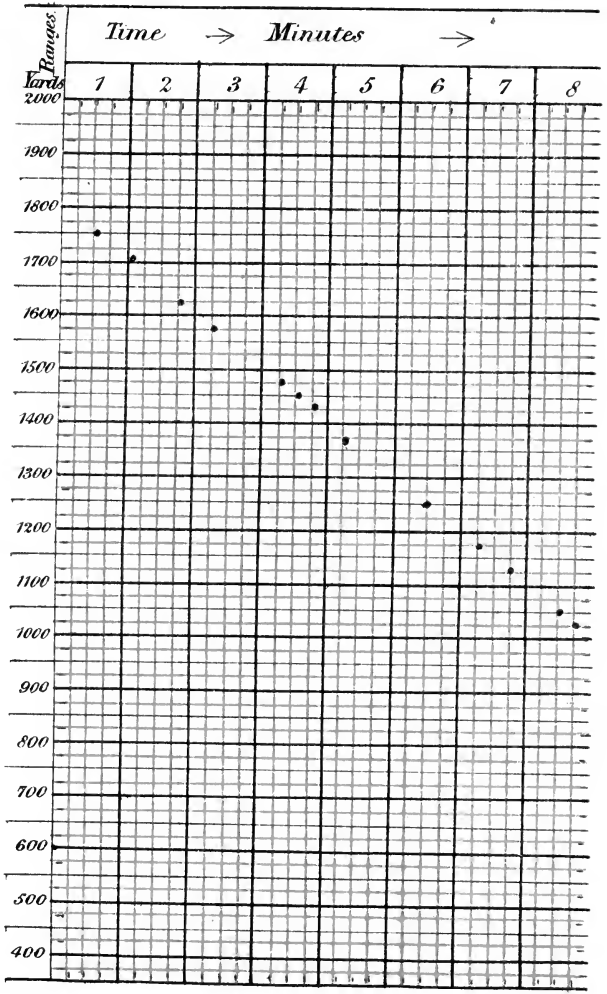

*Range Card showing half minute readings on an object moving out at the rate of 150 yards per minute from 1050 yards to 1800 yards. Time 5 minutes.*

*From such a track it would be noted that in 2 minutes time the object would be at a range of 2000 yards*

*N.B. For distances between 2000 and 3000 yds. count the first 1000 on the card as 2000 and so on.*

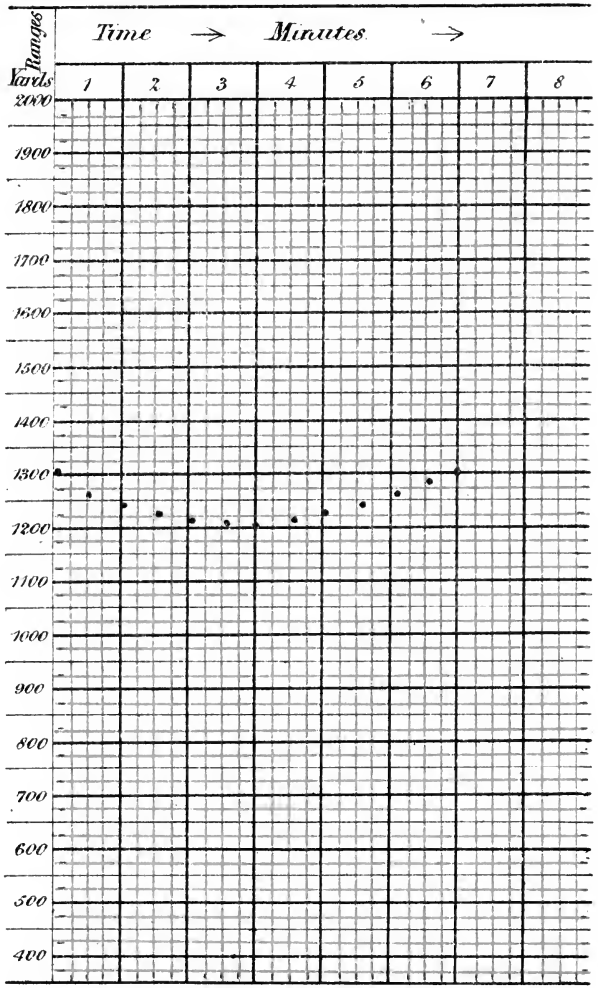
*For distances between 3000 and 4000 yds. similarly count the first 1000 on the card as 3000.*

Judd & Co Ltd Lith 73 & 75, Farringdon Rd & Doctors Commons 3611.1/31.

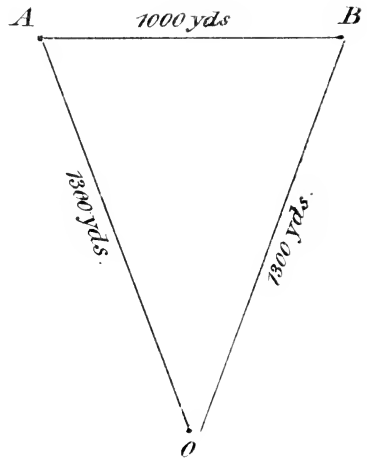



*Range Card showing readings at various intervals of time on an object coming in at the rate of 100 yards a minute from 1800 to 1000 yards.*
*Time 8 minutes.*

Judd & Co Ltd Lith. 73 & 75, Farringdon Rd & Doctors Commons 2611.1/21.



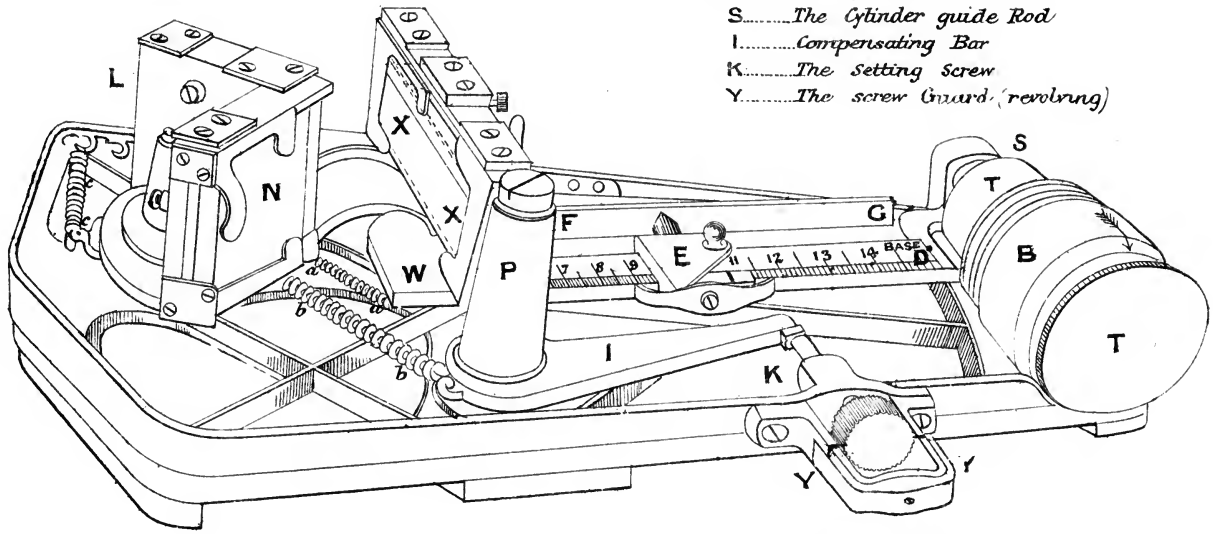

*Range Card showing approximate half minute readings on an object directly crossing the front on the line A B as seen from 0*
*Time occupied 6 minutes.*




Lith. 73 & 75 Farringdon Rd & Doctors Commons

# FIELD TELEMETER. PERSPECTIVE VIEW. *(Cover removed.)*

T.T.....*The Cylinder.*
B.....*The Cylinder Band*
S.....*The Cylinder guide Rod*
I.....*Compensating Bar*
K.....*The Setting Screw*
Y.....*The screw Guard (revolving)*




W.D.....*The base bar.*
E.....*The sliding collar*
F.G.....*The steel bar*
X.X.....*The horizon glass*
L.N.....*The index glasses*

*a.a.....Base bar spring.*
*b.b.....Compensating bar springs.*
*c.c.....Steel bar spring.*

*Scale about ⅔ full size.*

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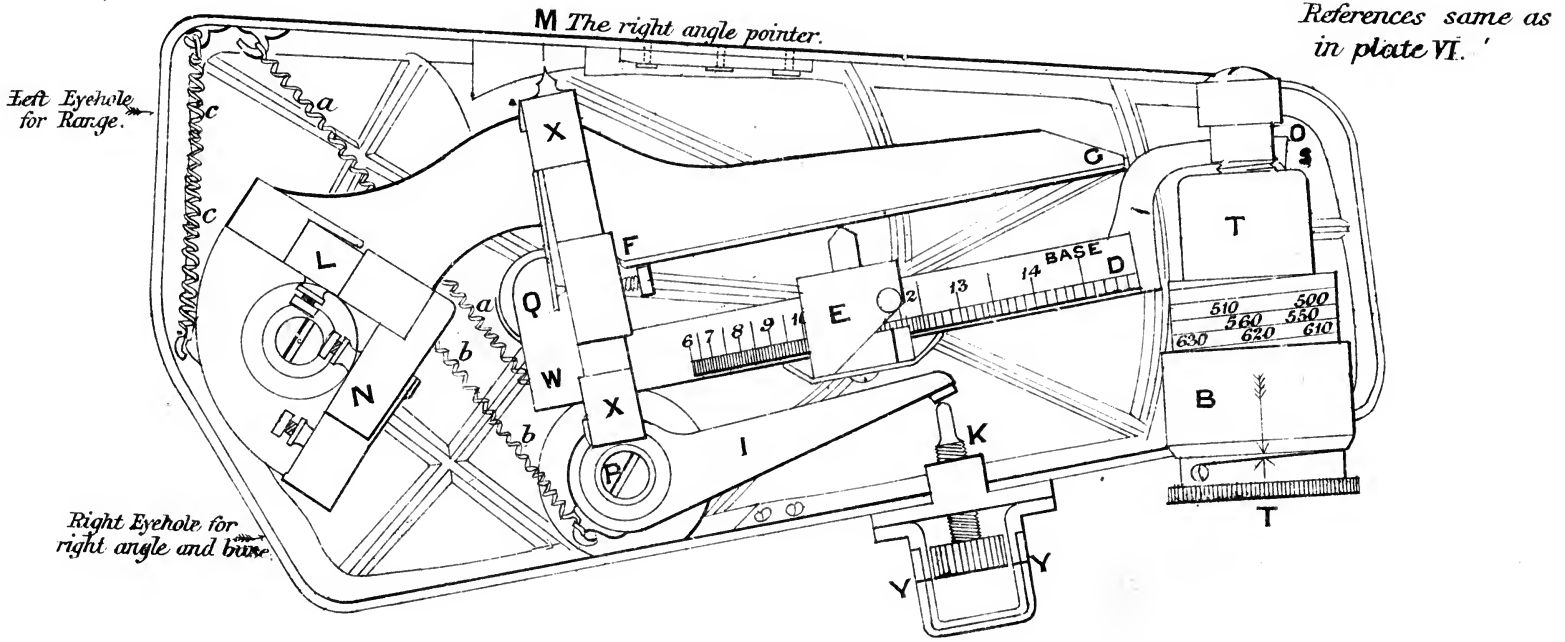
# FIELD TELEMETER PLAN. *( Cover removed.)*




*Scale about ⅔ full size.*

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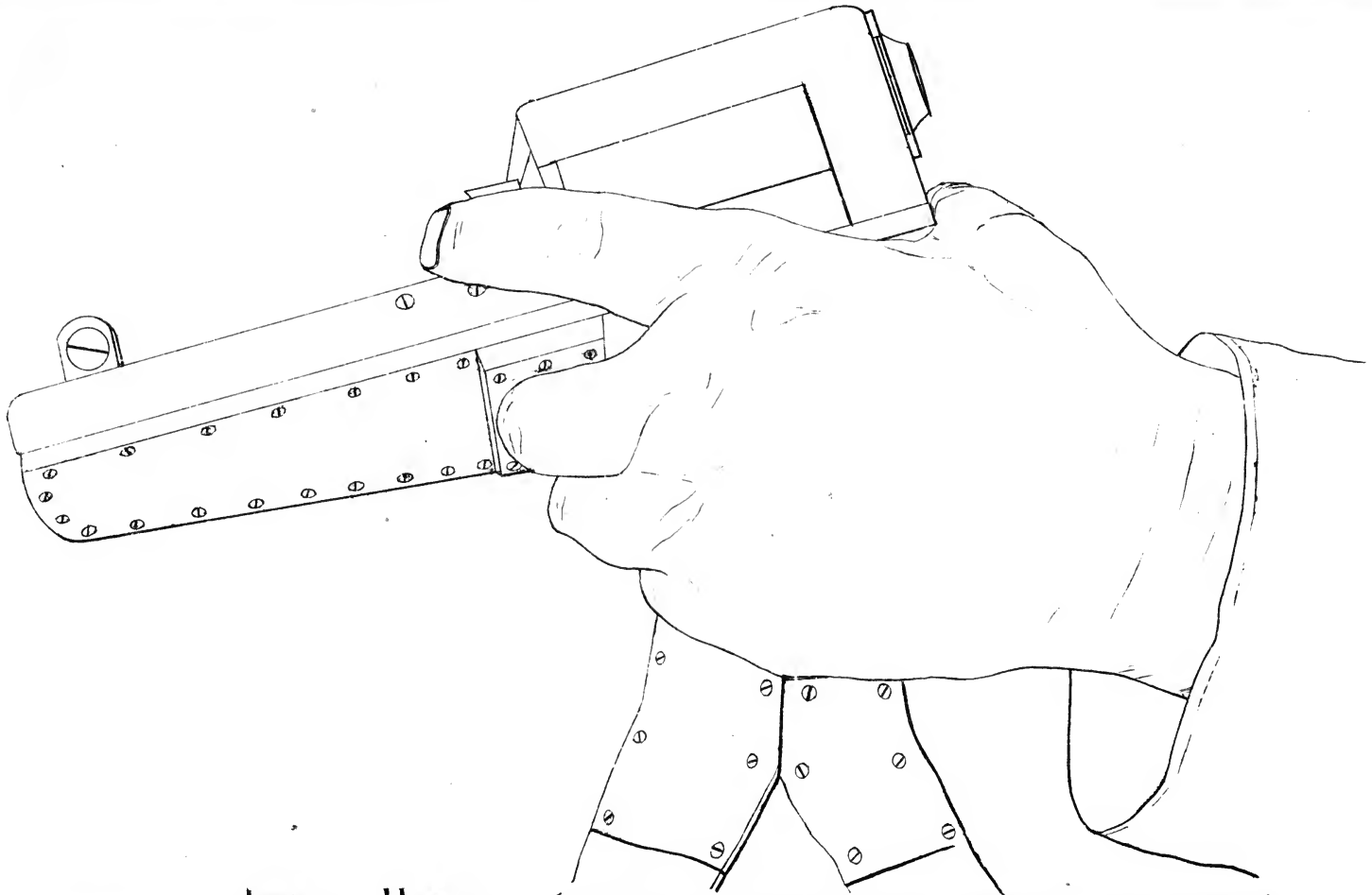

LEFT HAND. *(Holding Telemeter in position on Picket.)*

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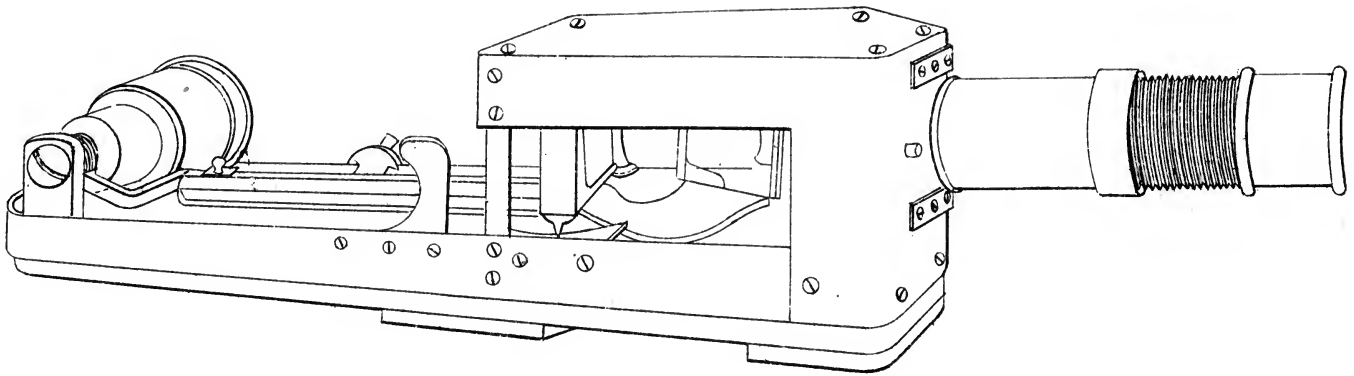
# FIELD TELEMETER PERSPECTIVE VIEW.

*(Corer on,-showing left side – Clip for forefinger of left hand & Telescope.)*



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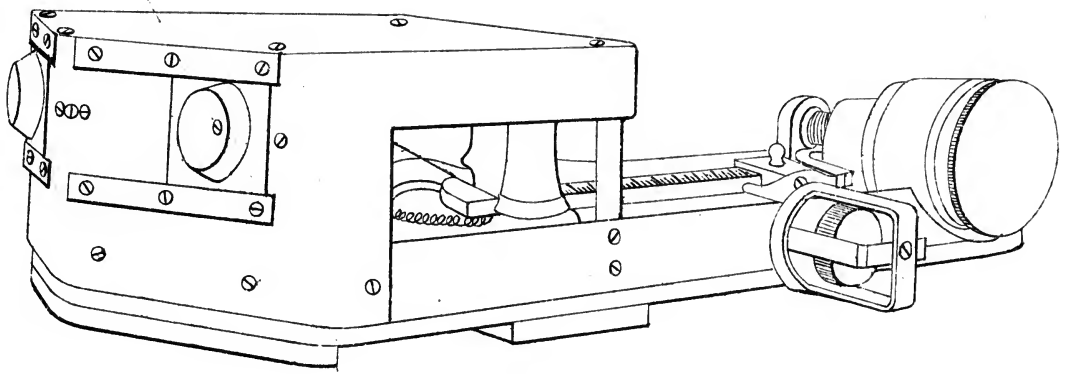
# FIELD TELEMETER PERSPECTIVE VIEW.

*( Cover on.- showing right side - adjusting screw & Eyehole shutters.)*



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