CHAPTER VI

# ERRORS IN LAYING AND TRAINING DUE TO MOVEMENT OF THE SHIP

## SECTION 1. ERRORS IN ELEVATION DUE TO MOVEMENT IN THE VERTICAL SIGHT PLANE

### GENERAL

119. If the ship is rolling and/or pitching and the guns are trained so that these movements have a component in the vertical sight plane, the Director Layer will have to move his director setting handwheel to keep his crosswires or collimator on the point of aim.

It is not possible for the Gunlayer to follow the movement of the director pointers at a power-worked gun if the Director Layer follows the target continuously. To overcome this difficulty the Layer should stop moving his director setting handwheel a few seconds before his crosswires come on to the target, and allow the movement of the ship to bring his line of sight finally on to the target. This gives the Gunlayer time to get his pointers accurately in line by the time the gun fires, and there should then be no angular difference between the elevation transmitted electrically to the gun and that shewing on the mechanical pointers at the instant the gun fires.

One difficulty is, however, inherent in the above arrangement. This is that the gun, at the moment of firing, will be moving up or down in the vertical plane of sight. Although its movement relative to the deck plane should have stopped a second or so before it is fired, that very fact means that it will be moving relative to the medium in which the shell has to travel. This introduces certain complications in the laying of the director.

Since the Director Layer stops moving the director setting handwheel before he is on the point of aim, the crosswire in his telescope stops relatively to the deck plane, but, owing to the motion of the ship, moves up or down in space.

A certain interval of time must elapse between the moment that the Director Layer judges that his crosswire is " ON " and the instant that the shell leaves the muzzle of the gun. Up till that instant the shell is affected by the movement of the ship and, if the Layer fired when he judged the crosswire to be on the point of aim, would fall short of the correct range on a down roll and beyond it on an up roll.

This time interval between the Director Layer saying to himself "**Fire**" and the shell leaving the muzzle is composed of three components :—

(*i*) *The Human Lag* of the eye to see, brain to appreciate, finger to press the trigger.

(*ii*) *The Gun Firing Interval,* from the moment that the trigger is pressed for the circuit to be completed, the charge to fire and the shell to travel down the bore.

The total of these two intervals is found to be between 0·2 and 0·4 of a second.

(*iii*) A further error is introduced by the fact that the gun is stationary relative to the deck plane and hence is moving through space. This imparts an angular velocity or throw upwards or downwards in the direction in which the end of the gun is travelling, at the moment at which the shell leaves the muzzle.

The magnitude of this throw will depend upon the speed of roll relative to a fixed point in space and the distance of the muzzle from the centre of roll. Its effect is about one-eighth of that due to the time interval.

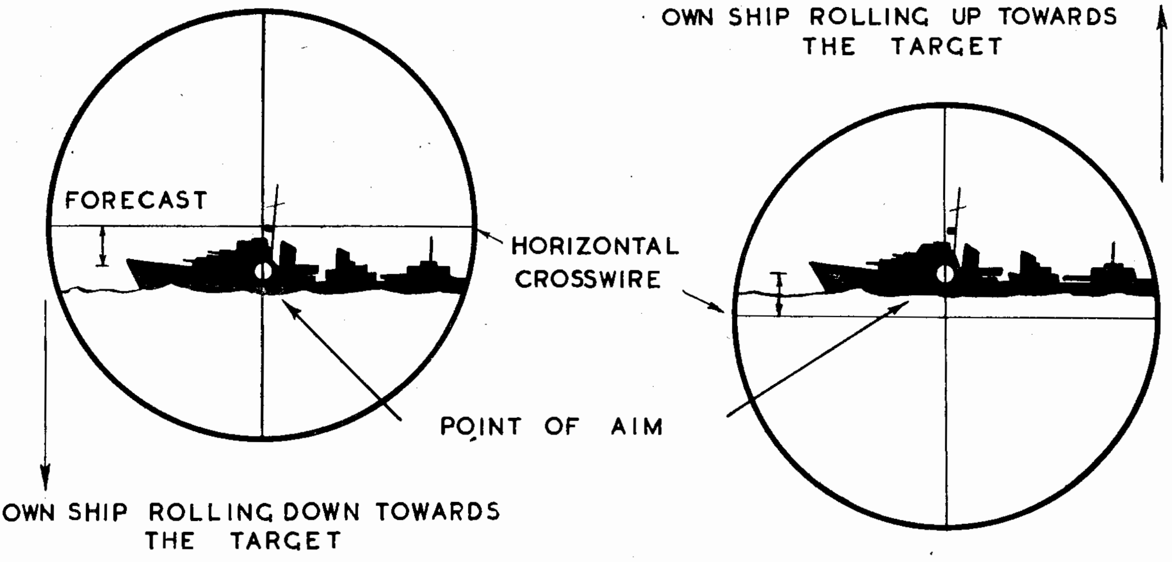
To overcome the combined error the Director Layer must complete the firing circuits in advance of the moment at which his crosswire is on the point of aim. This will be when his crosswire or collimator is above the target on the down roll and below the target on the up roll. This is called ***forecasting*** and the amount will vary with the time interval for the particular ship, the speed of roll at the moment of firing and the particular mark of gun. The method by which this forecast is applied depends upon the type of fire in use, and the details of the director installation.

### FORECASTING IN DIRECTOR FIRING

120. In director firing the estimation of forecast has to be made entirely by eye, and is the most difficult and important part of the Layer's job. *Diagram 4* shews what the Layer should see at the moment of pressing his trigger in Director Fire with a rate of roll requiring a forecast of two target heights.

From the above it will be seen that, if the Layer waits until the end of the roll and fires at the moment when the ship is stationary no forecasting will be necessary. This is not acceptable, however, under normal conditions of roll and pitch, as it would slow up the rate of fire and would also introduce cross-levelling errors of an unacceptable size. Under conditions of heavy roll, however, when the amount of forecast required near the middle of the roll, when the angular speed is greatest, would be greater than the field of the telescope, it is necessary to adopt this method of firing when the ship is momentarily stationary.

*Diagram 4.* **Forecast in Director Firing. View in Layer's Telescope at Moment of Pressing Trigger.**




## FORECASTING IN GYRO FIRING

121. In directors fitted for gyro firing, the Layer's and Trainer's line of sight is kept stabilised in the vertical sight plane by a gyro-controlled prism, except in the " P " sight where the whole binocular arm is stabilised by a power-follow-up system.

The effect of this is that the Layer looks at the target all the time, and, so far as his view is concerned, the ship might be stationary. However, the need for forecasting still exists since the time taken to make the relay which is controlled by the firing contact on the stabilised portion of the sight is actually longer than the human lag, and the other two components of the time interval remain as in director firing.

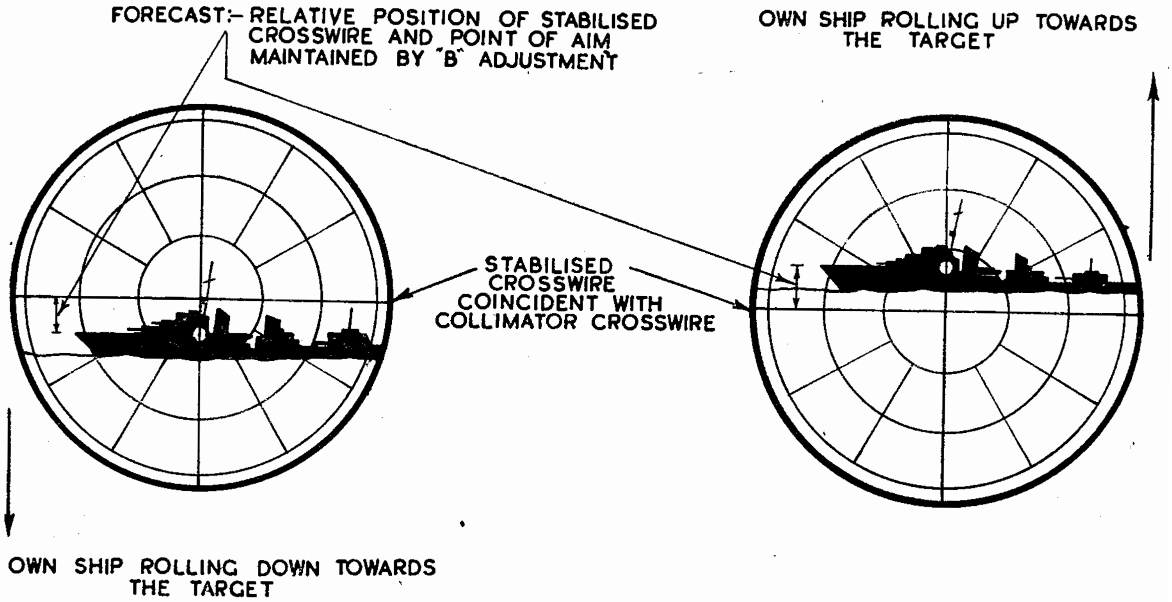
In the standard gyro sights types G, H and J a special crosswire, known as a collimator, is fitted in the stabilised telescope. This is attached to the unstabilised portion of the sight, and therefore moves across the stabilised field of view at the same rate as the ship is moving. It thus gives the Layer the necessary indication, on which to base his forecast, of how fast the level angle is changing. In the " P " sight a special strip collimator is used. The principle of this is exactly the same as described above, but the operation is different. This is fully described in *Part 14* of this series.

The gyro contacts close the circuit to the firing relay at the moment that the collimator crosswire is in line with the stabilised crosswire. The " P " sight has no firing relay, but the firing switch which replaces the relay and contacts is similarly closed at the moment when the centre point of the special strip collimator is in line with the stabilised crosswire.

In ships in which time-interval compensating gear is not fitted, or when it is not being used, forecasting is done by moving the position of the stabilised crosswire, by means of the " B " adjustment, relative to the point of aim. The relay contacts close when the collimator crosswire coincides with the stabilised crosswire.

To achieve the required effect the latter must obviously be positioned above the point of aim on the down roll and below it on the up (*Diagram 5*). This is fully explained in *Parts 2 and 13* of this series.

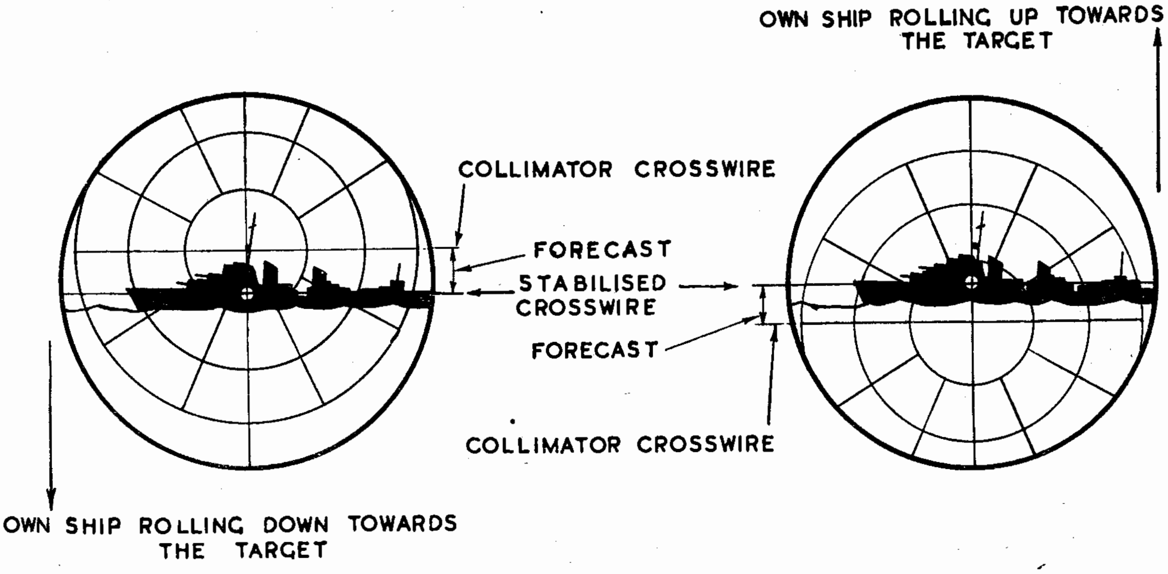
*Diagram 5.* **Forecast in Gyro Firing. View in Layer's Stabilised Telescope at Moment of Gyro Relay Contact. No T.I.C. Gear.**



## TIME-INTERVAL COMPENSATION GEAR (T.I.C.)

122. T.I.C. gear is fitted to most gyro sights and calculates automatically the amount of forecast required. This correction is measured in minutes of arc and transmitted to the time-interval receiving gear (T.I.R.) by which it is applied to the contact plate or firing switch of the gyro firing gear. With T.I.C. gear in use the Director Layer does not have to forecast. So long as the stabilised crosswire is kept on the point of aim and the firing pedal pressed when the fire gong is rung, the firing circuits will be energised at the correct moment to allow the necessary forecast for the rate of roll at the time. The Director Layer must realise that the firing circuits will be energised before the collimator has moved into alignment with the stabilised crosswire, and he will not therefore be certain at what instant the guns will fire. He must therefore be particularly careful that he allows sufficient time for the Gunlayers to get their pointers in line, or gross pointer-following errors will result. Details of the T.I.C. gear are given in *Part 13* of this series.

*Diagram 6.* **Forecast in Gyro Firing. View in Layer's Stabilised Telescope at Moment of Gyro Relay Contact. Forecast of Two Target Heights automatically applied by T.I.C. Gear.**




*NOTE : Similar diagrams for the " P " sight are given in Part 14 of this Series.*

Gyro firing in conjunction with T.I.C. gear provides the most accurate form of laying that there is under ~~all~~ normal weather conditions, and should be used whenever possible. The only disadvantage is that the gyro telescopes are sometimes less satisfactory for use at night than are the unstabilised binoculars, but even so, the fact that they give an elevation datum which is sufficiently accurate for blind fire should be considered before the decision to change to director firing is made.

The following table gives the actual amount of forecast required for a 10° level angle in various ships at various ranges.

**Maximum Errors due to 10° Level Angle and Required Forecasting**

| (1) SHIP | (2) GUN | (3) ANGULAR ERROR IN MINUTES FOR 10° LEVEL ANGLE IF NO FORECAST WERE MADE | (4) RANGE OF TARGET (YARDS) | (5) RANGE ERROR RESULTING FROM ANGULAR ERROR IN (3) AT RANGE IN (4) | (6) FORECAST REQUIRED. TRUE TARGET HEIGHTS (30 FT. B.P.T.) |
|---|---|---|---|---|---|
| *Nelson* .. .. | 16-in. | 44·6 | 20,000<br>3,000 | 820<br>1,510 | 25<br>6 |
| 8-in. Cruisers .. | 8-in. | 29·3 | 15,000<br>3,000 | 435<br>1,055 | 13<br>3 |
| 6-in. Cruisers .. | 6-in. Mark XXIII | 24·7 | 12,000<br>3,000 | 280<br>915 | 7<br>3 |
| Destroyers .. | 4·7-in. | 29·8 | 7,000<br>3,000 | 330<br>690 | 6<br>3 |

*NOTES :*

(*a*) *Errors calculated from maximum velocity of change in level angle, i.e. with ship vertical.*

(*b*) *Level angle* (*Col. 3*) *is from vertical to " out ".*

(*c*) *Errors have been calculated for full charge S.C. cordite.*

(*d*) *For level angles other than 10° the angular errors* (*Col. 3*) *are directly proportional and the resulting range error and forecasting required* (*Cols. 5, 6*) *are approximately proportional.*

## LIMITS OF FORECASTING

123. Experience shows that in director firing it is not possible to forecast more than four " target heights " whatever the target may be. This is because, under conditions which would require greater forecasts, the target may move so quickly across the field of view that the Layer has not sufficient time to judge his forecast.

In gyro firing, even without T.I.C. gear, it might seem possible that greater forecasts could be made, owing to the target being apparently stationary, but in practice two difficulties arise :—

(*i*) Under conditions when the limits of level angle are greater than the field of view of the stabilised telescope, the collimator moves beyond the field of view at each end of the roll, and the Layer cannot appreciate the rate at which the level angle is changing at that moment.

(*ii*) It is not easy to keep adjustment " B " continually on the move between four " target heights " above and the same number below. Larger forecasts would be impracticable.

If conditions are such that forecasting beyond the above limits would be necessary, it may be preferable to confine firing to the ends of the roll, taking the normal point of aim and accepting a reduced rate of fire. This must never be done without a direct order from the Control Officer, since it will inevitably reduce the rate of fire and may introduce considerable cross-levelling errors if no corrector unit is fitted.

## USE OF GYRO AND DIRECTOR FIRING—POLICY

124. The following is a guide to the method of fire to be adopted with the standard gyro sights under various conditions.

**When T.I.C. gear is fitted**—" *GYRO* " is to be considered the primary method of firing under all conditions.

**When T.I.C. gear is NOT fitted**

In slight or moderate seaway, where a forecast of less than four " target heights " is required, gyro firing is to be considered the primary method of firing.

In a heavy roll requiring a forecast of more than four target heights director firing will probably produce better results and should be considered to be the primary method of firing. The relegation of gyro firing to a secondary position does not imply the abandonment of the trainer's stabilised telescope, which should continue to be used whenever possible.

**Trainer's Telescope only stabilised**

Director firing is to be the primary method of firing. Trainer's stabilised telescope should continue to be used whenever possible in order to retain the advantage of the stabilised line of sight.

## CH. VI. SECTION 2. ERRORS IN TRAINING DUE TO MOVEMENT AT RIGHT ANGLES TO THE VERTICAL SIGHT PLANE

## CANTED-TRUNNION ERROR

125. If the trunnions of a gun become canted from the horizontal, an error in line will result owing to part of the elevation being converted into training. The cant of the trunnions may arise from roll or pitch, or heel due to alteration of course, having a component at right angles to the line of sight to the target. Since roll angles are nearly always larger than angles of pitch, the occasions when this canted-trunnion error is most noticeable are when firing on fine bearings ahead or astern.

The size of the training error introduced depends upon :—

(*a*) The cant of the trunnions. This is equal to the angle of roll or pitch which is causing it multiplied by the cosine of the bearing of the gun relative to the line about which the movement is taking place, i.e. fore-and-aft if the ship is rolling and athwartships if pitching. It may be composed of a combination of the components of roll and pitch, or a more permanent list due to alteration of course, action damage, etc. It is known as the cross-level angle.

(*b*) The tangent elevation of the gun. At zero elevation no error occurs, but it increases progressively up to 90 degrees.

The angular error in training (cross-level training correction) is given by the formula :—

$$\text{Tan } \alpha = \sin.\ \theta \text{ Tan. } \phi$$

Where $\alpha$ is the angular error in training due to cant of the trunnions (cross-level training correction),

$\theta$ is the angle of cant of the gun trunnions (cross-level angle),

and $\phi$ is the tangent elevation of the gun.

The angle $\theta$ is obtained by multiplying the angle of roll, pitch, or heel which is causing the cross-level angle, by the cosine of the bearing of the gun relative to the line about which the movement is taking place, i.e. fore and aft if the ship is rolling or heeled and athwartships if the ship is pitching or badly trimmed. Normally the cross-level angle will be made up of a combination of the above effects.

As an example, the cross-level training correction required when firing 6-in. guns right ahead at a range of only 12,000 yards at the end of an 8-degree roll is approximately 12 units of deflection. A 600-foot target at that range subtends only 9½ units even when broadside on. At long range the error becomes very serious indeed and large errors in line will result if it is not corrected.

## CROSS-LEVELLING GEAR

126. This is fitted to correct the above error. The theory upon which its design is based is fully explained in *Part 16* of this series.

The existing cross-levelling sight is hand-operated, the reason for this being that it has, until recently, been Admiralty policy to refrain from fitting automatic corrector gear until R.P.C. for training has been fitted to the mountings, owing to the difficulty of pointer-following when the electrical pointers in the training receivers at the guns are continuously moving owing to the cross-levelling correction.

The use of hand gear enabled the above difficulty to be avoided but entailed the use of forecasting by the cross-levelling operator. This in turn required a system of exceedingly complicated co-operation between the Director Layer and the cross-levelling Operator, in order that both might be on the point of aim simultaneously. This was found to be impracticable. The policy has now been revised, and automatic cross-levelling gear will eventually be fitted to all low-angle director systems. In the meantime, the existing cross-levelling gear is to be used to give a constant correction, i.e. the cross-levelling Operator is to ***lay on the horizon continuously*** and make no attempt to forecast. Under difficult conditions this will inevitably introduce pointer-following errors at the guns, but, although the line spread may thus be somewhat increased, the M.P.I. of salvos should be more correctly placed. Under conditions of moderate roll it is considered that a well-drilled turret's crew should be able to deal with the movement of the electrical pointers without serious pointer-following errors.

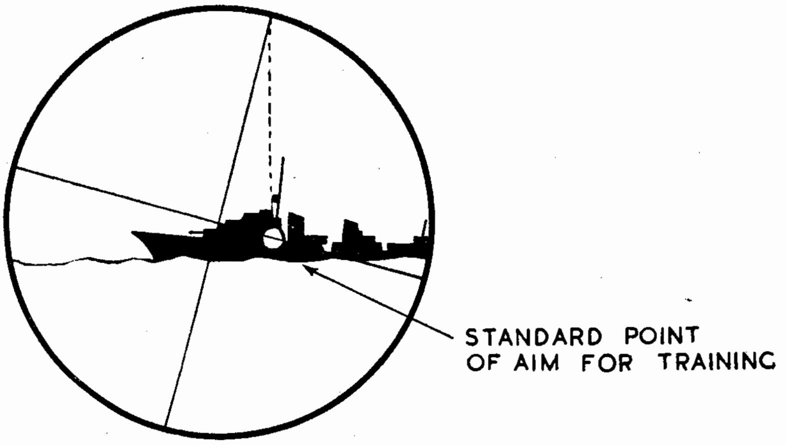
When R.P.C. of training is fitted, this possible source of error will disappear, since the power follow-up at the mounting should compete satisfactorily with any normal movement of the cross-levelling Operator's handwheel.

Under conditions of exceptionally heavy rolling, when the cross-levelling Operator finds it impossible to lay continuously on the horizon, the cross-levelling unit must be locked in the zero position and one of the methods of reducing the error described in the following paragraphs be adopted.

## METHODS OF REDUCING THE ERROR WHEN NO CORRECTOR IS FITTED

127. In ships where no cross-levelling gear is fitted or under conditions described above, the errors can be mitigated to some extent by the Director Trainer keeping the ***top*** of the vertical crosswire above the point of aim. The lowest-power magnification should be used in his telescope when doing this. (*Diagram 7.*)

*Diagram 7.* **Position of Trainer's Vertical Crosswire when reducing the Effect of Canted-Trunnion Error.**



Another alternative is for the Layer to fire only when he judges the ship to be upright and only in ***one direction*** of roll.

This method has, however, two serious disadvantages, firstly it reduces the rate of fire which is not usually acceptable in ships with fast-firing guns, and, secondly, it requires the Layer to fire at that point of the roll when the angular velocity is greatest and when the largest forecast will therefore be required. Under heavy weather conditions this amount of forecast may well be outside the limits of the four target heights which is the maximum feasible forecast without T.I.C. gear. In this case the first alternative would have to be adopted, the probable errors in line being accepted.

128–142.

CHAPTER VII

# NEW EQUIPMENT FITTED TO EXISTING DIRECTOR SYSTEMS

## SECTION 1. RADAR

### EFFECT OF RADAR ON THE DUTIES OF THE DIRECTOR CREW

143. The function of gunnery radar sets at present fitted is to act as the principal rangefinder of the armament concerned, and to measure the bearing of a ship or aircraft which has not yet been sighted.

The principal gunnery sets are the Type 284 for purely low-angle directors and the Type 285 for combined H.A./L.A. and H.A. directors. In both cases the aerials are mounted on the director and the training of them is done by the Radar or Bearing-Plot Operator indicating a bearing for the Director Trainer or the Auxiliary Trainer to follow, or by the Auxiliary Trainer himself looking at a radar training tube mounted in the director. Very close co-operation is therefore required between these ratings. The latter may sometimes be an additional member of the Director Crew, but is usually the R/E Operator or the communication number according to the type of equipment. When the Auxiliary Trainer is training the director, the Director Trainer should always look through his telescope or binoculars and try to pick up the target optically, if there is any possibility of a visual sighting.

Radar additions to the directors therefore affect the Trainer rather than the Layer at present, the latter using his gyro stabilisation to give him the required datum for elevation as in most other blind-fire procedures.

### PROCEDURES WITH LOW-ANGLE RADAR SETS

144. There are three main ways of making use of the Radar sets in low-angle fire :—

(*a*) **Sweeping.** The set is used to pick up a target previously reported by a warning set, the D.C.T. sweeping over an arc centred about an alarm bearing.

(*b*) **Following.** The set is used to supply the range, error in rate and bearing for fire against an unseen target. The tower is trained by the Auxiliary Trainer where one is available, from information transmitted from the radar tube in the T.S. to the table training pointer in the director training dial, or by an O.F.I. controlled from the radar office, or by a radar training tube mounted in the director.

(*c*) **Ranging.** The set is used as a rangefinder and error-in-rate finder against a visible target.

Full details of the duties of the crew and of the above procedures are given in "*Radar Operating Procedure, Part 2*".

## CH. VII. SECTION 2. REMOTE POWER CONTROL OF GUN MOUNTINGS

### EFFECT ON THE OPERATION OF THE DIRECTOR

145. The fitting of remote power control of the guns does much to simplify the Director Layer's task. Theoretically, if the Layer and Trainer lay and train continuously on the target and the follow-up at the gun is perfect, the gun becomes stabilised in space. With manual follow-up this perfection of following at the gun has not been possible, and the Director Layer has had to stop moving his handwheel before he came on the point of aim to allow the Gunlayers to catch up. This has entailed the acceptance of movement of the gun at the speed at which the ship is rolling at the moment it is fired.

This movement of the gun introduces a variety of complications which are overcome by "Forecasting". This is described in *Chapter VI, Section 1,* but it should be clearly understood that the whole problem only arises because it is necessary to allow the gun to move with the ship for the instant at which it is fired, instead of keeping it pointed at a fixed position in space and letting the ship roll around it.

The advent of an accurate automatic follow-up at the guns would enable the forecast to be dispensed with under conditions of roll such that the Layer and Trainer, or stabilisation in the latest directors, could keep the line of sight accurately and continuously on the target.

At the present moment the power follow-up at the guns under conditions of moderate or slight roll should be sufficiently accurate, and the problem of laying and training continuously on the target sufficiently easy, for the theoretical conditions to be met, and hence for the Director Layer to adopt the above method and avoid having to forecast.

Under conditions of heavy roll, the limiting accuracy of the R.P.C. and the difficulty of keeping continuously on the target will make a reversion to the pause before firing and the consequent forecasting once more necessary.

If the continuous following method is adopted, a difficulty arises if there is a breakdown of R.P.C. at one mounting, for with continuous laying the Gunlayers are bound to have considerable errors.

In Mark VI and similar directors, no gyro firing arrangements are fitted and the Director Layer is therefore deprived of all the elaborate aids to forecasting with which he is provided in other modern sights. If, therefore, the normal method of laying is to be adopted with this type of director, the Layer must revert to his own visual estimation of the amount of forecast required with all the inevitable inaccuracies which that implies. The adoption of continuous laying, with consequent elimination of errors in forecasting, may even with existing systems of R.P.C. prove more accurate under all conditions of roll than the standard method of laying with older sights. Some " pointer-following " errors will creep in owing to the lag in the R.P.C. system, but these should be less under almost all conditions of roll than the errors introduced by bad forecasting.

## LAYING PROCEDURE

146. Sea experience of R.P.C. is, as yet, somewhat limited. It is, however, recommended that the following modifications to the standard methods of laying be adopted.

(*i*) In directors with T.I.C. gear, keep the collimator continuously on the point of aim when it is possible to do so, and use gyro firing No forecast is necessary under these conditions and the ***T.I.C. gear should be locked.***

If conditions are such that the collimator cannot be kept continuously on the point of aim, revert to the normal method of dwelling a pause before firing and allowing the movement of the ship to bring the collimator on. In this case forecast is necessary and the ***T.I.C. gear should be unlocked*** and allowed to make the necessary forecast.

(*ii*) In directors not fitted with gyro firing gear, the director should be kept in " *STABILISED* " as for H.A. fire. The line of sight will thus be kept continuously on the point of aim and no forecast will be necessary.

147–152.

CHAPTER VIII

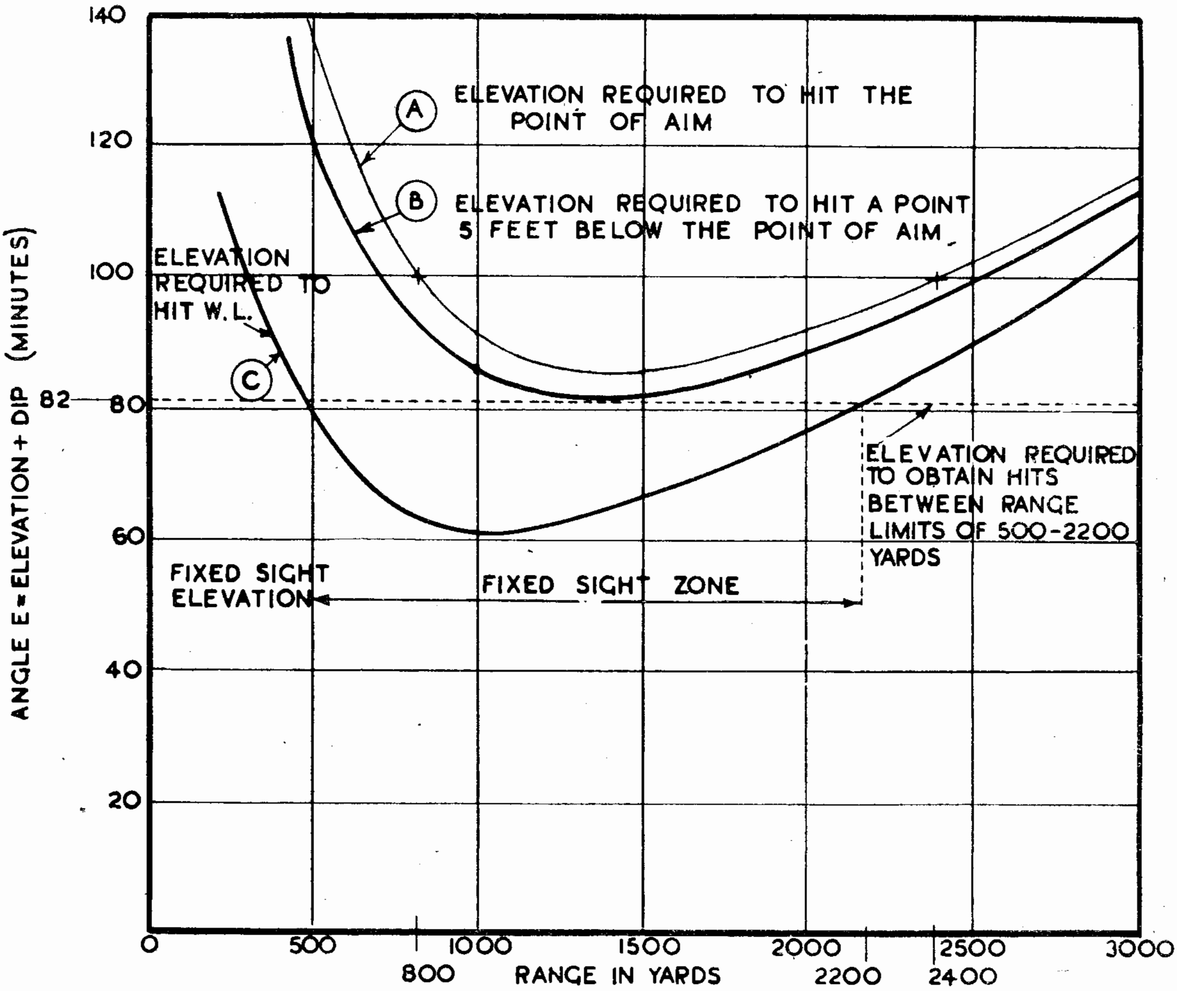
# DIRECTOR FIXED SIGHT

## GENERAL

153. At very short ranges, owing to the large effect of dip when the aloft director is controlling, a point is reached where the increase in dip equals the decrease in elevation required due to the decrease in range. Below this point the increase in dip is actually greater than the decrease in elevation. From this point, therefore, the curve of the cam in the R/E gear would have to be reversed so that **more** elevation was produced for **less** range. An alternative would be to reverse the range graduations so that, for instance, the 1,000 yard mark would coincide with the 2,800 yard graduations. The former is not a practicable proposition owing to mechanical difficulties and the latter would introduce such a complicated pattern on the range dial of the R/E or sight range dial that confusion would inevitably arise.

To avoid the difficulty a fixed sight graduation and procedure are employed.

*Diagram 8.* **Fixed Sight Elevation Curves.**




## THEORY

154. In order to make the shell from any gun hit a point of aim a given distance away, it is necessary to measure the angle of sight to the target and add to that angle an amount equal to the range-table elevation for the range. This is done by the sighting mechanism, which may be situated locally at the gun or remote from it as in the case of a director system. If the sighting mechanism is at some distance above or below the bore of the gun which it is controlling, an angle of dip has to be added to the elevation described above. Thus an amount, which is the sum of the range-table elevation and the dip for the range in question, must be added to the elevation of the line of sight to the target. This ensures that, when the telescope of the sighting mechanism is laid on the point of aim, the necessary elevation above the line of sight will be applied to the gun. In *Diagram 8* this angle of elevation (E) is plotted against range to produce curve " A ". The shape of the curve will depend upon the type of gun for which the tangent elevation is being calculated and the height of the sight (director or local) above the bore from which the amount of dip is being calculated. With a director at a considerable height above the guns the dip becomes very large at short ranges, and it can be seen from curve A in *Diagram 8* that " E " becomes a minimum and then increases again. Thus the graduation for each range below this turning point corresponds to the graduation for some range above it, e.g. 800 to 2,400.

It will be noted that for a considerable zone on either side of the turning point the elevation plus dip (Angle " E ") remains practically constant. Thus if the sighting mechanism is set to some range which, combined with dip, will produce an elevation within this zone, shots should hit the point of aim, or very near it, if the target is at any range within the zone. **This is the basis of director fixed sight.**

The standard point of aim is the level of the forecastle deck. It is, however, desirable to hit lower down than this on the main hull of the ship ; to do this it is necessary to use less elevation on the director. This applies at all ranges, but the correction is only appreciable at short ones, owing to the shape of the trajectory. It is assumed in all cases that the point it is desired to hit is 5 feet below the point of aim. Working out the angles subtended by 5 feet at different ranges and plotting them below curve " A ", curve " B " is obtained, giving the elevation necessary to hit the top of the desired target. Similarly, if it be assumed that the waterline is 25 feet below the point of aim curve " C " can be similarly obtained giving the elevation necessary to hit the waterline.

It is evident that if the sight be set to the minimum elevation of curve " B " (82 minutes), hits will be obtained on some part of the target if the range is anywhere between 500 and 2,200 yards, assuming the height of the target to be not less than 20 feet. At 2,200 yards the waterline will be hit ; as the range decreases the hits will get higher until at 1,350 they will be near the top of the target, 5 feet below the point of aim ; they will then get lower again until at 500 yards the waterline will be hit again.

If the target is outside the zone, either further **or nearer,** shots will miss short, and misses over will result if the height of the target is less than that for which the fixed-sight settings are calculated.

The above elevation is known as " fixed-sight elevation " and the range zone in which it is effective as the " fixed-sight zone ".

In guns 8 in. and above, it is assumed that the target is 20 feet high, as in the above example, i.e. from 5 to 25 feet below the point of aim, but for 6-in. guns and below, the target is assumed to be 10 feet high only.

For reduced charges, the height of target is taken as 30 feet (battle practice target) and for sub-calibre, 15 feet,

As in all instances the top of the target is assumed to be 5 feet below the point of aim, the " fixed-sight elevation " is not affected, but with the smaller targets the zones are somewhat reduced.

In most new and re-armed ships whose fixed-sight settings have been calculated since 1935, no separate settings have been produced for reduced charge, M.A.C. or sub-calibre firings, so that in order to simplify drill, the same settings are used for all firings. The errors involved are not large, and can be accepted for the practice firings for which these charges are used.

The effect of this when using reduced charges in all cases is :—

(*i*) To raise the highest point of the M.P.I. when in the fixed-sight zone from 5 feet below the point of aim to the level of the point of aim or slightly above.

(*ii*) To increase the amount that a " *DOWN 800* " correction lowers the point of aim, thus tending to counteract the effect of (*i*).

It should be noted that in the above cases all that is actually necessary, in order to find the fixed-sight elevation and zone in any case, is to plot portions of curves " B " and " C ".

## CALCULATION OF FIXED-SIGHT ELEVATION

155. Add together tangent elevation and dip, for director height above standard level minus 5 feet, for various ranges. The minimum value of this combination to the nearest minute is the fixed-sight elevation. The greater the datum height the greater the fixed-sight elevation.

In all calculations tangent elevations must be taken from the appropriate range tables and for the M.V.s for which the range cams of the R/E.D. unit were cut.

*Example :—*

" Kent " class. Fore director, full charge. Range table No. 206. M.V. 2,725. Datum height, 35·25 feet.

| *Range* | *Tangent Elevation* | *Dip for 30·25 feet* | *Total* |
|---|---|---|---|
| 1,000 | 22·9′ | 34·7′ | 57·6′ |
| 1,100 | 25·2′ | 31·6′ | 56·8′ |
| 1,200 | 27·6′ | 29·0′ | 56·6′ |
| 1,300 | 30·0′ | 26·7′ | 56·7′ |
| 1,400 | 32·5′ | 24·8′ | 57·3′ |

Hence fixed-sight elevation is 57 minutes.

## FINDING THE POSITION OF THE FIXED-SIGHT MARK

156. Drawings are available in ships showing the elevation transmitted by the R/E cam plotted against range. From this curve it is possible to read off the range corresponding to the fixed-sight elevation.

The range cams are only accurately cut between certain range limits and below the lower limit the cam is cut in an arbitrary manner, so as to bring tangent elevation to zero for zero range.

Thus, it will often be found that the range to set for the fixed-sight mark will not correspond to the range at which the fixed-sight elevation, found as described above, actually occurs.

*Example :—*

"Kent" fore director. Full Charge. Vickers' Drawing 11150D.

If fixed-sight elevation is 57′, the fixed-sight mark will be 1,375 yards.

For convenience, however, the fixed-sight mark will always be placed at the nearest 100 yards, i.e. 1,400 in this case.

If the above drawing is not available, one can be constructed as follows :—

Set range to zero, then set gun elevation repeat to zero. Set various ranges and read off corresponding elevations, plotting the points so obtained.

## CALCULATION OF THE FIXED-SIGHT ZONE

### For 8-inch guns and above

157. Add together tangent elevation and dip for datum height minus 25 feet. The two ranges at which this formula gives the fixed-sight elevation are the upper and lower limits of the fixed-sight zone. The greater the datum height the smaller is the fixed-sight zone.

*Example :—*

"Kent" class, fore director, full charge. Range table No. 206. M.V. 2,725. Datum height, 35·25 feet.

| *Range* | *Tangent Elevation* | *Dip for 10·25 feet* | *Total* |
|---|---|---|---|
| 100 | 2·2′ | 117·5′ | 119·7′ |
| 200 | 4·4′ | 58·8′ | *63·2′* |
| 300 | 6·7′ | 39·2′ | 45·9′ |
| 2,100 | 49·9′ | 5·6′ | 55·5′ |
| 2,200 | 52·5′ | 5·3′ | *57·8′* |
| 2,300 | 55·0′ | 5·1′ | 60·1′ |

Fixed-sight elevation was 57 minutes.

Fixed-sight zone is therefore 200 to 2,200 yards.

If the datum height is less than 25 feet, dip will be negative, and must be subtracted from the tangent elevation. It is evident that the low limit will in this case be zero.

**For 6-in. guns and below,** full charge, use the formula :— tangent elevation plus datum height minus 15 feet.

For all guns, reduced charge, use tangent elevation plus datum height minus 30 feet.

For all guns, sub-calibre, use tangent elevation plus datum height minus 15 feet.

## ADDITIONAL GRADUATIONS BELOW THE FIXED-SIGHT MARK

158. The fixed-sight mark gives theoretically the minimum elevation normally required, but in certain circumstances described later, it may be necessary to spot down from fixed sight.

To provide for this, two graduations are placed below the "fixed sight mark" marked "*1st down 800*" and "*2nd down 800*", respectively.

The effect of each of these "800's" is to lower the M.P.I. vertically by 20 feet for guns 8 in. and above, and 10 feet for guns 6 in. and below **at a range in the middle of the fixed-sight zone.**

In all ships fitted with A.F.C.T. Mark V and later and A.F.C.C.s, the fixed-sight range and the ranges corresponding to the 1st and 2nd down 800's are engraved on the top of the table.

If the rate, or spotting corrections bring the range down to or below the fixed-sight range, the table is tuned to it and the tuning handwheel is left "*IN*" to stop the rate. If down corrections are then ordered the table is tuned to the ranges which correspond to these settings. The R/E Operator, in the case of the Mark V table only, continues to follow his pointer in the usual way although a scale shewing the positions of the fixed-sight range, and 1st and 2nd down 800's is actually marked on the dial of the R/E unit.

In older ships special strips, graduated as above for full charge, reduced charge and sub-calibre, are incorporated in the R/E.D. unit range dial. The requisite strip appears through a window in the dial and can be changed by a small milled knob on the outside of the unit. In this case the R/E Operator carries out the fixed-sight procedure outlined above.

## POSITIONS OF THE 1ST AND 2ND DOWN 800 MARKS

159. **8-in. guns and above, all charges.** Work out the angle subtended by a height of 20 feet in the middle of the fixed-sight zone.

The elevation of the 1st down 800 is obtained by subtracting this angle from the fixed-sight elevation.

The elevation of the 2nd down 800 is obtained by subtracting this angle from the elevation for the 1st down 800.

*Example* :—

Fixed-sight elevation is 60′.
Fixed-sight zone, 200–2,200 yards.

Angle subtended by 20 feet at 1,200 yards (middle of zone) is – $\frac{20 \times 1,146}{1,200} = 19'$.

Hence elevation for 1st down 800 is 41′.
" " " 2nd down 800 is 22′.

It may sometimes happen that the fixed-sight elevation is not large enough to permit of two down 800's, calculated as above, to be placed below it.

In such circumstances, if fixed-sight elevation is greater than the angle subtended by 20 ft. 1st down 800 should be placed at half the fixed-sight elevation, and the 2nd down 800 at zero.

If, however, fixed-sight elevation is equal to or less than the above angle, 1st down 800 must be at zero, 2nd down 800 being omitted.

*Example* (*a*) :—

Fixed-sight elevation 30′.
Angle subtended by 20 ft. at middle of fixed-sight zero – 20′.
1st down 800 will be 15′.
2nd down 800 will be at zero.

*Example* (*b*) :—

Fixed-sight elevation 15′.
Angle 20′.
1st down 800 will be zero.
There will be no 2nd down 800.

**6-in. guns, all charges.** As in the preceding paragraph but substituting the angle subtended by 10 instead of 20 feet at the centre of the fixed-sight zone.

## GRADUATION OF RANGES AT AND ABOVE THE FIXED-SIGHT MARK

160. For convenience of fire control, the fixed-sight mark is labelled with some convenient range. Further, for spotting purposes, there must be range graduations from the fixed-sight mark upwards, and each increase of 100 yards must give a definite increase of elevation up to the upper limit of the fixed-sight zone.

The most suitable increase of elevation per 100 yards is the angle subtended by a height of 5 feet at this upper limit.

Thus the range graduations at and immediately above the fixed-sight mark are arbitrary ones, i.e. they do not give the correct tangent elevation plus dip for datum height for the range marked ; this, however, is of little importance, as the presence of the arbitrary graduations markedly simplifies the fire-control procedure.

Wherever practicable the range with which the fixed-sight mark is labelled is made 400 yards or less below the top of the fixed-sight zone so that, when at "*FIXED SIGHT*", an "Up 400" correction will take the range to the top of, or out of the fixed-sight zone.

In Admiralty fire-control tables and clocks with internal R/E gear, and in ships with the R/E gear in the D.C.T., this is arranged as follows :—

The fudged portion of the R/E cam at low ranges is so adjusted that the elevation required at the fixed-sight mark is given by a range 400 yards or less below the top of the zone. The curve is also adjusted so that the elevations required by the 1st and 2nd "Down 800's" are given by setting ranges of an exact hundred yards, and so that the two "Down 800" corrections are spaced as evenly as possible.

The fixed-sight zone is 400–2,200 yards, and, where the R. to E. gear is in the table, the ranges to set are shown on a tally plate on the table, viz. :—

| | |
|---|---|
| Fixed-sight mark .. .. .. .. .. .. .. | 1,800 yards |
| 1st Down 800 .. .. .. .. .. .. .. .. | 1,400 yards |
| 2nd Down 800 .. .. .. .. .. .. .. .. | 1,000 yards |

The equally-spaced range graduations of the R/E.D. units are required for use above 10,000 yards, as well as from zero to 10,000 yards ; they cannot therefore be altered in any way, so the increase in elevation required for each of the graduations must be decided upon, and the cam cut to suit.

The method of confirming that the change of elevation per 100 yards is suitable, is shown in the following example :—

"Kent" fore director. Full charge. Vicker's drawing No. 11150D.

Upper limit of fixed-sight zone is 2,200 yards. 5 feet at this range subtends an angle of :—

$$\frac{5 \times 1{,}146}{2{,}200} = 2\tfrac{1}{2} \text{ minutes}$$

Fixed-sight mark is at 1,400 yards.

From curve 1,400 yards is 57·2′ elevation.

| | | | | | | |
|---|---|---|---|---|---|---|
| ,, | ,, | 1,500 | ,, | , | 59·1′ | ,, |
| ,, | ,, | 1,600 | ,, | ,, | 60·9′ | ,, |
| ,, | ,, | 1,700 | ,, | ,, | 62·6′ | ,, |
| ,, | ,, | 1,800 | ,, | ,, | 64·2′ | ,, |
| ,, | ,, | 1,900 | ,, | ,, | 65·9′ | ,, |
| ,, | ,, | 2,000 | ,, | ,, | 67·6′ | ,, |

Average change per hundred yards, 1·7 minutes.
Though $2\frac{1}{2}'$ is desired, 1·7′ is quite acceptable.

If the change of elevation per hundred yards had not come within acceptable limits it would be necessary to reconsider the design of the cam.

When new cams are designed, the above requirement should be borne in mind ; it is, however, of greater importance that the change of elevation per hundred yards should remain more or less constant for some distance above the fixed-sight mark than that its value should be exactly as stipulated above. The practical application of the fixed-sight procedure is described in the "*Firing Manual*" *Parts 2 and 3.*

161–166.

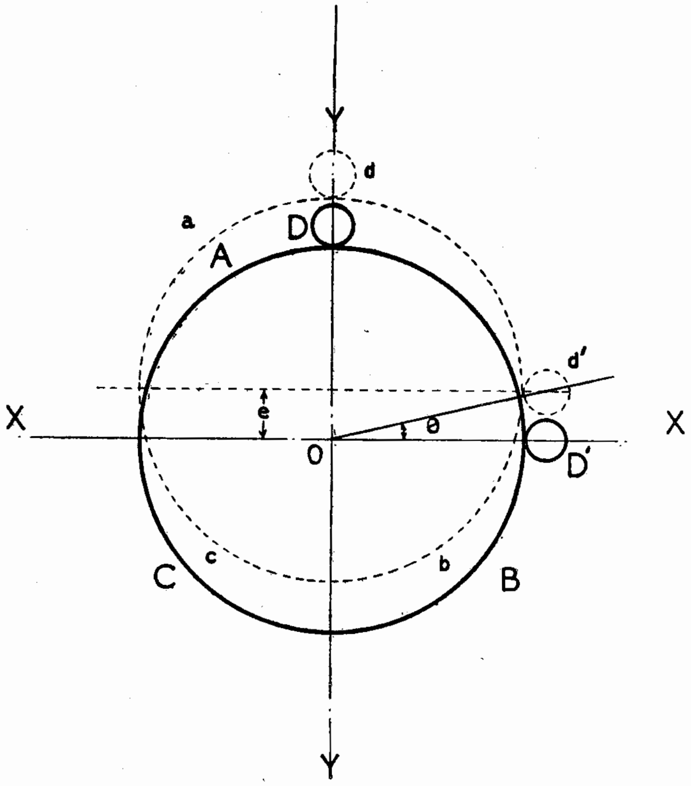
CHAPTER IX

# ECCENTRICITY OF TRAINING RACKS

**ERRORS IN TRAINING (arising from eccentricity of rack driving mechanical training pointers)**

167. In order to understand the importance of concentricity in the erection of the training racks, which drive the black pointers of director receivers, a working knowledge of the considerable error which otherwise occurs is necessary. There is no error when the mechanical pointers are driven off the training gears as opposed to the training rack.

*Diagram 9.* **Eccentricity of Training Racks and the Errors involved.**




Irregularities in a director test for training will reveal the error, and it will be found that it disappears on the diameter " YY " and rises to a maximum right and a maximum left on opposite ends of the diameter " XX " at right angles to " YY ".

Suppose the circle " A, B, C " to represent the correct position for a training rack, whose centre of rotation is at " O " and " *a, b, c* " to represent the rack as laid down eccentrically.

Let " D " be the rack pinion engaging in the first circle and " *d* " the rack pinion engaging in the second.

Now if the gun director be trained through 90° and the guns trained so that the black pointers are again in line with the red, pinion " D " will move to " D′ " and pinion " *d* " to " *d′* ", because both rack pinions must revolve the same number of times to move the black pointers through 90°.

Consider the two racks as being on separate gun mountings, and it is at once apparent that the bearing, on which the first gun is trained, differs from that upon which the second is trained by the angle $\theta$.

The relation between the amount of rack eccentricity and the angle " $\theta$ " is determined as follows :—

The distance " *e* " between the centre of rotation of the mounting and the centre of the rack can be measured at the circumference on the diameter " YY ", and the pitch radius of the rack, " R " is known.

**CALCULATION OF TRAINING ERROR (introduced by a known degree of eccentricity)**

168. Having regard to the probable size of the angle and the relatively large pitch radius of the rack, the distance along the arc between the position of the two pinions may be considered as approximately equal to the distance " *e* ".

$$\text{Therefore } \theta = \frac{e}{R} \text{ radians}$$

$$\text{or } \theta = \frac{e}{R} \times \frac{180}{\pi} \text{ degrees}$$

As an example, consider a 6-in. mounting, whose training rack is found to be ¼ inch out of centre, and see what error will be caused in training.

The pitch radius of the training rack is 24·44 inches.

$$\text{Then } \theta^\circ = \frac{\frac{1}{4}}{24{\cdot}44} \times \frac{180}{\pi}$$

$$\theta = 35{\cdot}2 \text{ minutes}$$

or 307 feet at 10,000 yards.

**CALCULATION OF THE DEGREE OF ECCENTRICITY (causing a known training error)**

169. Conversely, if a 4-in. mounting is found to have a maximum training error of ½°, how much eccentricity does this represent ?

The pitch radius of the rack is 20 inches.

$$\text{Then } e = \frac{\frac{1}{2} \times 20 \times \pi}{180} \text{ inches}$$

$$= 0{\cdot}175 \text{ inch.}$$

That is to say, that the rack is 0·175 inch out of centre.

**METHOD OF TESTING FOR ECCENTRICITY**

170. The training racks of transferable mountings can be quickly tested for eccentricity as follows :—

Attach a pointer to the revolving part of the mounting, in any convenient position, such as the bracket carrying the bearing reader. Arrange it almost to touch a parallel roller, of diameter equal to the chord of the gap between the teeth of the training rack on the pitch circle, placed in the space between the teeth. The circle, which the pointer will describe, as the mounting is trained, will be concentric with the centre of rotation of the mounting. Train the mounting through its full arc and notice whether the centre of the roller remains the same distance from the pointer. If it does not, the rack is out of centre and must be shifted.

*NOTE* :—In the event of it not being practicable to adopt the above method the tips of the teeth of the rack could be worked to, but it cannot be guaranteed that the pitch circle will be absolutely concentric with the circle, which included the tips of all the teeth. Arrangements are being made for the pitch circle to be marked in future on all training racks. This will enable any eccentricity between the centre of rotation and the centre of the pitch circle to be readily detected.

The training rack of a turret is of so large a diameter that errors of concentricity are unlikely to be very noticeable in the receiver ; and they must in any event be accepted.

**171–176.**

CHAPTER X

# TRAINING OF DIRECTOR CREWS AT SEA

**GENERAL**

177. The selection and general technical training of Director Layers is undertaken in the gunnery schools. The instruction given in the schools equips the Director Layers with considerable technical knowledge, but with little practical experience beyond that obtained on the Rypa mountings.

At sea no reasonable opportunity of practice under varying weather conditions should be missed, and the Gunnery Officer must personally supervise from time to time to ensure that the practice is being carried out on the right lines. He can verify the aim at the trainer's telescope or at an alternative director as described in *Chapter VIII of the " Handbook of Gunnery Organisation "* (B.R. 974). His occasional supervision of pointer-following practice is equally necessary to make sure that the conditions simulated are sufficiently realistic.

Likely conditions which are sometimes overlooked in training drills and practices are those in which there is considerable cross-level angle. Under those conditions the task of the Director Layer is particularly difficult, since he has to forecast (when T.I.C. gear is not being used) with his horizontal crosswire (whether stabilised or not) canted out of the horizontal. Most Rypas on which he will have received his preliminary training do not cater for this aspect of cross-level, and it is therefore one in which he will require considerable practice and guidance.

Briefly, it must be remembered that no Director Layer can be proficient by virtue of qualifying alone and none are exempt from the necessity of continual practice and the co-operation of the Gunnery Officer in their training.

**NON-FIRING PRACTICES**

178. The following are routine drills for exercising the Director Crew and Gunlayers.

### Follow-the-Pointer Drill

This is primarily for the benefit of the Gunlayer, but is also valuable for getting the Director Layer used to the time interval between salvos. The guns must be brought to the loading position between salvos and the normal rate of fire used by the fire gong operator. This drill must be carried out very frequently at sea and in harbour. It is highly desirable that the pointer-following errors be recorded, officers being used for this purpose whenever possible in order that a reliable record may be obtained.

### Time-on-Aim Practice

This is important, since the time on aim after the fire gong has rung has a serious effect on the rate of fire.

The Gunnery Officer or Director Gunner should take the Trainer's telescope to check the amount of forecast being applied. The time from Fire Gong to " *FIRED* " should be recorded. This exercise can only be done at sea when some form of target is available.

### Co-operation between Fire Gong Operator, R/E Operator and Director Layer

The object of this practice is to cut down the interval after a spotting order. Dummy control runs should be exercised, and some form of record taken of the above interval. Again this exercise is only suitable for carrying out at sea.

### Knowledge of the Behaviour of the Ship

Layers, Trainers and Cross-Levelling Operators should take every opportunity of closing up at their director when the ship is manœuvring at sea under all conditions of weather. Without the intimate knowledge of her behaviour under various conditions of weather and helm which this will give them, forecasting and hunting the roll by the director layer will never be satisfactory, while the Trainer and Cross-Levelling Operator will never develop the ability to train and lay smoothly and continuously. Although some other ship in the vicinity is of great value as a target, some valuable practice can be obtained by the Layer and C.L. Operator laying on the horizon if no other target is available.

### Practice in Forecasting

This is the most difficult practice of all to get without carrying out actual firings. It can, however, be done at sea when firing tubes. The Gunnery Officer should then take the Trainer's telescope and verify that the crosswire is on the point of aim when the tubes go off. It should be remembered, however, that the sound of discharge will take some little time to reach the director. Under normal conditions of roll this lag should just cancel out that part of the time interval which allows for throw of the shell, and the crosswires should therefore appear to be on the point of aim as the sound reaches the director. Particular attention should be paid to this exercise when it is being done on a bearing where there is considerable cross-level angle.

## RECORDS OF FIRING PRACTICES

179. The most valuable practice, from every aspect, is actual full-calibre firing. To analyse the Director Layer's performance the following records should be kept.

(*a*) **Graphical record of level angle**

This is kept on the H.A. table. Throw the director elevation at the table 30 degrees out of step with the director and set 7,500 feet on the height dial in order to get the plot into the centre of the paper. The Layer at the H.A. director then lays on the main armament target and the generated plot gives a record of the level angle, which is the angle which affects the forecasting by the Director Layer. The times of the firing of the main armament salvos are marked on the plot and hence all necessary data concerning the point at which the salvo fired can be obtained.

(*b*) **Record at the secondary director**

Where a secondary director is fitted having a director elevation repeat which can be seen from the Director Layer's position, the following record should also be taken :—

One rating lays the director by following the electrical transmission from the controlling director as if laying a gun. The Layer of the secondary director looks through his telescope and notes the position of his crosswires at the moment that the gun fires.

If these two records are studied in conjunction with the " hitting gun range curve " on the analysis chart, it can be seen to what extent the forecasts were effective.

(*c*) A *TIME-ON-AIM* record should always be taken during all firing practices.

180–184.