THE HIGH ANGLE CONTROL SYSTEMS, MARKS III AND IIIc

The High Angle Control System Mark III is fundamentally the same as the H.A.C.S. Marks I*** and II***, the main difference being the use of an improved transmission system consisting of oil power motors with A.B.C. control in place of electrical D.C. motors. The design of the calculating table has been altered to improve the accessibility of parts and the general maintenance.

2. The most important modifications introduced in the Mark III system may be summarised as follows. Some of these have since been or are being incorporated in the Mark I and Mark II tables.

(*a*) The observed plot is produced directly by mechanical combination of log sin S*p* and log height without power follow-up. The $\frac{1}{R}$ transmitter controlling the rangefinder prism is contained in the table and driven by a power follow-up of observed range.

(*b*) The generated plot is produced by a combination of the log height in use and log sin S*p* generated by the rate unit: thus the generated plot is not directly affected by irregularities of laying or roll correction.

(*c*) Range/height conversion gear has been completely re-designed to overcome the mechanical faults of H.A.C.S. I and to give increased accuracy.

(*d*) Convergence correction mechanism is provided in conjunction with the own speed corrector to correct vertical and lateral deflection crosswires for the lateral distance to the mean point of the guns on the fore and aft line. In ships where the distance apart of guns is such that a mean convergence correction would not be sufficiently accurate (*e.g.*, anti-aircraft cruisers), a gun training unit and convergence corrector is fitted in conjunction with the table for lateral deflection for L.A. fire.

(*e*) Provision has been made for marking the plot when a prediction is made in order that the plot operator can see subsequently whether his prediction was accurate or not.

(*f*) The addition of a high angle director forward area sight (H.A.D.F.A.S.) to the control officer's bracket in the director and the provision of associated projectors in the deflection unit. The use of this sight is described in Part (A) of this handbook.

(*g*) Improved fuze prediction and fuze transmission gear, the latter being automatic. *Note.*—It is not necessary or possible to read off the fuze setting direct from the plot, but a fuze number indicator is provided at the end of the table adjacent to the fuze range handle.

(*h*) Improved transmission system consisting of oil power motors with A.B.C. control in place of electrical D.C. motors.

(*i*) Target speeds up to 350 knots can be set, and an improved projection system is fitted, the latter being considerably more accurate than H.A.C.S. I. Certain projection inaccuracies inherent in previous types of projection units have been to a great extent obviated by moving the position of the axis of the tilting plate relative to the axis of projection.

(*j*) The provision of a gyro roll corrector in place of the liquid pendulum type for feeding roll into the table. This corrector is a separate unit and also provides power stabilisation of the director sight in the vertical sight plane (roll compensation) in the Mark III* director.

(*k*) Mechanical improvements and improved cable leads, switches, etc., have been adopted in the table.

(*l*) The director has been strengthened generally and a 15-ft. range/height-finder has been fitted supported in an anti-vibration cradle.

(*m*) The addition of G.R.U.B. when available. The use of this unit is described in Part (A) of this handbook.

(*n*) The provision of a third log range screw driven by the R.D.F. set.

(*o*) The provision for transmission of deflections and $\frac{1}{R}$ to a table for augmenting fire.

3. Each H.A.C.S. III director works with its own calculating table. Where a group of guns can be controlled from more than one director, circuits are led to the guns from each calculating position and change-over switches at the guns determine the director and table from which they are controlled.

4. The system is intended primarily for high angle fire, but can be used for low angle fire in conjunction with an Admiralty fire control clock, or transmitting clock and low angle deflection calculator. When so fitted, the system is designated Mark IIIc. A typical layout of an H.A./L.A. installation is shown in Plate 23, and some notes on the H.A./L.A. control arrangements are given in Chapter VI.

CHAPTER II

THE CALCULATING TABLE

11. Views of the Mark III calculating table are given on Plates 1A, B, C, 2 and 3. The table is generally similar to previous marks, but considerable improvements have been effected in the layout.

12. A general layout of the calculating gear is shown in Plate 4. The calculating table is fed from its own director with all information other than own speed and the ballistic corrections.

13. Instructions for erecting, dismantling and testing the tables are given in Appendices III and IV. The tables should be tested periodically and their performance compared with the figures recorded on installation. These can be obtained from the official test sheets, one copy of which is supplied with each table.

14. The table is built up of three main structures, the base, the shelf and the deflection screen ; each table unit is bolted to one of these structures. Lining up and erection marks are engraved on all parts.

15. **The base** of the table is secured to the deck of the calculating position and carries the oil motor unit, the constant speed main drive motor, the fuze and firing interval clock, the projection unit slide and the electrical terminal unit.

16. **The shelf,** which bolts to the top of the base, carries the majority of the shafting, the deflection control gear for positioning the deflection projection unit, the tangent elevation gear, the range/height conversion gear, the fuze prediction gear and the elevating and training gear units.

17. **The deflection screen,** which is bolted to the end of the base and the top of the shelf, contains the ground glass screen and deflection crosswires, the angle of presentation mechanism, the azimuth conversion gear and the own course and speed and convergence corrector.

18. **The electric terminal unit** is in a separate compartment at the plot end of the table, access being obtained by removing the end cover. Incoming cables enter at the side of the table under the left-hand side of the plot and are protected by a metal shield. A typical layout is shown on Plate 28, the actual layout for any table being shown on the diagram on the inside of the end cover of the table

19. A 125-watt, 220-volt **heating element** is installed in all tables to expel any moisture that may accumulate when the table is not in use.

20. Five-power follow-up **oil motors** are fitted together with their control gear and cut-offs in a common monobloc on the training and elevating side of the table. The unit is fully described in Chapter VII.

21. **The constant speed drive** is from a 1/6 h.p., 2,400 r.p.m., 220-volt D.C. motor, fitted with the usual form of speed governor. The drive is used for the fuze and firing interval clock ; the plot, the rate unit and the oil motor dither shaft. Consideration is being given to provision of a hand drive for use in event of the main drive motor failing.

SEE NEW PARA 21A ATTACHED.

22. **Alternative hand drives** are fitted wherever necessary to allow the table to be worked should the power follow-ups fail, and are described in detail in the following chapters. The operation of changing over to the hand drive position also operates an Arens rod control, which locks a sprag gear on the oil motor unit. This sprag gear forms part of a shock absorber unit, the other part being keyed to the oil motor shaft.

23. **Autolocks** are fitted throughout the table. They consist of a mechanical device to prevent backdrive.

24. **Stop gears** are fitted where necessary to prevent damage to the table mechanism. No stop gears are fitted on training drives so that any independent unit (*i.e.*, gyro roll corrector) must be suitable for unrestricted training or be fitted with some form of automatic disengaging gear.

25. **Starting the table.** When starting the table the following procedure should always be adopted to prevent any of the power follow-ups running away :—

(1) Make 20-volt L.P. supply and L.P. fuze panel switches.

(2) Make 220-volt generators and A.C. generators.

(3) Close the by-pass valve.

(4) Start the main drive.

(5) Start the oil pump and fan.

(6) When pump is running, open the by-pass valve.

(7) Make A.C. supply to roll gyro.

(8) Start follower motor for roll corrector when gyro is running.

~~26. **A fall of shot instrument** is provided on the bulkhead of each H.A.C.P.~~ It is set by hand with future angle of sight and fuze range, ~~the operator~~ getting his information from the tangent elevation drum ~~and fuze~~ range dial. In calculating positions in which the fall of shot ~~operator~~ cannot conveniently get his information from the fuze ~~range dial~~, the fall of shot instrument is graduated for the fuze ~~numbers which the operator can obtain from the bulkhead fuze transmission unit.~~

See slip

27. **A gyro roll corrector,** which is fully described in Part (D) of this handbook, is fitted in the H.A.C.P. as a separate unit. Director training is fed into this unit by flexible shafting from the table, and roll from the corrector is transmitted electrically to the table.

28. **The duties of the personnel** in the H.A.C.P. are given in the High Angle Firing Manual. A plan of the table showing the positions of the operators is given in Plate 22.

Tests

29. When a table is fitted on board, either new or after reconditioning, the ship's officers are responsible for seeing that it functions satisfactorily, and gives a performance equal to that obtained during the final shop tests after manufacture or reconditioning.

Copies of the results of the final shop tests of the individual tables are supplied to ship's officers. These test results are to be carefully preserved and treated as an essential part of the H.A.C.S. table equipment.

Arrangements are to be made by ship's officers to carry out periodical tests of the table equipments, using the results of the final shop tests for comparison. If the performance of any part of the gear is deemed to be unsatisfactory immediate action is to be taken to rectify the defect.

If a table is transferred to another ship or landed for any purpose, the copy of the result of shop tests is to be handed over with the table and a receipt obtained from the ship's officers or from the appropriate department of the dockyard concerned.

30–40.

(G. 03688/42.—C.A.F.O. P.327/42.)

CHAPTER III

THE DETERMINATION OF DEFLECTION

41. The general principles of the determination of deflection are described in Part (A), Chapter IV, of this handbook. The gear as fitted in the H.A.C.S. III table is shown on Plate 7. The scope as regards target speed is 35 to 350 knots.

THE PROJECTION UNIT (Plates 9 and 10)

42. A diagrammatic arrangement of the optical projection unit as fitted with the A.R.L. projection device is shown on Plate 9. The gear :—

(i) traverses the projection unit as a whole towards or away from the screen by means of the screwed shaft L, which is turned according to u/A.P.V. by the deflection control gear (*see* para. 54 below) ;

(ii) tilts the tilting ring to an angle S_f with the optical axis of the unit ;

(iii) applies a projection correction (*see* Part (A), para 91) by moving the tilting ring in guides inclined at an angle of 45° to the optical axis.

43. The feathered shaft M is driven for future angle of sight and rotates rod H through the bevel wheels J, which are secured to the projector bracket and move along the shaft M when u/A.P.V. alters. The rod H communicates its motion to a worm on the tilting ring framework F through two universal joints, the arrangement being such that the true movement (S_f) of the shaft M is exactly transmitted to the tilting ring notwithstanding any small movement of the framework on its guides.

44. The cam D is rotated for S_f by suitable gearing from the angle of sight drive. The lever B is held against the cam by a flat spring (shown diagrammatically) and the cam is so shaped that it moves the lever about its fixed pivot C in accordance with $\frac{\sin 2 S_f}{2}$.

45. A roller R, carried by a crank lever pivoted on the projector bracket, is pressed against the surface of lever B by a spring. It is connected by a rod and crank lever to the framework F, the movement of which in its guides is thus dependent on the movement of the lever B and on the distance of the roller R from the pivot C.

46. The pivot C is at such a distance from the screen that the roller R is immediately above it when the unit is in the position of true projection and no movement of the tilting circle away from the optical axis is required. In other positions the projection correction described in Part (A), paras. 90 and 91, is applied.

47. The angle of sight movement of the worm and wormwheel is transmitted to the tilting plate through a spring cage which normally keeps the stop k (Plate 10, Fig. 4) on the tilting ring bearing against the stop l in the wormwheel. At very low angles of sight the projection of the ellipse ceases to be sufficiently accurate and movement of the tilting ring below 15° angle of sight is therefore prevented by the fixed stop m which takes against the stop n on the tilting ring. Movement of the angle of sight drive below 15° is absorbed by the clock spring, the stops k and l remaining apart until the angle of sight is again 15°, when the tilting ring is once more moved in the ordinary way.

Note.—Stop m has been altered, so that the lower limit of movement of the tilting ring is now 9° angle of sight. P429/42.

Adjustment of the Projection Unit (Plate 10)

48. The scale of the deflection screen is such that the distance in inches the crosswires are moved from the centre of the screen for any deflection angle is 22 tan deflection angle, *i.e.*, 22 u/A.P.V. Since the angle of projection is $\tan^{-1}\frac{1}{3}$ (*see*

Part (A), Chapter IV, para. 91) the distance in inches of the point of projection from the screen for any value of u/A.P.V. is 22 u/A.P.V. $\times$ 3 and the position of true projection (when u/A.P.V. $= \frac{1}{3}$) is with the point of projection 22 inches from the screen (*see* Plate 9). In this position, no movement of the tilting plate framework in the guides should occur when the angle of sight is altered and the centre of the tilting circle should be accurately on the optical axis of the unit. This can be checked by means of a peg which, with the tilting ring in correct alignment, can pass through corresponding holes in the framework and guide. This position is adjusted during manufacture by altering the effective length of the crank lever (adjustment A in Plate 10) and should not require subsequent attention.

49. Detail of the projection unit is shown on Plate 10. It must be assembled so that the optical axis of the unit is parallel to the projection slide and passes through the centre of the deflection screen. This may be tested by setting 90° S_f and seeing that the centre of the projected circle coincides with the centre spot of the screen for all values of u/A.P.V. With the tilting circle in the position of true projection (para. 47 above), the necessary adjustments can be made at B, C, D and E (Plate 10), the projection unit being moved upwards by B and C and sideways by D and E. The adjustments are normally made on erection and should not be subsequently moved unless absolutely necessary.

50. **Illumination** is from a fixed focus 220-volt, 100-c.p. Point-o-lite lamp with a 22-volt, 30-watt auxiliary projector lamp (Plate 10). Normally the auxiliary lamp is not in use, but, if the Point-o-lite fails, it can be raised at once into a position of correct focus by unscrewing the butterfly nut Q and moving the whole lamp-carrying bracket (para. 52 below).

51. The Point-o-lite is aligned with the optical axis by means of the screws F and G, and is focussed by the screw H. Focussing is best carried out with the angle of sight about 45°. In this position the circle is not all in the focal plane of the lens system and a sharp focus throughout is unattainable, but in the best position the blurring of the image is not very great. If the Point-o-lite is not in the optical axis, the light on the screen will be coloured and definition will be poor. Re-adjustment of the Point-o-lite will usually be necessary whenever a new lamp is shipped.

As the auxiliary lamp is carried on the main assembly of the Point-o-lite lamp the setting of the auxiliary lamp should also be checked and if necessary re-adjusted whenever a new Point-o-lite lamp is shipped.

52. The Point-o-lite and auxiliary lamp are carried in a common bracket which is normally in the position shown (Plate 10, Fig. 2) with the toe P butting against the carrier. It is in this position that the Point-o-lite is adjusted. The auxiliary lamp is brought into position by unscrewing the butterfly nut Q, tilting the bracket up against the adjustable stop N and securing it. In this position the auxiliary lamp is aligned with the optical axis by the screw L (which gives a sideways adjustment relative to the Point-o-lite) and the stop N (which governs the height the auxiliary lamp is raised). Focussing is then done by means of the auxiliary lamp focussing knob. The two latter adjustments are to a certain extent interdependent.

53. It will be realised that all the above adjustments are done by trial and error, the lamps being set to the position that will give the most satisfactory projection over the full range of the unit.

The unit should be tested periodically in accordance with Appendix IV.

DEFLECTION CONTROL GEAR (Plate 8)

54. The projection unit is positioned for u/A.P.V. by the **deflection control gear** shown in Plate 8.

55. The *average projectile velocity* is obtained from the *A.P.V. drum,* which is rotated by the *follow log H drive* and is graduated in *fuze range curves.* The latter are so constructed that hand positioning of the pointer against the appropriate fuze range curve (as read off the fuze range receiver) : —

(i) sets the average projectile velocity on the A.P.V. slider of the control gear (*see* Fig. II) ;

(ii) positions the convergence cam (*see* para. 71 below), where the gun training unit with convergence gear is not fitted ;

(iii) positions the drift cam (*see* para. 79 below).

56. **Enemy's speed** (u) is estimated by the control officer and set on the target speed transmitter in the director tower. This controls the target speed " M " type motor in the control gear, which positions the target speed slider and a pointer on the target speed dial. Where G.R.U.B. is fitted the target speed is produced by the G.R.U.B. and transmitted to the table in place of that estimated by the control officer.

57. Movement of the target speed and A.P.V. sliders is communicated to the u/A.P.V. sensitive quadrant, which is thus rotated according to $\tan^{-1} u$/A.P.V., and offsets the hunter controlling the " A " element of the u/A.P.V. oil motor.

58. The u/A.P.V. oil motor runs and :—

(i) positions the projection unit ;

(ii) drives the u/A.P.V. power quadrant, which converts u/A.P.V. into tan u/A.P.V. to recentre the hunter controlling the " A " element and stop the oil motor.

59. **Stops** are fitted to restrict the settings as follows :—

A.P.V.	4-in., Mark V gun, 870 to 2,100 ft. per second, 4-in., Mark XVI gun, 1,050 to 2,350 ft. per second, 4·5-in., Mark I and 4·7-in. Mark VIII guns, 1,000 to 2,230 ft. per second ;
Target speed ..	35 to 350 knots ;

u/A.P.V. giving deflection angles from 1° 30′ to 25°.

60. An alternative hand drive, with sprag gear and shock absorber unit is fitted for u/A.P.V. When using the hand drive, the " A " element must be followed, *i.e.*, the line on the moving disc must be kept in coincidence with the two fixed lines. An arrow on the moving disc indicates which way to turn the hand drive, should the centring line be out of sight.

ANGLE OF PRESENTATION (Plate 7)

61. The angle of presentation set by the control officer to align the graticule in his binoculars is transmitted to an " M " type motor (yellow), which rotates the angle of presentation ring in the deflection screen. When G.R.U.B. is fitted the ring is rotated by the presentation transmitter in this instrument. The angle of presentation pointer is fixed to this ring, which has all round movement corresponding to twelve hours change in angle of presentation, no stop gear being fitted.

62. An angle of presentation receiver is also fitted at the plot end of the table for the information of the plot operator.

AZIMUTH CONVERSION GEAR (Plate 7)

63. The movement of the vertical crosswire on the screen is a measure of the tangent of the lateral deflection angle (*see* para. 48 above), *i.e.*, $\propto \tan D_l$. Before being applied to director training the movement must be converted into deflection in azimuth according to the formula :—

$$\tan D_a = \tan D_l \sec S \text{ (see Part (A), Plate 2).}$$

When G.R.U.B. is fitted corrections are applied to angle of presentation and target speed to suit the inherent errors of the H.A.C.S. The D_l therefore produced is correct and requires to be multiplied by sec S_p to produce tan D_a. The formula for the azimuth conversion gear with G.R.U.B. fitted thus becomes :—

$$\tan D_a = \tan D_l \sec S_p.$$

64. This is done by the azimuth conversion gear, shown in Plate 7. The two green quadrants AA are rotated about the pivots CC by the angle of sight drive so that the arms BC are now moved through an angle S_f from the normal, thus positioning the bar BB at a distance proportional to cos S_f from the pivot D, which lies on the line CC. The mauve deflection slider carrying the yellow sliding block E is rotated about D by the deflection quadrant according to the movement of the lateral deflection handwheel. The slider E positions the orange result rack FF, which moves along the bar BB and drives the lateral deflection crosswires through the result pinion G.

65. From Plate 7, Fig. II, it will be seen that if DD is the perpendicular from D on to BB, and DF represents the movement of the result rack, then the angle DDF represents the movement of the deflection handwheel and DF is proportional to the movement of the lateral deflection crosswire. Hence, ignoring constants,

$$\tan \angle DDF = DF/DD$$
$$= \tan D_l / \cos S_f \quad (DF \propto \tan D_l, \text{ para. 63 above}).$$
$$= \tan D_a.$$

The movement of the lateral deflection handwheel is therefore a true measure of the deflection in azimuth and it can be added differentially to director training (*see* para. 84 below).

To compensate for the unavoidable working backlash in the azimuth conversion gear, the lateral deflection handwheel has an intentional backlash device fitted, which allows it to be moved sufficiently to take up the backlash before any deflection correction is fed into the director training drive.

66. Mechanical **stop gear** is fitted to limit deflection in azimuth to values between 0° and 50° right and left. At low angles of sight this is outside the scope of the deflection screen and the lateral deflection crosswire screws are therefore fitted with a wrap up at each end to accommodate the extra movement.

67. The arrangements for applying deflection in surface fire are discussed in Chapter VI.

OWN COURSE AND SPEED AND CONVERGENCE CORRECTOR (Plate 7)

68. As stated in Part (A), paras. 101 and 102, the formulæ to be solved are :—

Vertical — *Lateral*

Own course and speed :

$$\tan D_V^S = \frac{S \cos B \sin S_f}{V} \qquad \tan D_l^S = \frac{S \sin B}{V};$$

Convergence :

$$\tan D_V^C = \frac{L \cos B \sin S_f}{R} \qquad \tan D_l^C = \frac{L \sin B}{R};$$

Total correction :

$$\tan D_V^{S+C} = \left(\frac{S}{V} \pm \frac{L}{R}\right) \cos B \sin S_f \qquad \tan D_L^{S+C} = \left(\frac{S}{V} \pm \frac{L}{R}\right) \sin B.$$

69. In the corrector the brown bearing disc is rotated according to future training from the gun training drive. On its back the disc has two guides which are thus positioned for *bearing*. Setting own speed moves a yellow slider in these guides so that the pin (1) is a distance corresponding to $\frac{S}{V}$ from the centre of the disc, the muzzle velocity (V) being, for practical purposes, constant.

70. Future training is also made to rotate the speed setting knob and dial as otherwise rotation of the bearing disc would cause a setting of own speed to be applied.

71. The brown **convergence cam** is rotated by a drive from the A.P.V. handle (para. 55 above) and converts A.P.V. into $\frac{1}{R}$ at a mean angle of sight, the errors at other angles of sight being negligible, to drive the convergence quadrant. The movement of the convergence quadrant is added differentially to the future training drive to the own speed setting knob and dial, the gearing being arranged to suit

the distance (L) in the fore and aft line between the director and the mean position of the guns. No allowance is made for the guns being out of the fore and aft line of the ship, as the error is too small to justify the complications necessary to correct it, nor is any allowance made for individual guns.

72. The own speed setting is thus given an additional movement corresponding to $\frac{L}{R}$ and the pin (1) on the bearing disc is moved a distance corresponding to $\left(\frac{S}{V} \pm \frac{L}{R}\right)$ from the centre of the disc. The pin positions two blue sliders (2 and 3) which are set at right angles to each other so that they move along and across the line of fire in the horizontal plane. The movements imparted to them therefore represent $\left(\frac{S}{V} \pm \frac{L}{R}\right)$ sin B and $\left(\frac{S}{V} \pm \frac{L}{R}\right)$ cos B respectively.

73. The value thus obtained for the correction for **speed across and lateral convergence** is a measure of tan D_L^{S+C} (para. 68 above) and can therefore be added differentially to the lateral deflection drive from the azimuth conversion gear, which is also a measure of tan D_l (para. 63 above). The correction moves the lateral deflection crosswire which has to be realigned by the deflection handwheel, thus adding the necessary correction in azimuth to the training drives.

Note.—In H.A.C.S. IIIc fitted with A.F.C.C. Mark VIII, and sometimes when in association with range transmitting clock and deflection calculator, the convergence member of the differential is locked by means of a fixed spur gear which takes the place of the convergence result wheel. The $\frac{1}{R}$ cam and quadrant remain in the table but the quadrant does not engage with the result wheel.

In certain recent ships the $\frac{1}{R}$ cam and quadrant have not been fitted.

74. The value obtained for *speed and separation along* the line of fire has to pass through a further link mechanism to obtain the vertical deflection. The gear is arranged as follows :—

(*a*) the blue intermediate slider (3) raises the end of the yellow pivot bar (4) a distance representing $\left(\frac{S}{V} \pm \frac{L}{R}\right)$ cos B by means of the pin (5);

(*b*) the green S_f quadrant (9) is rotated by the green angle of sight drive and through the pin (8) moves the sin S_f slider (7) transversely an amount representing sin S_f (Plate 7, Fig. III) ;

(*c*) The sin S_f slider (7) positions a yellow pin (6) on the pivot bar (4) a corresponding transverse distance from the grey fixed pivot (the pivots of the bar and S_f quadrant are in line) and in so doing moves the pin upwards a distance representing $\left(\frac{S}{V} \pm \frac{L}{R}\right)$ cos B sin S_f (Plate 7, Fig. III).

75. The latter movement is equal to tan D_V^{S+C} (para. 68 above) and is communicated through a rack on the blue vertical result slider (10) to a differential in the vertical deflection handwheel drive. The vertical deflection crosswire is thus offset by the red vertical deflection crosswire screws and must be realigned by the vertical deflection handwheel.

76. The movement of the vertical deflection handwheel is transmitted to the horizontal crosswire through tangent screws so that while the movement of the handwheel is vertical deflection, the movement of the crosswire represents tan D_V (*see* para. 48 above). The correction for own ship and vertical convergence is added by the differential to the drive between the handwheel and the screws and the elevation correction applied is therefore tan D_V^{S+C} instead of D_V^{S+C}, but since the correction is small the error is inappreciable.

77. The normal maximum own speed setting arranged for is 40 knots, and the corresponding scope of the corrector is 1° 38′ in any direction.

Note.—In certain ships having a large forward convergence it has been necessary to restrict the maximum own speed setting to about 37 knots, although never more than 40 knots own speed movement is provided. The total scope of the corrector is approximately 80 knots or 3° 18′ in any direction, the additional 40 knots movement being used for convergence effect when guns are forward of the director. The convergence effect for guns abaft the director is opposite to that of own speed, and consequently the movement of the corrector is always less than 40 knots (except that it would throw off in the reverse direction at zero own speed and maximum A.P.V. and this could, with a large aft convergence be as much as the equivalent of 80 knots).

Damage to Lateral Deflection Crosswire Lead Screw

P.1146/41 78. ~~In ships where the H.A. guns are *forward* of the H.A. director there~~ There is a possibility of damage being caused due to the combination of certain settings of lateral deflection, own speed and convergence correction necessitating a greater travel of the lateral deflection crosswire than is permitted by the lead screw. Reference should be made to the caution plate on the table concerning the positions of the deflection wires when table is left unattended.

Convergence Correctors in A.A. Cruisers

79. In anti-aircraft cruisers, where individual guns are widely separated, special arrangements are fitted to apply the lateral convergence corrections. These arrangements are dealt with in detail in Chapter VI.

DRIFT CORRECTION (Plate 7)

80. In H.A. fire drift correction is a function of angle of sight and A.P.V. The gear required to give an exact correction would be complicated, so a mean correction is obtained from a drift cam (mauve) rotated by a drive from the A.P.V. handle (para. 55 above). The correction obtained is very nearly correct at 30° angle of sight and except at extreme ranges the errors at other angles of sight are negligible. The drift cam fitted to most Mark III tables is arranged to give 6′ correction at maximum A.P.V., *i.e.*, minimum fuze range. In a few recent tables, where reduced charges have been arranged for, the drift cam gives no correction at maximum A.P.V.

81. The drift correction is applied through the azimuth conversion gear. Rotation of the drift cam moves the shaft engaging the deflection quadrant longitudinally, thus rotating the deflection quadrant and displacing the lateral deflection crosswire. The lateral deflection crosswire has then to be realigned by means of the lateral deflection handwheel, the movement of which applies the drift correction differentially to director training (*see* para. 84 below).

TANGENT ELEVATION (Plate 4)

82. Tangent elevation is applied differentially to the director setting drive. It is a function of angle of sight and range and is obtained from the tangent elevation drum. The drum is rotated for future angle of sight and is marked with fuze range curves, against which a pointer is set by hand in accordance with the range showing on the fuze range receiver. The graduations include an approximate correction for **dip.**

83. Mechanical **stop gear** limits the tangent elevation settings from 0° to 21° and an **auto-lock** is fitted to prevent the correction being altered by a back drive from the table gearing.

BARRAGE FIRE

84. Deflections in barrage fire are obtained by means of a **H.A.D.F.A.S.** (*see* para. 323) fitted in the H.A. director. This is used in a similar manner to all eyeshooting sights (*see* Part (A), Chapter II, of this handbook), the control

officer setting the required point of aim by **independent laying and training handwheels** which move the H.A.D.F.A.S. relative to the director telescopes. The movements of these handwheels are measures of the vertical and lateral deflection, and each controls an **independent projector** in the deflection unit. The projectors are moved electrically through the required angles of deflection and when switched on throw two strips of light on to the deflection screen. The deflection operator aligns his crosswire with these strips and deflections are fed into the table in the ordinary way.

A **barrage switch** is fitted on the deflection screen for switching on the independent projectors when required.

SURFACE FIRE

85. Arrangements for estimating the deflections required in surface fire are discussed in Chapter VI.

GUN TRAINING (Plates 4 and 6)

86. The arrangement of the table training drives is shown diagrammatically on Plate 4 and in more detail on Plate 6. Gun training is obtained as follows :—

(i) Movement of the director trainer's handwheel controls the director training oil motor feeding director training into the table and also driving the director training black pointer, the director training repeat transmitter and the flexible drive to the roll corrector.

(ii) Movement of the lateral deflection handwheel adds deflection in azimuth (including the corrections for own speed, convergence and drift) differentially to the power drive to make gun training which drives the gun training transmitter, gun training dial black pointer and own course and speed corrector. An autolock is fitted in the lateral deflection handwheel drive to prevent a back drive from director training.

87. An alternative two speed hand training drive is fitted, movement of the handwheel in and out altering the training speed. The hand/power lever locks the training handwheel when put to " power," and sprags the oil motor drive and inserts a shock absorber when put to " hand." When hand training is used the operator follows the green pointer of the director training dial, which is driven direct by " M " type transmission from the director, with the black pointer.

88. There are *no stops* in the training drives.

GUN ELEVATION (Plates 4 and 6)

89. The arrangement of the table elevation drives is shown diagrammatically on Plate 4 and in more detail on Plate 6. Gun elevation is obtained as follows :—

(i) Movement of the director setting hunter, in the director, controls the director setting oil motor feeding director setting into the table and also driving the director setting black pointer and the director setting repeat transmitter.

(ii) Tangent elevation from the tangent elevation drum and vertical deflection (including the corrections for own speed and convergence) from the vertical deflection handwheel are added differentially to the power drive to make gun elevation, which drives the gun elevation transmitter and the gun elevation dial black pointer. Auto locks are fitted in the vertical deflection and tangent elevation handwheels to prevent a back drive from director setting.

90. An alternative two speed hand elevating drive is fitted, movement of the handwheel in and out altering the elevating speed. The hand/power lever unclutches the elevating handwheel when put to " power " and unclutches, sprags and inserts a shock absorber in the oil motor drive when put to " hand." When hand elevating is used, the operator follows the green pointer of the director setting dial, which is driven direct by " M " type transmission from the director, with the black pointer.

91–110.

CHAPTER IV

RATE OF FIRE AND DEAD TIME

111. The factors governing the choice of a definite rate of fire and dead time are discussed in Part (A), Chapter V, where a brief description of the fuze and firing interval clock will also be found.

THE FUZE AND FIRING INTERVAL CLOCK (Plates 11 and 12)

112. The clock as fitted to H.A.C.S. III is fundamentally the same as that fitted in other marks, the main frame of the clock forming part of the table instead of being constructed as a separate component as in H.A.C.S. I. In order to examine and check the clock the cover can be removed and replaced without the necessity of applying particular settings to the clock, the red crosses on the setting dials being for checking purposes only. With these settings (six rounds a minute and eight seconds dead time) the combination stops should be in operation and the red crosses on the variable speed ball carrier should be in line with the index, as shown on Plate 12.

113. The **rate of fire** is adjustable from 6 to 21 rounds a minute and the **dead time** from 4 to 14 seconds. In early tables (up to September, 1937) the combination stops limit the scope of the clock from 0·8 to 1·8 rounds dead time, the limits being 0·8 to 1·1 rounds for no overlap and 1·1 to 1·8 for single overlap. In later tables the upper limit has been reduced from 1·8 to 1·7 rounds dead time. No arrangements are made for firing with double overlap.

113 A New paragraph see slip A.L. 8.

114. **INSTRUMENTAL DATA**

(i) **The predict lamp** can be adjusted to light up between limits of $\frac{1}{6}$ and $\frac{1}{3}$ of a loading interval before the load lamp.

(ii) **The load lamp** burns for 1·2 seconds irrespective of the rate of fire, and the lighting of the load lamp indicates the commencement of the dead time interval.

(iii) **The fire buzzer** sounds for $\frac{1}{3}$ of a loading interval and the middle of the firing interval coincides with the end of the dead time interval.

(iv) **The intermediate release contact** is energised while the load lamp is burning, *i.e.*, for 1·2 seconds constant time.

(v) **The pointer release contact** is energised for 0·8 second constant time and is arranged to remain energised for ·03 of a firing interval after the fire buzzer has ceased to sound.

115. A diagrammatic arrangement of the fuze and firing interval clock is shown on Plate 11. The clock is started or stopped by a clutch which connects or disconnects the various drums from the table constant speed drive. When the clock is started, drum 1 controls the burning of the predict and load lamps and drum 2 the sounding of the fire buzzer and the burning of the fire lamps. Drum 3 governs the point at which the change from single to no overlap takes place and drum 4, the dead angle drum, is set according to the dead time and rate of fire in use.

116. The clock is controlled by a starting lever which has three positions: "Stop," "Stand-by," and "Start." When the starting lever is put to **Stop** :—

(i) the two contact drums (1 and 2) are automatically brought to the starting position by means of a recentring cam and lever actuated by the starting handle. The positive brush on drum 2 engages in a notch in the drum and tends to hold it in the starting position ;

(ii) the recentring arc brings the dead angle drum to the starting position with the movable stop (5) bearing against the straight side (7) of the raised portion of the drum ;

(iii) the starting switch breaks the electrical supply to the clock and prevents the fire buzzer sounding or the lamps burning while the drums are moving back to the starting position.

117. When the starting lever is put to " **Stand-by** " the circuits are made, but the clutch is still disconnected. Putting the starting lever to " Stand-by " also engages the paper drive clutch and the paper commences to run (*see* para. 151).

118. When the starting lever is put to **" Start "** :—

(i) the starting clutch (red, *see* Plate 12) engages and drum 1 starts to revolve, burning the predict and load lamps (contacts M and Q) for each round according to the rate of fire set on the variable speed gear ;

(ii) drum 2 is held by its positive brush and the dead angle differential (A) drives the dead angle drum until the pale green stop (5) has moved from the straight to the curved side of the raised portion, when the dead angle drum is stopped ;

(iii) drum 2 is then driven through the dead angle differential at the same speed as drum 1, but in the opposite direction, sounding the fire buzzers and burning the fire lamps (contact G) for each round.

119. The dead time allowance depends on the time that elapses between drum 1 and drum 2 starting to revolve and is set on the dead angle drum as follows :—

(i) dead time in seconds and rate of fire in rounds a minute are set by two handwheels, blue and orange, against logarithmic scales on the clock ;

(ii) the two settings are added in the rounds dead time differential (B) and position the stop 5 in accordance with

log dead time in seconds + log rate of fire in rounds per second *= log dead time in rounds.* P276/42.

120. The raised portion of the dead angle drum is cut so that the angular distance between the straight and curved sides at any point represents the dead time allowance in rounds on a logarithmic scale and the drum is therefore free to rotate an amount corresponding to the dead time in rounds (called the **dead angle)** from the starting position. When dead time or rate of fire are altered with the gear running, the stop 5 is moved through the differential and takes up a new position on the drum. If the change entails a decrease in rounds dead time the stop drives the dead angle drum backwards and if the change entails an increase the drum is allowed a further movement. The settings can be altered at any time without upsetting the working of the clock.

121. It should be noted that the contacts in the clock are so arranged that when the dead angle is set to zero (*i.e.*, when the dead angle drum does not revolve when the clock is started) the dead time allowance is equal to 0·8 round and the dead angle is therefore equal to dead time minus 0·8 round.

THE FUZE RANGE INDICATOR (Plate 11)

122. With improved fuze prediction gear prediction is continuous. The plot operator positions his fuze prediction cursor by means of his fuze range handwheel and in so doing transmits the fuze number to the guns and sets fuze range on the yellow main element (x) of the fuze range indicator (Plate 11). The main element is connected to the red intermediate element (y) by an arm and roller bearing on a heart shaped cam, which tends to keep the two elements in line. The element (y) normally engages with the intermediate release arm and is held until the arm is withdrawn by the intermediate release magnets, which are energised through the load contact Q in the fuze and firing interval clock at the beginning of each loading interval (*see* Part (A), Plates 5 and 6).

123. The fuze range receiver pointer is connected to the intermediate element by a similar blue system (z) and is held in position by the pointer release arm until the release magnets withdraw the arm and allow the pointer to align itself with the intermediate element. The release magnets are energised through the pointer release contact P in the fuze and firing interval clock at the end of each firing interval.

124. In the clock is a pale green **auxiliary contact drum** (3) which is turned through the dead angle when rate of fire and dead time are set. The associated overlap contact E is connected in parallel with the pointer release contact and the contacts on the auxiliary drum are so arranged that if the settings require no overlap, the overlap contact is made and the pointer release arm is disengaged irrespective of contact P. If an overlap is required contact E does not make and the pointer release arm is controlled by contact P.

125. On starting the clock with a single overlap set, the pointer release contact P is energised until the mauve drum 4 has turned through the dead angle and drum 2 starts to revolve. This keeps the pointer and the intermediate element in the fuze range receiver in line long enough for the first fuze to appear on the pointer and, since the dead angle is 0·8 round less than the dead time (para. 121 above) the pointer release contact is broken in sufficient time for the pointer to be locked before the second prediction is made. When starting with a single overlap the sequence of events therefore is :—

(i) Starting lever put to "Stand-by." The main switch is made, but except in later tables, the release magnets are not energised and the predicted fuze does not appear on the fuze range receiver pointer. This may be inconvenient with a short dead time (Part (A), paras. 130 and 131) and an additional switch is fitted in later tables (para. 127 below).

(ii) Starting lever put to "Start." Load lamp lights, contact Q makes and the predicted fuze is communicated to the intermediate element. Contact P remains made until drum 2 starts to revolve and so the fuze range pointer aligns itself with the intermediate element, *i.e.*, it indicates the *first fuze.*

(iii) After 1·2 seconds the load lamp goes out, contact Q is broken and the intermediate element is locked with the *first fuze* set.

(iv) At the expiration of dead time minus 0·8 round, drum 2 starts to revolve, contact P is broken, and the fuze range pointer is locked with the *first fuze* set.

(v) The predict and load lamps light again, contact Q is made and a second fuze is communicated to the intermediate element.

(vi) The fire buzzer lamp lights for the first time and when it goes out contact P makes and the *second fuze* appears on the fuze range pointer.

126. Since contact Q is made while the load lamp is burning, the intermediate element is free to follow the main element during this period. To ensure that the fuze retained by the intermediate element is exactly the same as that set at the guns, the fuze range handwheel should not be moved while the load lamp is burning.

127. In later tables an additional switch is provided on the starting lever as shown dotted. When the lever is put to "Stand-by" the contacts P′ and Q′ make and both release magnets are energised, allowing the predicted fuze to appear at once on the fuze range receiver pointer. When the lever is put to "Start" the positive contact and contact P′ are broken, contacts Q and Q′ are short-circuited and the gear works as described above.

128. The **variable speed gear** is so designed that it gives the correct speeds when set direct from the logarithmic movement of the rate of fire handwheel. The same movement carries the three brushes M, P and Q along tapered sections on the drums, thus maintaining constant contact time with varying speeds of rotation. The fire buzzer brush G bears on a parallel section so that the period of contact varies with the rate of fire and is always one-third of a loading interval.

129. The **log conversion cam** converts the logarithmic setting of dead time into uniform motion for use in the fuze prediction gear (para. 182 below). This avoids setting dead time in two places.

130. **Adjustments.** Check the following :—

(i) In the " Stop " position

(*a*) the positive brushes on drums 1 and 2 engage with the notches cut in their contact rings ;

(*b*) contact M is made ;

(*c*) contact Q is just broken ;

(*d*) contact P is made ;

(*e*) contact G is broken with sufficient margin to ensure that it cannot be made by rotating the drum through the small angle which the lining up notch and positive brush permit.

(ii) In the "Stand-by " position the predict lamp lights and in later tables the fuze range pointer lines up.

(iii) In the " Start " position the load lamp lights and in earlier tables the fuze range pointer moves to agree with the fuze range cursor

(iv) At zero dead angle (the movable stop 5 against a fixed stop at the extreme right of the dead angle setting screw) the brush E is not made.

(v) At maximum dead angle (the movable stop 5 against a fixed stop at the extreme left of the dead angle setting screw) the brush E is made.

Minor adjustments can be made by the backing up strips under the brushes.

131. Details of further tests are given in Appendix IV and the test sheets.

132–150.