

Fire Control

A GUIDE FOR MODELLERS OF BRITISH WARSHIPS,
MAINLY 1939-45 PERIOD

by Peter Hodges

THE FIRST part of this article* covered the introduction of the Director system to British warships and dealt principally with the development of Director Towers and Director Control Towers associated with the Fire Control of surface weapons.

This month, the background to the directors employed in anti-aircraft control, as well as those adapted to fill a dual-purpose rôle will be traced.

As a preliminary, it is worth mentioning that before and during the second world war, the equipment which made up the 'anti-ship' armament was known as Low Angle, or 'LA'; and that associated with anti-aircraft fire, as High Angle, or 'HA'. Post-war, this was changed to 'SU'—for surface—and the self-evident 'AA'; and at about the same time, the use of Roman numerals to distinguish the various marks was abandoned in favour of Arabic numbers. (For example, 'HA/LA Mk VI' became 'AA/SU Mk 6').

POST 1919 DEVELOPMENTS

The potential of the military aircraft had been clearly demonstrated in the first world war, but during it no concerted effort was made to provide a solution to the fire control problem involved.

This in itself was difficult to solve for several reasons. The targets were already many times faster than those on the surface; they were considerably smaller; and their position relative to the firing ship was three- rather than two-dimensional. When one adds the extra complications of the aircraft's high manoeuvrability and that its speed could only be estimated, it will quickly be realised that the likelihood of scoring a direct hit on a distant airborne target was remote.

With this in mind, two forms of AA defence were evolved. The first was long range predicted fire using a time-fused projectile, set to explode in the vicinity of the target and produce a lethal 'volume' of splinters in the sky; and the second was close range fire using contact-fuse shells. In fact, the design of the time-fuse nose cap was such that it would also explode on contact, should the predicted trajectory be sufficiently accurate. In the case of the close range projectile, the fuse was designed with a 'graze' contact so that it was especially sensitive and would be detonated even if it merely 'brushed' the target.

Since the close range weapons were to fire these contact-fuse shells, it followed that to increase the hit-probability, they should have:

- (i) a high rate of fire
- (ii) multi-barrels wherever possible
- (iii) ammunition for sustained fire
- (iv) high elevation and training speeds.

These requirements led to the development of the 'pom-pom' style mountings but for the moment, they need not be investigated further.

The problems involved in predicting the future position of a manoeuvring target, flying at an unknown speed and at a changing height, were so severe that no attempt was made to solve them. Instead, the assumption was made that a high level bomber would have to remain on a constant course, at a constant height and at a constant speed if he were to hope for a successful attack. For, of course, the bomb-aimer had his problems, too.

The 'strike fighter' did not exist in those days and little damage was envisaged from an attack by the contemporary fighter planes. On the other hand, much concern was felt regarding defence against low-flying torpedo bombers, and if these escaped the long range fire, they were to be engaged by the close range weapons. It will be observed that the dive-bomber, which was to become such a menace, was not considered; and it was fortunate indeed that it could be engaged by the existing close-range guns—although these were frequently lamentably lacking.

PREDICTED ANTI-AIRCRAFT FIRE

Accepting the height-speed-course constants (which were justified insofar as the high level bombers were concerned), work commenced on the design of a control system to be capable of calculating the future position of the target and converting this into terms of Gun Training, Gun Elevation, and Fuse Setting. As we have seen, it was

*June 1970 issue, page 480



Top: The battleship Resolution in July 1935 with the first HACS arrangement, the director being visible above the Spotting Top on the foremast. **Above:** Battleship Barham in 1938 with the 'doubled up' HACS system on the centre line. One director remains atop the Spotting Top, the second director being on the platform between the mainmast legs.

too much to expect the trajectory to pass exactly through this future position but the shell had to burst close enough to inflict lethal damage. The well-proven Director System was used to control the guns and the arrangements were known as the High Angle Control System, or HACS.

THE HACS DIRECTOR

This was an integral part of the system as a whole and usually carried the same mark number as its associated HACS table. All the directors were fitted with a range finder instrument but in this application it was known as a Height Finder. It did, of course, measure range, but height is a simple trigonometrical function of range and elevation and could be easily determined provided that the latter quantity did not fluctuate. This, it was bound to do because the director layer would need to constantly counteract ships' movement in a seaway, so a gyro-stabiliser was fitted, either in the calculator position, or in the director elevation drive. This stabiliser 'ironed out' any fluctuating movements and fed a steady 'Angle of Sight' into the calculator.

THE HACS CALCULATOR

The calculator used mechanisms broadly similar in principle to those of its Surface counterpart but designed around the special requirements of AA control. It transmitted Gun Elevation and Gun Training quantities away to the long range AA guns and in addition, a Fuse Number, to which the shell nose-caps were set. At first, the fuse-setting was carried out by hand but later, fuse setting machines were evolved which did the job as accurately, and much more quickly.

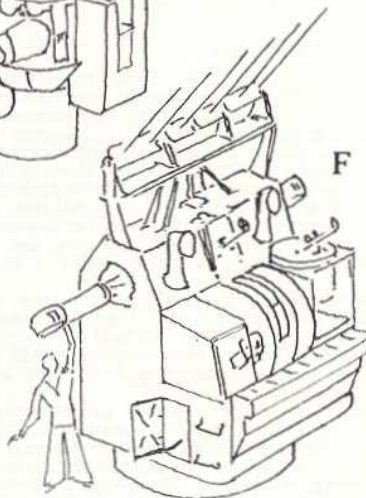
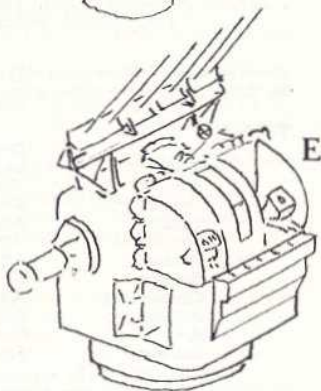
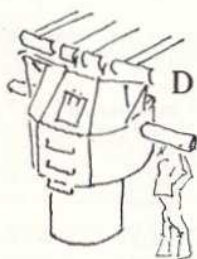
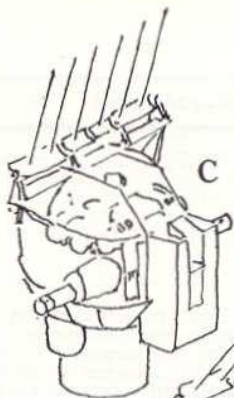
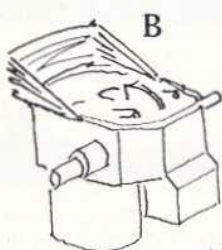
The HACS was the standard long range AA system for all capital ships, aircraft carriers and cruisers throughout the second world war and suitably modified to accommodate increased target speeds—and to control remote power control gun mountings—remained in service for some years after 1945.

EARLY HACS INSTALLATIONS—BATTLESHIPS

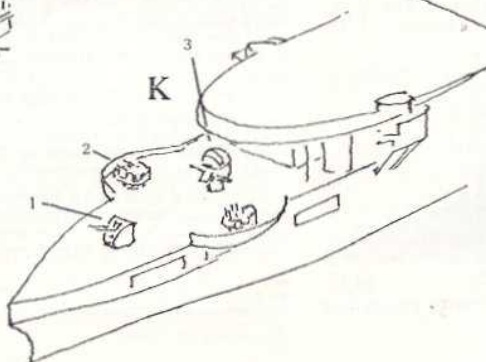
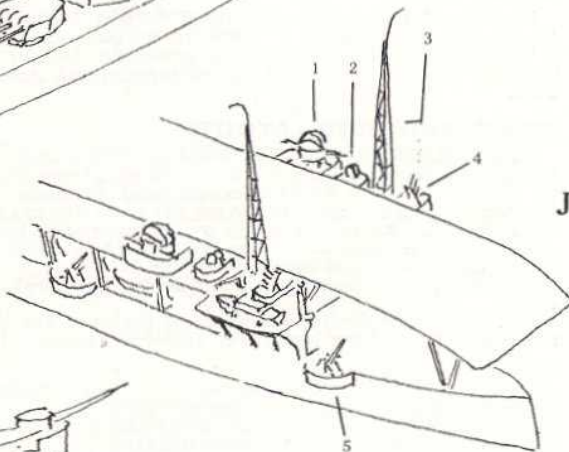
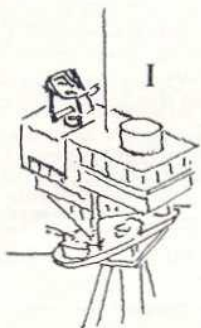
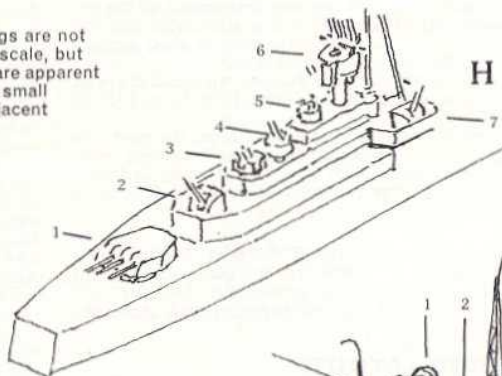
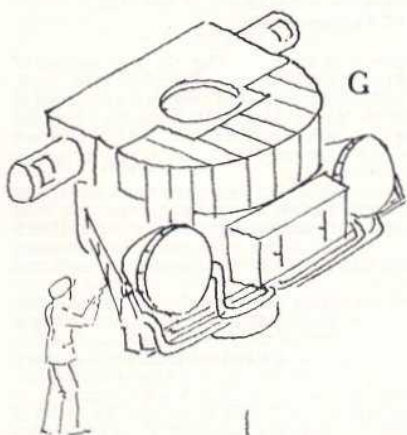
The 'Queen Elizabeth' and 'R' class battleships (and their contemporaries) had been designed long before the HACS emerged and in consequence had their systems 'tacked on' in the 1920s and 1930s. One system per ship was provided initially but in due course most ships had two. Both were on the centre line, set as high as possible and able to control either AA battery. When the system was

Continued on page 20

Key to drawings: HACS directors (A) Mk I, HACS. (B) Mk III HACS. (C) Mk IV HACS and Mk IV HA/LA plated in over Control Officer's position; radar added plus new crew compartment forward. (D) Mk II HACS. Access hatch in rear plating and radar added. (E) Mk V HA/LA. (F) Mk V (M) HA/LA, with special independent look-out sight on left side. (G) Mk VI HA/LA director with twin radar nacelles, totally enclosed structure and central retractable independent look-out sight. (H) Rear superstructure of HMS Swiftsure: 1—'Y' triple 6 inch turret. 2—centre line twin 4 inch HA/LA mounting. 3—'Quad' 2 pdr pom-pom mounting. 4—pom-pom director. 5—6 inch barrage director. 6—after Mk IV HA/LA director. 7—starboard after twin 4 inch HA/LA mounting. (I) 6 inch Spotting Top in Eagle with



NB: Drawings are not to common scale, but relative sizes are apparent from the small figures adjacent



◀ Key to drawings opposite ▶

Mk I HACS director. (J) Quarters of Glorious. 1—Mk I HACS director. 2—searchlight. 3—retractable W/T mast. 4—quadruple Vicker's .5 inch M/G mounting 5—single 4.7 inch HA gun on sponson at original deck level. (K) bows of Furious. 1—twin 4 inch HA/LA mounting. 2—eight-barrelled pom-pom. 3—forward Mk I HACS director.

Fire Control—continued

doubled-up, the original forward HACS director was retained above the Spotting Top on the foremast (a long climb to Action Stations) and the second director was sited on a platform abaft the mainmast.

Nelson also had two systems but in her case both HACS directors were on the centre line close together, abaft the DCTs on the main superstructure.

AIRCRAFT CARRIERS

The arrangements in the old aircraft carriers were very variable. Both *Eagle* and *Hermes* were weakly armed with single 4 inch AA guns—four in the former ship and only three in the latter—and rather unnecessarily retained their larger calibre surface weapons. *Furious*, too, originally had a mainly surface-weapon armament of ten 5.5 inch guns of a similar model to those in *Hermes* and *Hood* but just before the war these were replaced by twin 4 inch HA/LA mountings. The revised layout included two separate HACS systems, with one director on the centre line, immediately below the forward end of the foreshortened flight deck, and the other on the diminutive 'island' which was finally added to her originally flush deck.

The most realistically armed carriers were *Courageous* and *Glorious*, both with sixteen single 4.7 inch HA guns, arranged fairly equally along the ship's side on the level of the original upper deck. These were controlled by four separate HACS Mk I Directors carried on projecting sponsons at flight deck level in the four 'corners' of the ship.

This was a very viable arrangement and was adopted in principle for the New Construction carriers starting with *Ark Royal*. Unfettered by the limitations of an existing non-carrier hull, as had been the case in all the earlier ships (except little *Hermes*), the designers were able to arrange the guns into groups of two twin mountings in each 'corner' and at the same time build their sponsons higher, to give better 'sky arcs'.

It was both tragic and ironic that the two best-armed of the old carriers should be sunk early in World War 2 by submarine and surface vessels, when they would doubtless have given a good account of themselves had they been subjected to air attack.

Of the pre-war Fleet Carriers, only *Furious* survived the war, spending it on very active service in the Home Fleet from 1939 to 1944.

To keep the deck edge clear for flying operations, the port side directors of the later New Construction aircraft carriers were extendable and could be raised to their action position by hydraulic rams. When not in use they were retracted below flight deck level.

CRUISERS

Like the old capital ships, the first of the post World War I cruisers had one HACS Mk I Director on the centre line. In the 8 inch ships this was aft, but in the subsequent 'Leander' and 'Arethusa' classes it was moved forward superimposed above the DCT.

'ENDED' AND 'SIDED' LAYOUTS

Once the HACS had become established the single systems in the cruisers with twin 8 inch and twin 6 inch mountings were doubled up. Because their 4 inch AA batteries were 'sided', the single centre line director could only direct fire on one side of the ship at a time, but a second director could naturally control the opposite battery. Accordingly, the complete system-director, HACS Table and control circuits—was duplicated, and by the inclusion of change-over switches, it was possible for either director to control either battery.

When the second director was placed on the centre line of the after superstructure, the layout was known as 'Ended'; if the



Above: *Uganda* in 1943 with 'ended-sided' director layout. Right: *Coventry* as an AA cruiser in 1937 with Mk III director on Spotting Top.

20



Top: *Cruiser Shropshire* with original arrangement of one HACS Mk I director aft (abaft crane). Above: *HMAS Australia* in 1946 as modified with 'ended' HACS arrangement.

directors were sited on each side of the bridge, the layout was said to be 'Sided'. The table below shows some typical arrangements:

Table 1

Ship	Original position	Modernised arrangement
<i>Norfolk</i>	Aft	Sided
<i>Devonshire</i>	Aft	Ended
<i>London</i>	Aft	Sided
<i>Shropshire</i>	Aft	Ended
<i>Sussex</i>	Aft	Ended
<i>Berwick</i>	Aft	Sided
<i>Cumberland</i>	Aft	Sided
<i>Achilles</i>	Forward	Sided
<i>Ajax</i>	Forward	Sided
<i>Leander</i>	Forward	Not changed

Note: The Airfix *Ajax* kit components provide for her original layout (although the HACS Director forward is not well modelled). The box, on the other hand, shows her in her later modified state, with 'sided' HACS arrangements.

The next class of cruisers to be built after the two groups of 'Leanders' were the 'Arethusas'—a reduced version with three, instead of four, twin 6 inch mountings—and these were designed in the first instance to have an 'ended' layout. Its advantage over the 'sided' arrangement was that with the latter, the HACS directors were restricted to the 4 inch guns on their 'own' side, making the director somewhat less flexible.

There then followed a succession of cruiser classes and sub-classes all having a main armament of triple 6 inch mountings, and these had a combined 'Ended-Sided' arrangement. There were HACS Directors to port and starboard of the large main superstructure and a centre line director aft, working (via change-over switches) with two HACS Tables.

The second and third groups of the 'Town' class ships—*Manchester*, *Liverpool*, *Gloucester*, *Belfast* and *Edinburgh* were given a second DCT aft for divided control of the 6 inch guns in surface fire, and their after HACS director was a standard unit. In the others, this after director was specially adapted to fill a Dual-Purpose role and in contemporary language was called an HA/LA director.

As before, it could control either 4 inch battery in the event of damage to the 'sided' directors forward; alternatively it could control the after group of 6 inch surface fire, the after 6 inch DCT being omitted.

The last sub-group of the 'Colony' class not only had three HACS directors, but also a third HACS calculating table, each table working with its own director.

Finally, the reduction of the main 6 inch armament to three turrets by design, allowed a fifth (centre-line) twin 4 inch mounting to be sited in the original 'X' turret position, but only three ships—*Swiftsure*, *Superb* and *Ontario*—were so completed.

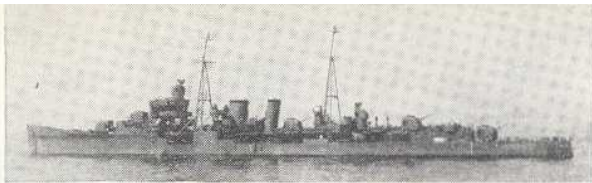
These ships had comprehensive 'change-over' arrangements which enabled their after HA director to control

- (1) Either broadside 4 inch battery, with or without the after 4 inch mounting.
- (2) The after 4 inch alone.
- (3) The after 6 inch turret in 'Divided' main armament control.
- (4) All the 6 inch armament.

The after 4 inch had a three-way change-over switch linking it to the Port, Starboard or After Director, so that three twin mountings could be used from a common system-and-director on either beam.

Similarly, the three after 4 inch mounts could all be linked to the





Above: Delhi after refit in America was an exception to the usual Royal Navy style and carried US 5 inch guns and an 'ended' US Mk 37 fire control system as in contemporary US destroyers and light cruisers (all photos by P. A. Vicary).

after director in the event of a concentrated air attack from the quarters, leaving the other sided pair of 4 inch switched to their 'own' director.

OTHER CRUISER LAYOUTS

Of the cruisers earlier than the 8 inch armed ships only *Emerald* and *Enterprise* were given an HACS system. *Frobisher* and *Effingham* were hastily equipped with twin 4 inch controlled by a Destroyer system, and *Delhi* was extensively refitted in the USA during the war, emerging with an 'ended' US Mk 37 system controlling five single centreline US 5 inch gun mounts; but the other 'D' class had to rely on their existing local gun control for their 4 inch single mountings.

The exception was those old 'C' class ships which were transformed to AA cruisers. They substituted their single 6 inch for a 4 inch AA battery (ten singles in the first conversions and four twins in the later) controlled by an 'ended' pair of HACS directors.

To this 'ended' layout, the 'Dido' class of 5.25 inch cruisers were built concurrently with the 'King George V' class battleships.

LAYOUTS IN CAPITAL SHIPS

During the late 1930s a scramble started to re-equip the British Fleet, and as many capital ships as possible were taken in hand for modernisation, but the only three fully refitted in time for the second world war were *Queen Elizabeth*, *Valiant* and *Renown*. Of the remainder, the 'R' class battleships were little changed and only small changes could be made to *Repulse* and *Hood*. The battleships *Malaya* and *Warspite* were partially modernised but not to the extent of the first three, who had their existing 6 inch secondary armament completely removed, together with their original 4 inch anti-aircraft guns, and were re-equipped with 20x4.5 inch in ten twin turrets.

This layout was split into four groups rather like that in the New Constructions Aircraft carriers, with two 'sided' HACS directors forward and two more aft. The HAC systems of the 'King George V' class battleships were similar.

HMS 'VANGUARD'

The only real short-coming of this 'four cornered' arrangement was that like the 'sided' set up, the directors were confined to the control of the mountings on their own side. To overcome this, the positions of the directors in *Vanguard* were revised. She had centre-line directors forward and aft and in addition a 'sided' pair approximately amidships. In her case, however, they were the American Mk 37 directors; were not associated with the HACS and did not see any war service in the Royal Navy (except in HMS *Delhi*).

HACS DEVELOPMENTS

During its lifetime, the HACS system progressed through four Marks, most of which had several sub-models and variants to suit the particular armament or layout concerned. As has been said, the Director was an integral part of the system, and its Mark corresponded to that of the calculator. An exception was the HA/LA Director Mk V, which was associated with the HACS Mk IV. The accompanying sketches show the appearance of various marks of director, whose allocations are given in the tables.

Mk I: This was the original, from which the later units were developed. It was open-topped, roughly circular in shape, and carried a crew of five. There were no power arrangements, but the trainer had a two-speed gearbox, which allowed him to slew the director rapidly to the bearing of the target. Both layer and trainer had monocular telescope sights and the Control Officer a binocular sight, all of which elevated together from the layer's handwheel. A take-off drive elevated the height finder at the same time.

When not in use, the director was covered by a canvas 'pram' style hood, and its open, exposed nature often made it uncomfortable to man in action.

Mk II: Various improvements were included in this mark, but its appearance was almost identical to the Mk I except that it carried a different model of height finder. As will be noticed from the table, it was not in service in many ships.

Mk III: This was much more widely fitted and was of noticeably different shape, being more elongated than the earlier marks. When fitted in the 'C' class AA cruisers, the director could be used to control the 4 inch guns in surface fire, if the occasion demanded, and for this reason an extra position for a sixth crew member was included in its slightly larger structure.

In due course, all three marks of director were adapted to take a 'fish-bone' style Radar aerial which was mounted on a frame work in the rear of the structure and elevated with the sights. An opportunity was taken to plate-in the rear of the casing to afford better protection for the Control Officer, and the pram-hood was removed. Instead a light girder framework was built forward and a canvas cover

Continued on page 31

Table 2. HACS Director Installations

Mark	Ship or class	Remarks
	15 inch Battleships and Battle Cruisers 8 inch Cruisers	Replaced by 'ended' Mk III systems in battleships Doubled up with Mk I systems ex-battleships Single systems
I	<i>Cyclops</i> <i>Eagle</i> <i>Emerald</i> <i>Enterprise</i> <i>Medway</i> <i>Resource</i> <i>Rodney</i> <i>Furious</i> <i>Courageous</i> <i>Glorious</i>	'Ended' Four-cornered
II	<i>Repulse</i> <i>Achilles</i> <i>Leander</i> <i>Neptune</i> <i>Orion</i>	Single systems, later doubled in some
III	<i>Hood</i> <i>Nelson</i> <i>Ajax</i> <i>Adventure</i> <i>Hobart</i> <i>Perth</i> <i>Sydney</i> 'C' class AA cruisers, 'Arethusa' class, and 15 inch Battleships on refit <i>Southampton</i> <i>Newcastle</i> Large AA Escorts	Single systems, doubled up later in <i>Ajax</i> and <i>Nelson</i> 'Ended' systems, except in <i>Warspite</i> which had 'sided' directors on the main superstructure 'Sided' systems; after director added later in <i>Newcastle</i> Converted merchant ships
IV and IV HA/LA	<i>Maidstone</i> <i>Forth</i> 'Dido' class Remainder of 'Southampton' class 'Fiji' class <i>Swiftsure</i> <i>Queen Elizabeth</i> <i>Valiant</i> <i>Renown</i> <i>King George V</i> <i>Prince of Wales</i> <i>Ark Royal</i> <i>Victorious</i> <i>Illustrious</i> <i>Formidable</i>	Single system Ended systems Combined 'sided-ended', <i>Newfoundland</i> , <i>Ceylon</i> and <i>Swiftsure</i> had three HACS tables; others two 'Four-cornered' systems
V HA/LA	<i>Duke of York</i> <i>Anson</i> <i>Howe</i> <i>Indomitable</i>	'Four-cornered' systems; <i>Anson's</i> directors later changed to Mk VI HA/LA
V(M) HA/LA	<i>Indefatigable</i> <i>Implacable</i>	'Four-cornered', in conjunction with interim Fire Control system
VI HA/LA (later redesignated Mk 6 AA/SU)	<i>Superb</i> <i>Ontario</i> <i>Anson</i> 'Battle', 'Weapon', 'Ch', 'Co', and 'Cr' class destroyers <i>Birmingham</i> <i>Newcastle</i> <i>Newfoundland</i> <i>Sheffield</i> <i>Hobart</i> <i>Mysore (ex-Nigeria)</i>	Combined 'ended-sided', in conjunction with interim Fire Control system In association with HACS IV Post-war, except in a few early 'Battle' class; range finder later removed 'Sided', only; post war modernisation with re-designed electronic Fire Control system; range finder removed
Mk 6* AA/SU	'Daring' class	Modified director with Radar nacelles raised and no range-finder; removed on modernisation in 1960s

was faced over it when the director was not in use. Some Mk III directors had a power operated stabilisation drive from an oil motor which automatically compensated for ship-roll, and when this was fitted, it was contained in a casing suspended below the director floor.

Mk IV and Mk IV HA/LA: By the time this mark emerged, many improvements had been incorporated into the system as a whole, and the director design was modified accordingly. Initially, hydraulic power training was fitted, with an alternative hand drive as before, while elevation remained a hand-control supplemented by a power stabilisation drive. Later, elevation was also given power-follow arrangements, and at the same time, a 'scooter' unit was added in the Control Officer's position by which he could control elevation and training in power aiming by a special open-sight, or merely slewing the director on to a target.

These improvements necessitated considerable structural alterations, which in general made the director rather cramped. Again, Radar was added and the rear of the director plated in.

In some applications the Mk IV was used in a Dual Purpose role for anti-aircraft or surface fire, and was then known as an 'HA/LA Director'. The after centre-line director in the later classes of 6 inch and 5.25 inch cruisers were of this type.

Mk V HA/LA: To overcome the cramped and rather uncomfortable conditions experienced in the Mk IV director, a completely new unit was designed, which became available for the battleships *Duke of York*, *Anson*, and *Howe*, and for the aircraft carrier *Indomitable*. As can be seen from the sketches it differed considerably from the earlier patterns, was much roomier, and afforded better protection for the crew. A number of technical improvements were incorporated, including binocular rather than monocular sights for the layer and trainer, and it was designed to carry Radar rather than having the aerial 'tacked-on' as had been the case with the previous marks.

Like its immediate predecessor, the director had hand or power training and power-stabilised hand elevation controls. No 'scooter' control was provided for the Control Officer, but he did have an independent training handwheel for power control only, by which he could train the director on to the selected target. An additional hand-training handwheel was fitted close to the layer's position, so that he could both train and lay the director sights himself in an emergency, for it was he who fired the guns from his Master trigger.

The director invariably controlled Dual Purpose weapons and only existed in the HA/LA style. It controlled them in HA fire through the HACS calculator, and in surface fire through an alternative surface Fire Control 'Clock'.

Mk V(M) HA/LA: Towards the end of World War 2 it was decided to cease production on the HACS for future ships, and to fit a modified 'small ship' installation in place of the original calculator, as an interim measure until the electronic computers under development were perfected.

The last two aircraft carriers of the *Illustrious* class—*Implacable* and *Indefatigable*—were so affected, and as a result of war experience, the Mk V HA/LA director was re-designed to include further technical improvements. The new tower, known as the Mk V(M), was almost totally enclosed and although externally similar to the Mk V, its control arrangements were entirely different. Full power control through electric driving motors was provided, and the tower could be operated in Remote Power Control by Radar operators in the Calculating Position below. It was only fitted in the two ships mentioned and went out of service when they were scrapped in the mid 1950s.

Mk VI HA/LA: A completely new configuration emerged with the arrival of this director which was the natural successor to the interim Mk V(M), but although it later became a quite widely fitted equipment, it saw almost no war service.

It introduced the twin-nacelled gunnery Radar and closely followed the comprehensive power arrangements of its forebear.

When first conceived it was intended to adapt it as a retrospective fitting to ships with HACS, but in the event only the battleship *Anson* had her Mk V directors replaced by Mk VI.

The last of the triple 6 inch cruisers—*Superb* and *Ontario*—employed it in the combined 'sided-ended' arrangement, but in both ships the directors were linked to the interim 'small ships' fire control and only the very earliest destroyers of the 'Battle' class carried the director to war in the closing months of the Pacific campaign, in 1945.

SURFACE CONTROL FROM THE HACS

In modernised and new construction capital ships, the secondary armament was designed around Dual Purpose guns, which could be used in a surface action if the occasion demanded. Thus, a capital ship could engage heavy enemy units with her main armament, and beat off enemy destroyer attacks with her secondary calibre guns.

The DP weapons were directed by the HACS Directors as in Anti-aircraft fire, but via a separate surface predictor rather than by the HACS Table.

In the 5.25 inch cruisers the guns were in any case normally directed by a DCT in Surface Fire, but could be 'divided' into forward and after groups, when the after group was controlled by the after HACS director via its HACS Table in a special surface mode. Should the DCT be 'knocked out' the forward HACS director could similarly control the forward group through its own HACS Table. Otherwise, the HACS directors were employed only in AA fire control in either one or two groups.

The twin 4 inch batteries in the 6 inch cruisers were principally for AA defence, but again could be used in surface if required, controlled through the HACS as in the 5.25 inch ships.

The subject of fire control will be concluded in the next instalment which will cover small ships' installations together with close range directors and miscellaneous equipment.