EVOLUTION OF THE MODERN GUN MOUNTING.*

PART II

The first high angle guns and mountings were designed at a time when the airship was thought to be the chief menace to warships from the air and two to three 3 in. H.A. guns were added to the armament of naval craft as an afterthought. Fig. 1 shows a 4 in. H.A. mounting designed in 1918.

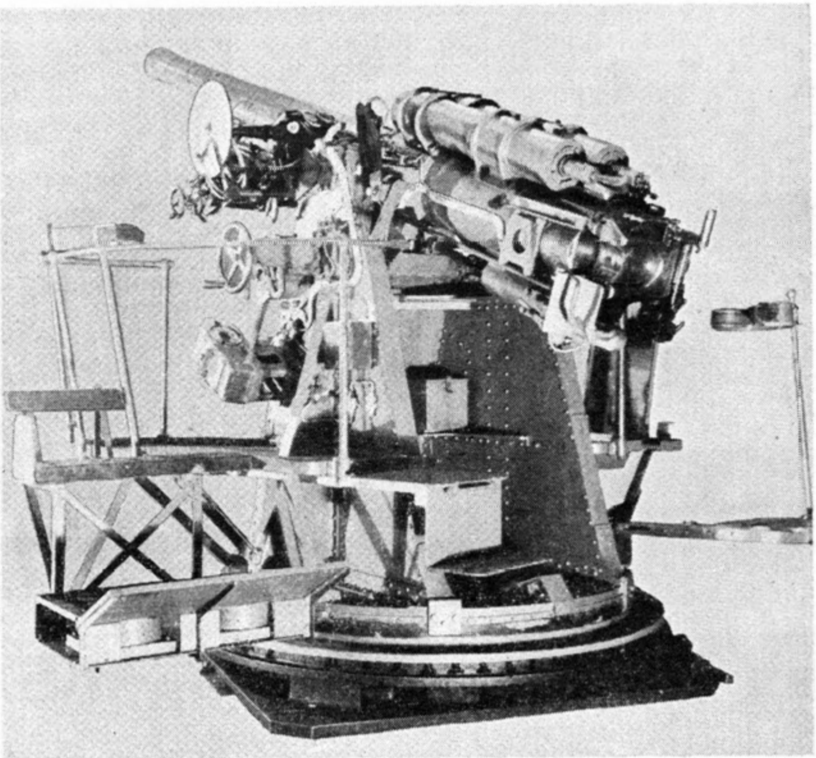

FIG. 1.—A 4″ SINGLE H.A. MOUNTING DESIGNED IN 1918 AND IN COMMON USE IN MAJOR UNITS OF THE FLEET UNTIL 1936-1938

The fuze of the shell was designed to explode on impact with the airship's fabric and as the target was very slow moving, existing methods of low angle fire control required comparatively little adaptation to meet the new requirement. Up to 1914 there had been no military or naval gunnery practice against targets approximating to the height and speed of the aeroplane and the prevalent tendency was to regard the hitting of such a target as an insuperable problem and make no attempt to tackle it.

The H.A. fire control problem in 1918

After the experiences of the 1914-1918 war on the Western Front, however, fast and high flying aircraft carrying bombs were thought to be the eventual form that the air menace would take. Against such targets existing methods of

*The first part of this article was published in *Papers on Engineering Subjects* No. 19.

fire control had to be scrapped because the flimsy nature and the small size of the target made it impossible to use impact fuzes in H.A. shells. Consequently some sort of time fuze had to be adopted which would explode at the place where the aircraft would be after the time of flight of the shell.

This meant that a complicated calculation had to be carried out very swiftly to predict the future position of the target at the estimated time of arrival of the projectile, and therefore " the deflections " or the amount the gun must be fired ahead of the target's present position. It was also necessary to calculate the correct fuze-setting to ensure the shell bursting at the right point in space.

The three-dimensional fire control problem had arrived.

Much greater accuracy required in H.A. fire

It is well to remember at this point not only that the H.A. problem is three-dimensional but that accuracy is of much greater importance than in low angle fire control. Not only is the aircraft target much smaller, but since the shell's lethal radius is so limited, it must be aimed virtually to hit, e.g. at a slant range of 10,000 yards. an angular error of one minute in gun-pointing equals about fifteen feet. Compare this with the low angle shell which, aimed to strike a ship's water line, will still hit the upperworks even if ranged several hundred yards " over."

Complications peculiar to Naval H.A. gunnery

The control of H.A. gunfire was therefore a formidable problem even on dry land, but from a rolling platform at sea it was enormously complicated by the difficulty of continuously and accurately laying the director sight on the target (the basis of all data on which the calculation of deflections depends), and by the great technical difficulty of establishing, by gyros or other means, an artificial horizontal plane on which the three-dimensional problem could be set up. Added to this, the gun had to be on aim at all times despite the antics of the ship, for the order to fire must originate from the calculating position and is given when the shell with the pre-determined fuze length applied is ripe for firing. In the face of such difficulties, it was understandable that the aeronauts considered that the navies of the world were in the bag.

No easy solution

Spurred on by impatient patrons, the early investigators of the H.A. problem, like the alchemists of old, wasted much time and energy in searching for a will o' the wisp in the form of a magic formula which would provide a simple solution to one of the most complex problems in the whole field of engineering. There is and can be no such short cut—that is the unpalatable truth. In order to make the problem a little easier, however, it was an obvious step to increase the calibre of the projectile and hence the size of the lethal sphere of the bursting shell.

Combination of H.A. and L.A. functions in same weapon

This naturally led warship designers to insist that the H.A. guns should also carry out the low angle functions of the secondary armament. The advantages to the ship designer are at once apparent, for a reduction in top weight and upper deck congestion naturally follow, but to the already formidable

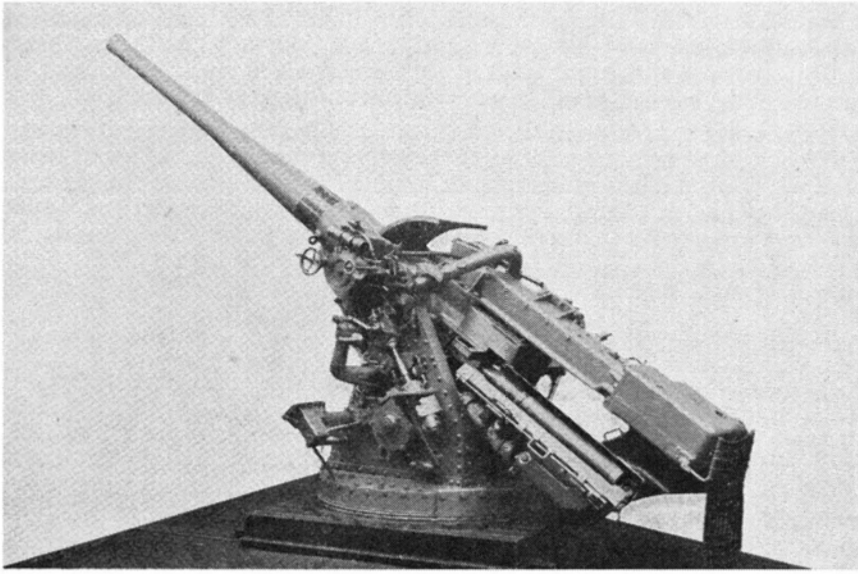

Fig. 2.—A typical destroyer 4.7″ gun mounting of the period 1934–1938 with only 40° elevation

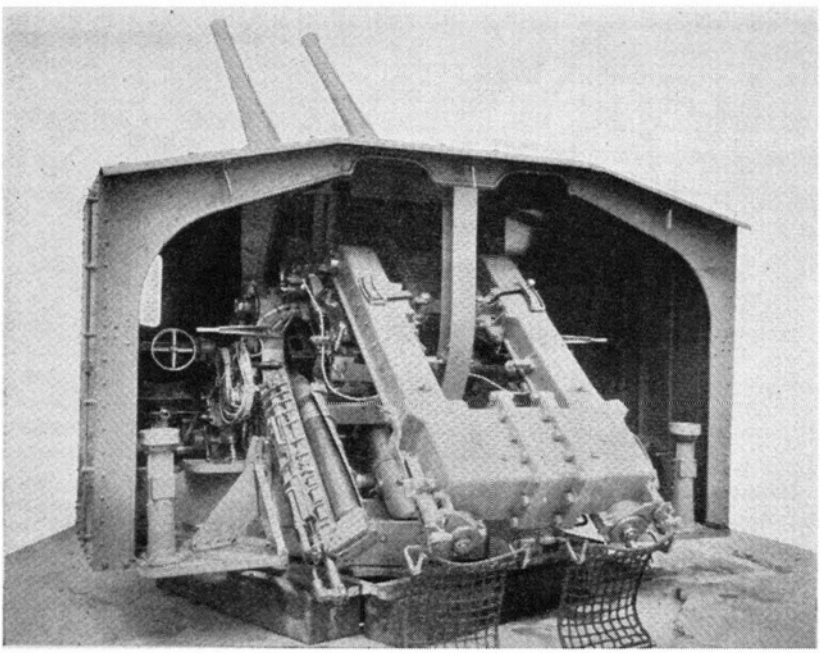

Fig. 3.—A twin 4.7″ gun mounting limited to 40° elevation which met staff requirements *circa* 1937

gunnery problem was added that of evolving gun mountings and control systems which had to be jacks of two trades and masters of both.

In producing a good H.A./L.A. weapon the first basic problem facing designers of the gun mounting was to reduce trunnion height, for it was obvious that an excellent H.A. gun would be useless for L.A. purposes if at low angles of elevation the breech was too high for the gun to be loaded conveniently. To reduce trunnion height, two steps must be taken, namely the length of recoil must be reduced and the breech put as near to the trunnions as possible. Figs. 2 and 3 show two typical low angle 4.7 in. mountings (*circa* 1937) with their guns at the maximum elevation of 40°. The H.A./L.A. mounting, on the other hand, must be capable of being elevated to 80°.

Recoil lengths were accordingly reduced to about 12—15 inches without much difficulty, but with proportionately greater stresses on the supporting structures and decks. At the same time, the mounting was designed so that the gun lay right forward in the cradle with its breech almost level with the trunnions (see Fig. 4). The loading tray and ramming mechanism, where fitted, were made integral with the cumbrous balance weight which became necessary to counterpoise the gun. These balance weights have several hollow pockets which are filled with lead in such a way as to bring the horizontal and vertical centres of gravity of the elevating mass on to the centre line of the trunnions. It is worth noting that the horizontal centre of gravity varies according to whether the gun is loaded or not.

In this connection also, it is important to remember that the largest H.A. gun which can be loaded and rammed " uphill " without the aid of a loading tray and rammer is the 4 in., and even this size requires a fairly brawny man for the round weighs some 63 lbs.

Twin mountings

In order to get the necessary number of H.A. guns into the small clear and blast-free space which could be allotted in the average warship, designers were soon forced to develop a twin mounting (Fig. 5).

This has the following advantages :—

- (i) One gun does not blast the crew of the other, therefore double the number of guns can be mounted in the same space, if weight and stability permit.
- (ii) If twin cradles are employed, only one layer and one trainer is required for two guns.
- (iii) The same shield can be used to protect both guns' crews from spray, blast or splinters.
- (iv) Given an equal number of guns, whether singles or twins, ammunition supply is simplified by adopting the twin.

The chief and immediate disadvantage was that the moments of inertia for training and elevating were seriously increased. These, combined with the high speeds and accelerations which are necessary if the gun is to be kept continuously on aim in a seaway, made it impossible to follow the pointers by hand and forced designers to introduce power operation throughout. The moment of inertia of the training mass can be kept down by grouping the heavy masses close to the centre of rotation, but congestion and inaccessibility set a limit to this.

Rapid growth of H.A./L.A. twin

It will be seen that the dual purpose H.A./L.A. weapon was fast developing into a miniature power-worked twin turret with its own central ammunition

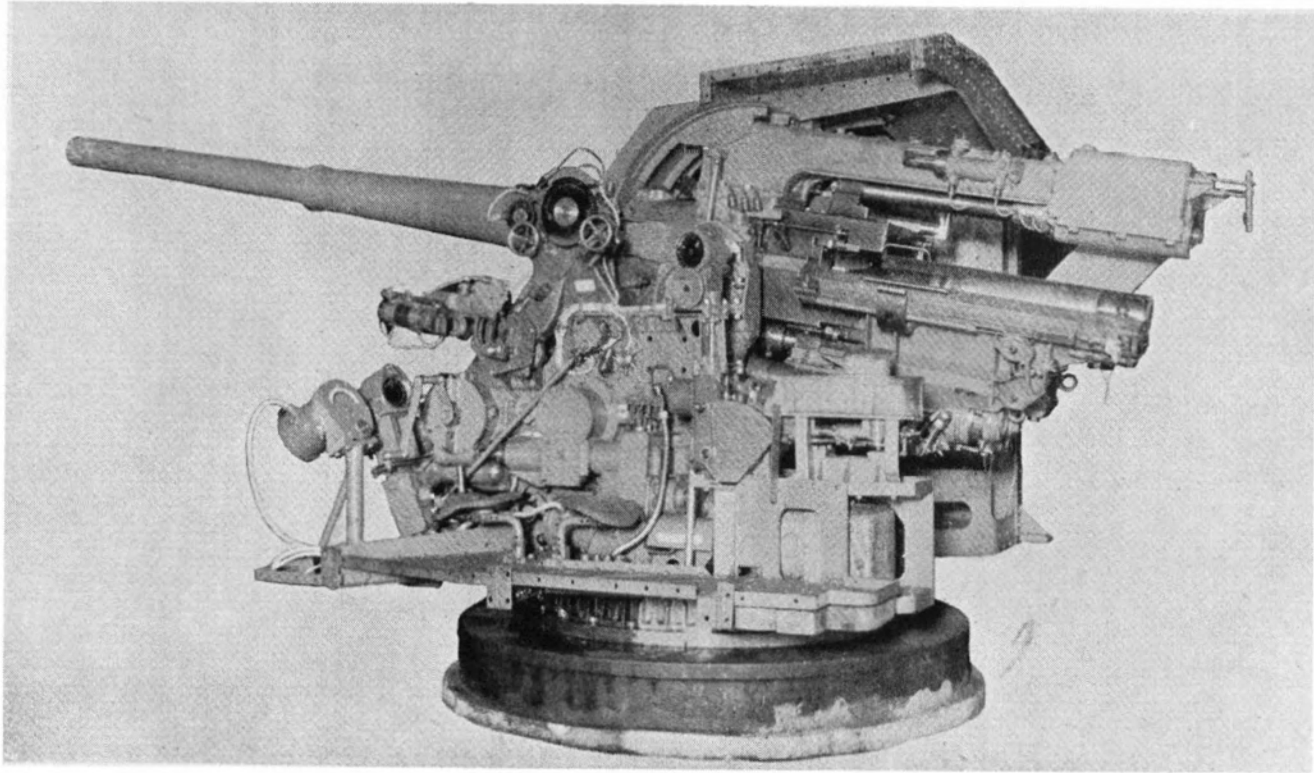

FIG. 4.—A 4.5″ SINGLE H.A./L.A. MOUNTING. NOTE HOW THE BREECH OF THE GUN IS ALMOST LEVEL WITH THE TRUNNIONS

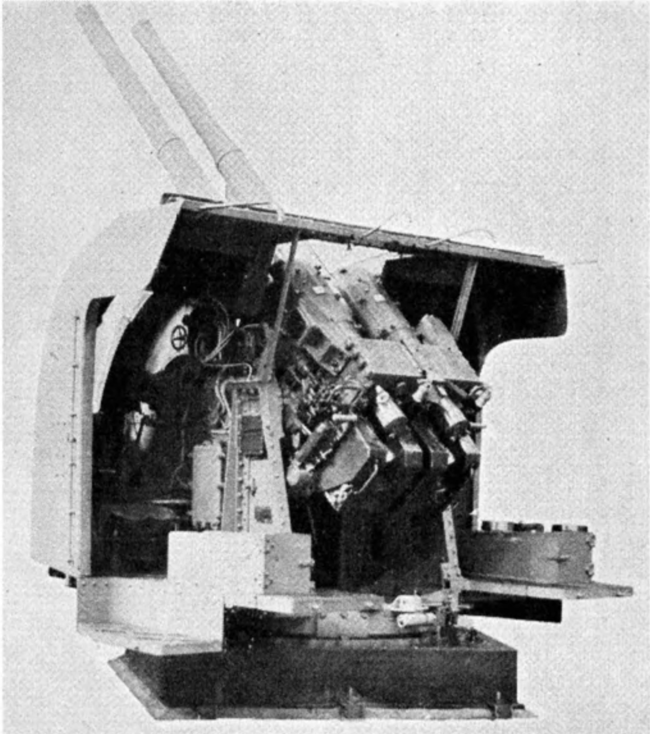

FIG. 5.—A HANDWORKED 4″ H.A. TWIN MOUNTING DESIGNED *circa* 1933. Note the absence of loading trays and the short distance available for recoil when the guns are at higher elevations. Nevertheless the trunnion height is too great for rapid L.A. fire.

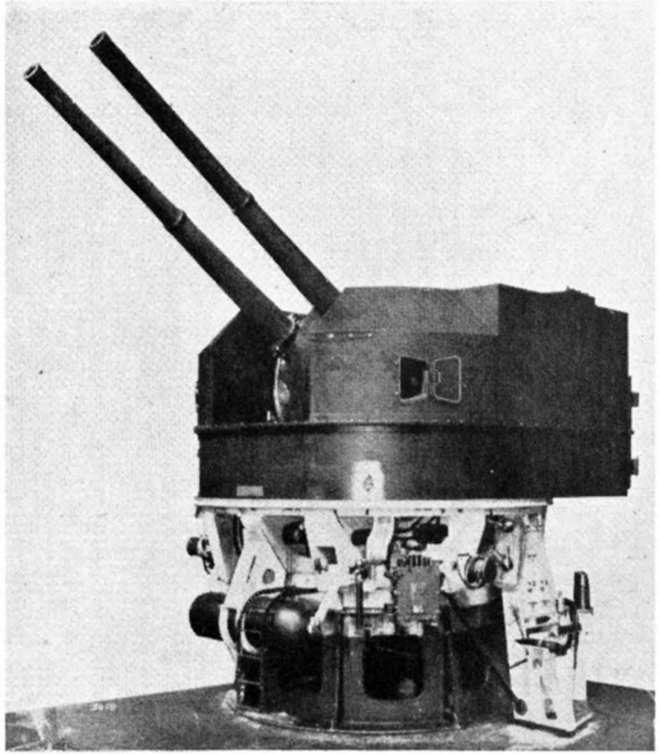

FIG. 6.—A TYPICAL FAIRLY MODERN 4.5″ H.A./L.A. MOUNTING WITH 80° ELEVATION

The speed of elevating and training is 20° per second.

supply. Two further inescapable requirements rapidly forced its development to that logical conclusion. One was the fact that the designers of warships, and particularly aircraft carriers, were forced to site the mountings so close to one another that nothing short of a totally enclosed cupola or turret would suffice to protect the crews from mutual blast interference (Fig. 6).

The second was the urgent necessity to increase still more the size of the lethal sphere round the shell burst, a sphere that was continually tending to contract as the armouring and local strength of aircraft improved. The radius of this sphere varies approximately as the calibre to the power of 3/2 and it was soon deemed imperative to go beyond the 4 in. which, it will be recollected, is the largest that can be loaded by hand. This finally and irrevocably forced inertia values in training and elevating beyond the point where hand operation was possible, and also made all-angle power ramming essential to maintain the high rate of fire that was invariably demanded.

Additional problems in H.A./L.A. mountings

Three other complicated problems had to be solved before the H.A./L.A. gun mounting could be considered effective :—

(a) The need for shifting rapidly from one form of target to another made a dual ammunition supply essential, one for projectiles and fuzes suitable for H.A. targets and the other for projectiles suitable for ship or land targets. Fig. 7 and 9 show a 5.25 in. twin H.A./L.A. mounting with integral H.A. and L.A. ammunition supply.

(b) The necessity for excluding human errors in gun pointing.

(c) Since the guns were no longer to be locally aimed, it was necessary to provide some automatic device which would prevent the closely grouped turrets firing into the ship's structure or into one another.

Rapid evolution in recent years

Thus, in the space of nine years between 1930 and 1939, the H.A. weapon unavoidably grew from a 4 in. single hand-worked mounting weighing three or four tons (Fig. 1), to the 4.5 in. or 5.25 in. twin power-worked turrets weighing about 45 and 90 tons respectively (Figs. 6 to 9). Long range H.A./L.A. weapons such as these are now mounted as the secondary armament of battleships and the main armament of aircraft carriers, destroyers and some cruisers. In terms of cost and therefore complication, the growth was from £2,000 to £50,000, a ratio of twenty-five to one.

But it is in destroyers, perhaps, that the effects of this rapid evolution are most evident. Whereas in 1914 the main armament of destroyers was three or four 12 Pdr. or 4 in. L.A. gun mountings of extreme simplicity, it now normally consists of six remotely controlled 4.5 in. guns mounted in three twin H.A./L.A. turrets of the latest type (see Figs. 6 and 10). This sudden jump in weight, cost and complication of gun mountings is difficult for the layman to understand unless he can appreciate the relentless logic of the warship designer's demands, and the increasing seriousness of the menace from the air.

Accurate gun pointing—the problem and its main factors

But while this revolution was going on during the nineteen thirties, it was becoming increasingly obvious that the problem of accurately pointing the H.A. gun in the right direction could never be satisfactorily solved until the directors were fully stabilised and all human links between the calculating

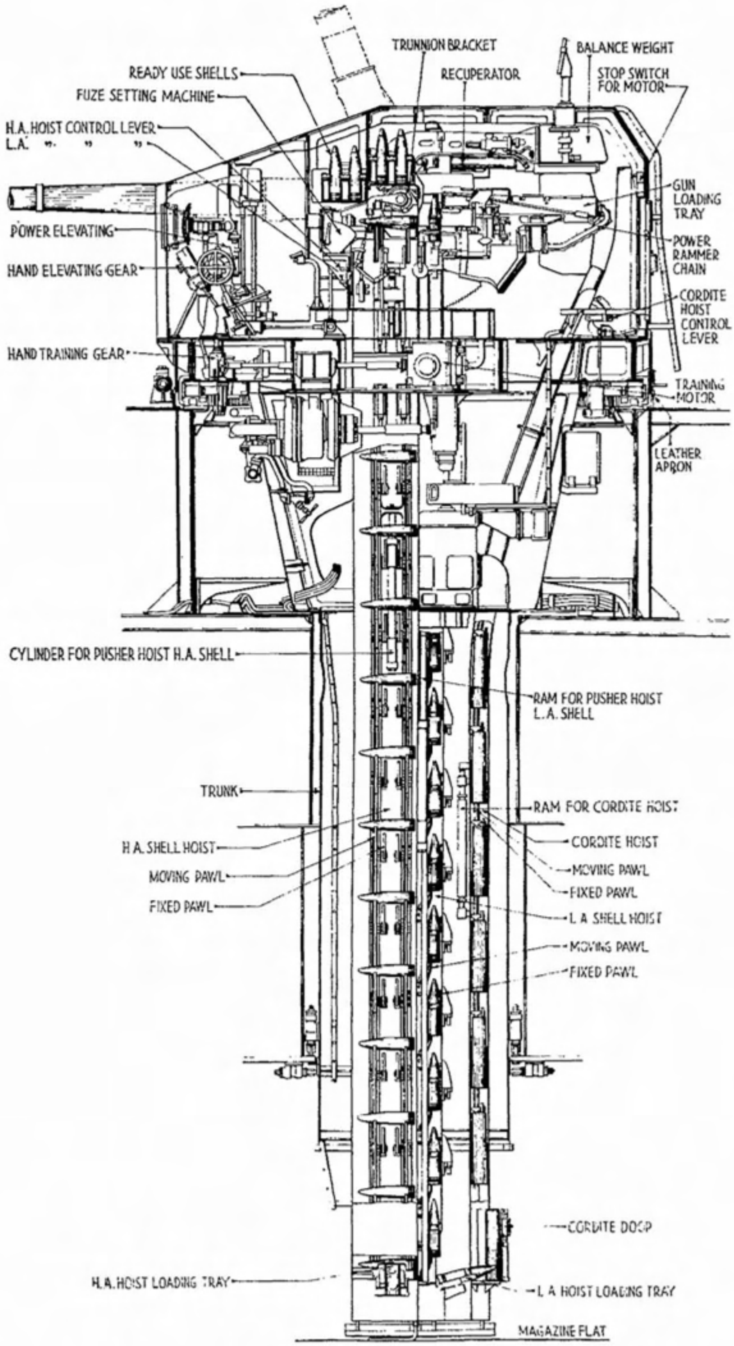

FIG. 7.—A 5.25″ TWIN H.A./L.A. MOUNTING WITH INTEGRAL H.A. AND L.A. AMMUNITION SUPPLY

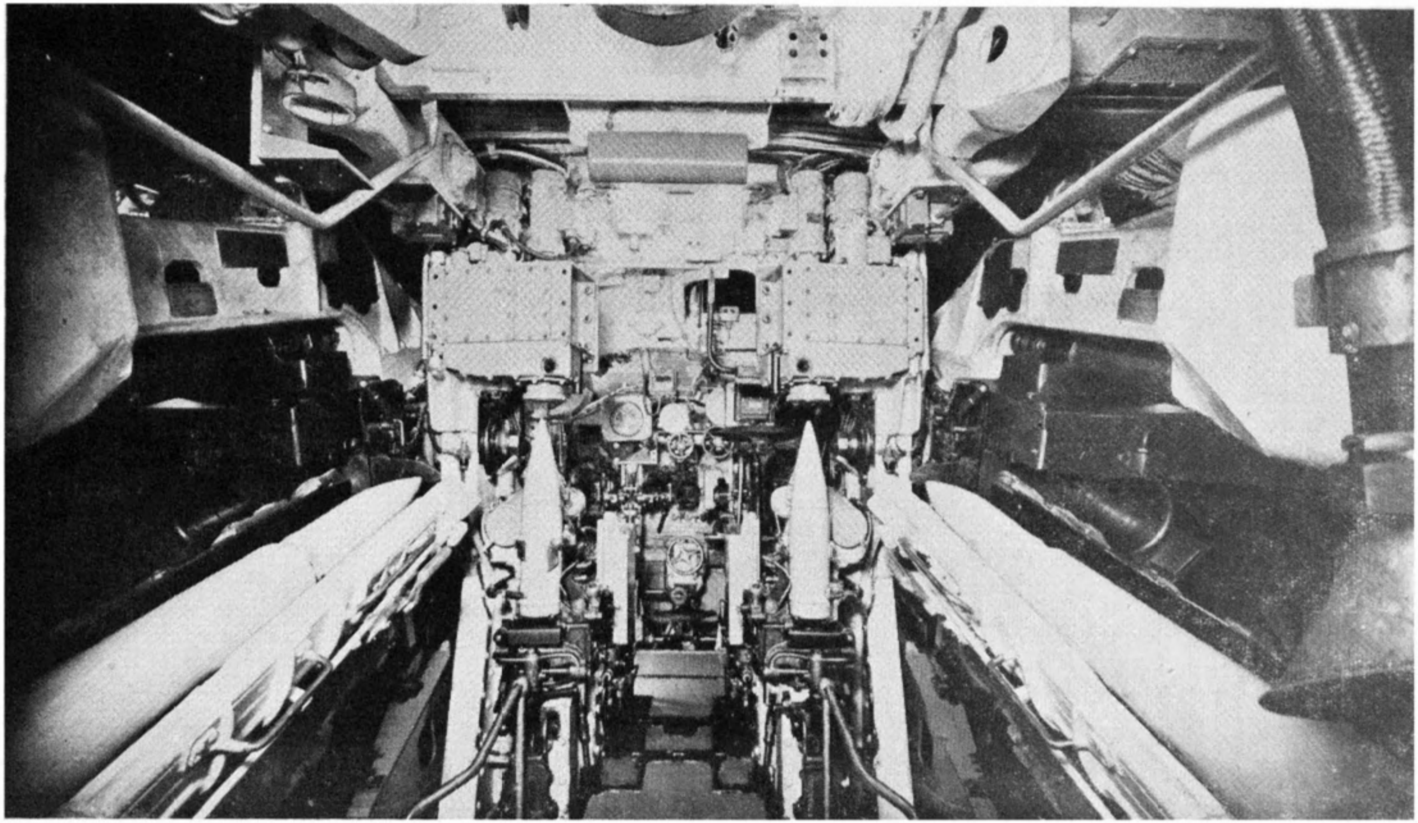

Fig. 8.—The inside of a 5.25″ H.A./L.A. turret looking towards the front

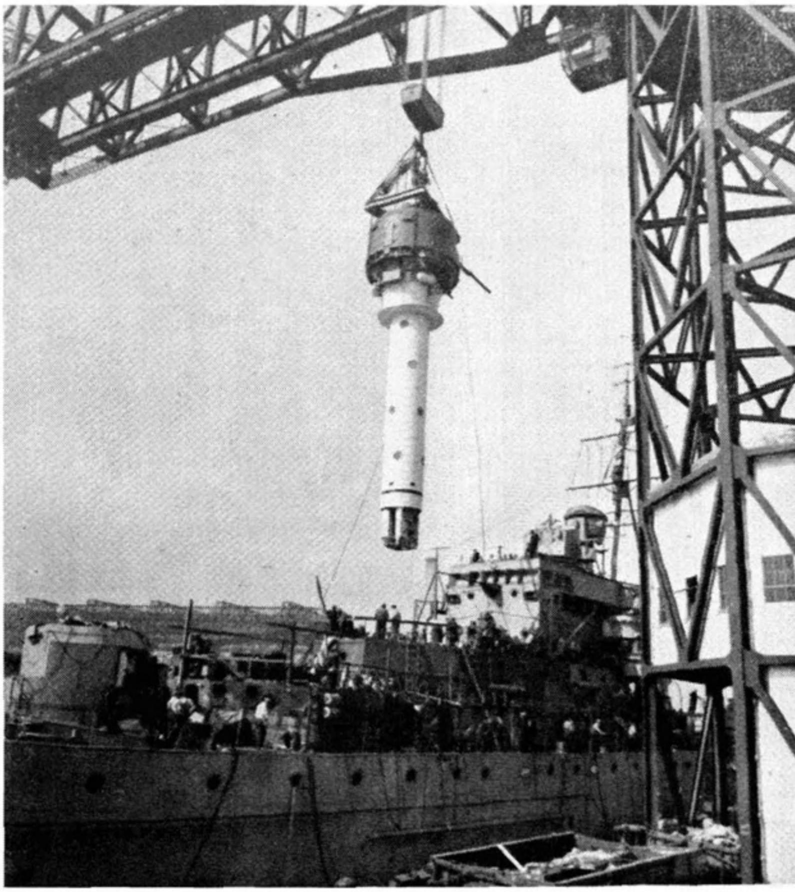

FIG. 9.—A 5.25″ H.A./L.A. MOUNTING BEING LOWERED INTO A CRUISER
Note the duplex central ammunition hoists integral with the turret.

machines and the guns had been eliminated. That is, until target rates and ship motion rates were accurately measured and automatically applied.

The necessity for stabilisation and remote power control are not generally understood by the unitiated and their introduction has evoked mistaken criticism in some quarters. One can bring them into correct perspective if one visualises them as two of the three interlocking links in the only chain which can produce accurate gun pointing. The three links of this chain are :—

(a) Stabilisation at the director sight.
(b) Calculation of the correct deflections at the computer.
(c) Actuation of the gun to move in strict conformity with the up-to-date calculated deflections and ship motion rates.

It must be emphasised that each link is useless unless combined with the other two. Of the three, stabilisation is probably the most important, for, besides producing dry land conditions at the director, so necessary for smooth tracking, its accuracy vitally affects the accuracy of the data fed to the deflection computer.

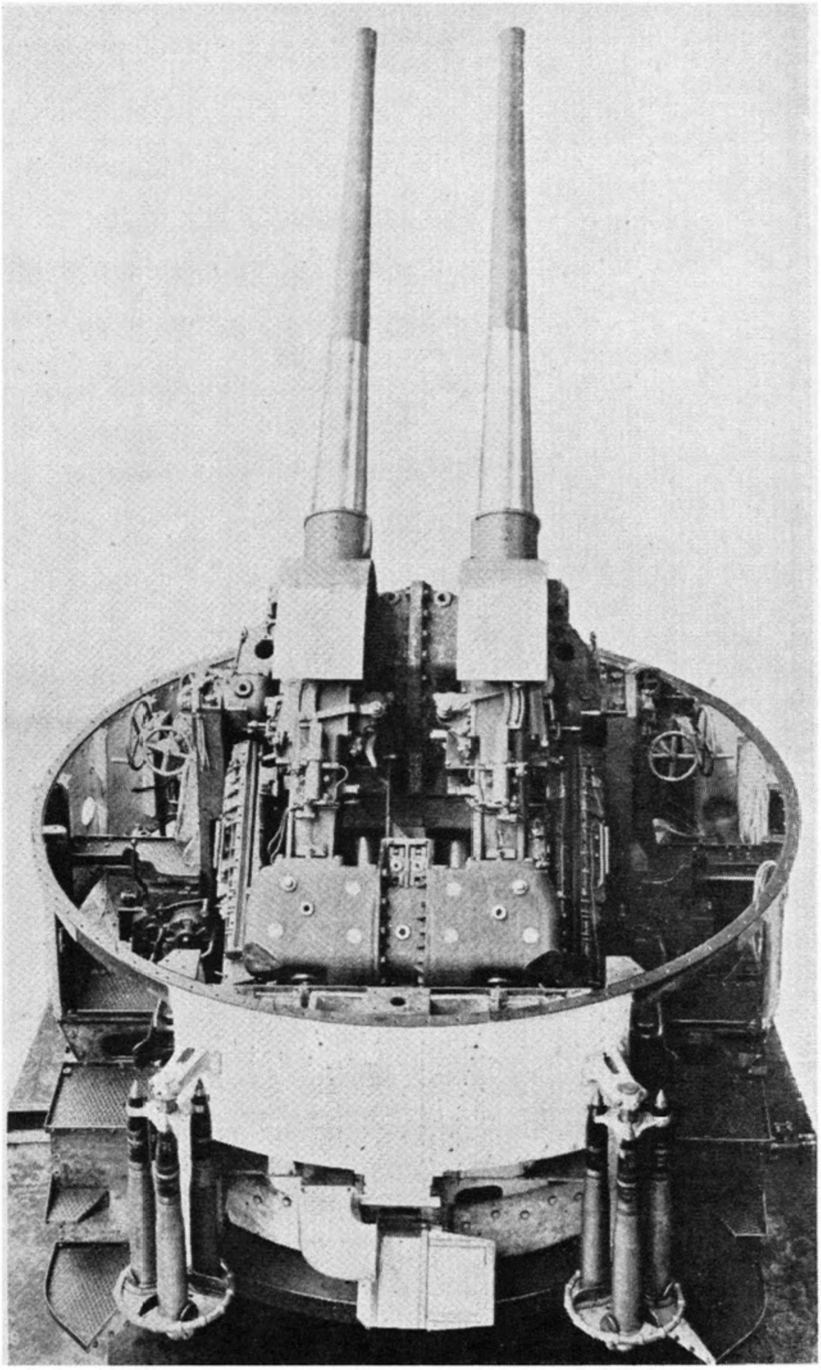

FIG. 10.—A 4.5″ TWIN H.A./L.A. MOUNTING WITH TOP OF CUPULA REMOVED
This portion of the mounting is below the upper deck

The function of the computer, the second link in the chain, is to calculate the deflections, i.e., the amount the gun must be aimed ahead of the target, and the setting which must be put on the fuze to make it detonate the shell at the right point in space. The answers to these sums obviously depend on the speed and range of the target, the shell's time of flight and its ballistic properties. But the most accurate calculating machine in the world will not bring the aircraft down unless the gun closely follows the order signals with which it is fed.

It is thus with the third link that the designer of gun mountings is most concerned.

Remote power control

It has already been shown how the H.A./L.A. mounting had unavoidably evolved from hand to power operation. The latter development, while relieving the layer from physical exertion, still left him with a most difficult task, that of keeping his gun pointer in line with an order pointer that was liable to move unpredictably and violently according to the movement on the ship. To follow the order pointer (Fig. 11) with accuracy demanded exhaustive practice and great skill, since the operator was required not only to appreciate the early incidence of pointer error, but also its rate of increase.

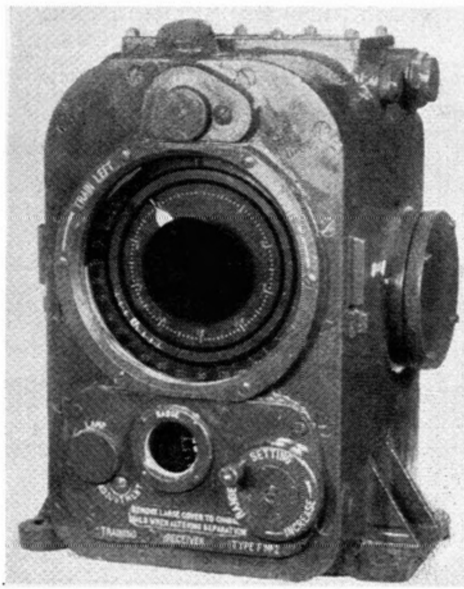

FIG. 11.—TYPICAL ORDER POINTER—A TRAINING RECEIVER USED ON H.A./L.A. MOUNTINGS

The efficiency of this human link, besides being affected by the ship's movement, also depended on the reaction time and the health of the individual, including even what he had to eat or drink the night before. The human link is particularly likely to be inefficient at moments of great excitement, which is just when it is most necessary for it to be efficient. It was clear that except under very easy conditions, the pointer following error would all too often lay the gun outside the limits set by the lethal radius of the shell burst. It was therefore essential to eliminate the human link and to actuate the gun direct from the deflection computer by means of a form of remote power control (R.P.C.).

There would be no difficulty in R.P.C. if generous lags and overshoot could be accepted—what is difficult is to ensure that the gun is pointing precisely in the desired direction irrespective of the acceleration or decelerations being applied at the director or by the stabilising element.

The significance of remote power control was much greater than the actual electro-mechanical development involved, since it brought continuous and accurate gun pointing into the realm of practical achievement. Its arrival, in effect, enormously increased the potency of the gun which could now be accurately laid in a sea-way. More will be said about R.P.C. in another article. It is mentioned here merely to show how it took its place in the series of interwoven problems confronting the designers of gun mountings.

Limited scope of this article

It is perhaps necessary to emphasise that this article deals only with the evolution of the *medium range* H.A./L.A. weapon. This weapon cannot meet all naval A/A defence requirements for the following main reasons :—

(a) neither the control nor the fuze have been sufficiently developed to deal with a close range high speed attack,

(b) a ship's bigger guns may be otherwise engaged, and it is therefore necessary to provide a close range armament as a final line of defence.

The evolution of close-range weapons will be dealt with in future articles.

Conclusion

In trying to bring this brief history of gun mountings and their control into focus, it is interesting to note that, whereas in the nineteenth and early twentieth centuries the improvements and inventions were generally imposed on the user by the engineer and scientist, the advent of the aeroplane caused the gunner to demand a better article ; that is to say, the driving force was supplied not by inventive genius but by the instinct of self-preservation.