C.B. 791.

NOTES ON SUBMARINE HUNTING, USING HYDROPHONES.

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1918.

NAVAL STAFF,
ANTI-SUBMARINE DIVISION,
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GENERAL REMARKS.

In hunting a submarine by sound, there are four stages more or less clearly defined :—

(1) Finding.
(2) Chasing.
(3) Closing.
(4) Attacking.

The third stage is generally now classed with the fourth as one evolution, but it will probably come to be considered worth separate and improved tactics.

With the "Plate" and other early types of hydrophone the first stage is possible, and some attempt can be made at the second. With the "Fish" and later types the second stage is feasible, and a beginning can be made with the third. The fourth stage is frequently tried, but under present conditions with only a remote chance of success.

Hunting a submarine by sound is much like hunting animals or birds by scent. There are occasions when everything goes well, and others when weather conditions interfere, or the dodges adopted by the hunted are successful. A fox may run through water or a flock of sheep; a wounded duck dive and hold on to reeds at the bottom, and so on; and a submarine makes use of just the same ruses, utilising traffic noises to drown his own, diving to the bottom, or "balancing." When any of these tricks is adopted there is always a chance of success, and it cannot, therefore, be expected that a chase will always result in a "kill." There is, however, no more reason to give up the hunt because a submarine has been able to use one or other of these dodges than there is to give up in sport. A fresh cast may pick up the scent again, and the best cast to be made is a matter of experience, knowledge of local conditions and weather lore.

Kills with a pack of hounds would be very few if they could not see when close: it is their eyes which lead to the final result. But a blind retriever can find a bird marked down in thick cover because he closes slowly and carefully, making sure of each advance. The method is different, and it is probable that to get in a position where an attack can be made on a submarine with fair prospect of success we shall have to introduce in the third stage of the hunt tactics more like those of the blind retriever than the pack of hounds.

At present we lack the right instrument. In order to locate a submarine on the bottom, or balanced and drifting with the tide, it may be necessary to use electrical or magnetic apparatus; but whatever it is, the requirements are that it shall be able to give direction within 5 degrees between 1,000 and 200 yards with the ship stopped or moving very slowly, whether the submarine is using her engines or not, in any reasonable state of sea or weather.

Our existing instruments will bring us to within about half a mile, and locate a submarine at that distance in a circle of about 200 yards radius if she is using her engines. With practice and care to obtain accuracy, it may even be possible to reduce this radius to 100 yards, but we are not likely to do better than this, and, unless she is then moving very slowly, the chance of a "kill" is small.

It is proposed to consider the problem under the following headings:—

(1) The probable tactics of enemy submarines.
(2) The limits of accuracy now obtainable compared with those required for a successful attack.
(3) Formations at present in use.
(4) Typical instructions and methods of working.
(5) Points worth remembering.

I.—THE PROBABLE TACTICS OF ENEMY SUBMARINES.

Hydrophone Hunting from the Point of View of a German Submarine Commander.

The following orders and rules for guidance are what it is considered might be given to every submarine by the commander of the flotilla:—

(1) Care must be taken to proceed at good speed by night, and keep as far as possible inside the 40-fathom line, this being considered the maximum safe depth.

(2) By day when on passage proceed at moderate speed, and keep a very good look-out all round the horizon. If the visibility is low, and you are in areas in which enemy patrols are likely to be encountered, it may be advisable to stop, or proceed submerged at slow speed, keeping a good watch with hydrophones and periscope.

(3) If anything is sighted, stop at once until you have made it out. If it turns out to be a merchant ship, you can safely proceed to manœuvre for an attack.

If the vessel sighted appears to be a patrol vessel's masts, it is a safe and most economical course to remain stopped, and watch for developments.

In clear weather, with plenty of sea room, it may be possible to avoid detection by steaming away on the surface with as little buoyancy as possible, and gradually work round to one

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beam or the other. Whilst so doing, be particularly careful to keep a good look-out all round the horizon, and do not allow the vessel in sight to occupy all your attention.

(4) If you are unable to evade the patrol vessel in this manner, or if other craft are sighted that you cannot avoid, dive at once, and carefully adjust your trim to be as nearly neutral as possible.

If the state of the sea permits of it, without having to speed up on coming near the surface, make good use of your periscope, and endeavour to work out of the immediate path of the approaching vessels. Remember that once you are heard, you may be in for a protracted hunt, and all hunting craft within a large area will be called up to assist.

(5) If you consider you have been heard, your subsequent action depends on the depth of water you are in :—

(a) *If depth is too great to go to the bottom with safety* :—

Your only chance of escape is to make your periods of absolute silence as long as possible. Dive to a depth of about 150 feet and work your adjusting tanks very carefully. Avoid getting upward or downward momentum, which may force you to use your motors at a critical moment in order to avoid breaking surface or going too deep. Listen for the sound of the engines of the hunting craft, and note carefully the times of stopping and starting. By this means, you may be able to pick up the system on which the hunt is being conducted, and anticipate the stopping periods. Only work one motor dead slow, and then if possible only when the hunting craft are working their engines. If hunting craft are anywhere near you, it is unsafe to get to periscope depth except under most favourable conditions of weather. If the surface is smooth, you run great risk of your periscope being sighted. If rough, you may be forced to speed up to get the boat under control.

Note.—Actual trials carried out recently in British submarines give 4 to 6 minutes as the longest time a boat could remain balanced at 60 feet in moderately rough weather. The time would probably be rather longer in smooth weather, and at a greater depth. This time is exceeded if submarine is going fast when she stops her motors. In one case a submarine going at 5 knots has balanced for 11 minutes, but this appears to be above the average.

The most dangerous situation in which you can find yourself is when you are surrounded by listening craft who are lying stopped. If you are forced to move your motors under these conditions, remember that your best chance of escape is to take advantage of the effect of wind on the surface craft. If there is any wind, they will be forced to steam up wind more or less frequently, according to its strength, if they wish to remain in the same place. Consequently work to windward, and take advantage of any movement of their engines to work out of the circle.

At Night.—If still surrounded, and your compressed air is getting used up, it may be possible to lie with very little buoyancy if the night is dark. The drift of the surface craft due to wind will still be in your favour, and if you are sighted some warning will be obtained by hearing the surface craft start their engines, and you will have time to dive.

If you decide to attempt to escape on the surface, start your motors at full speed, blowing at the same time, and work up your gas engines to full speed as soon as you can get them started.

(b) *If you can go to the bottom* :—

Careful study of the direction and strength of the tide is necessary, and the time it has been running.

Generally speaking, it is best to get away from the vicinity of the spot where you were last heard as soon as possible. This spot will probably be buoyed, and there is a natural tendency for the hunt to concentrate round it. Remember that probably the tide has least strength on or near the bottom. Consequently, to make as much progress as possible, work your adjusting tanks so as to lift the boat well clear of the bottom, and "land" as lightly as possible when necessary to do so.

Progress along the bottom will be difficult when it is hard and uneven, but a certain amount of damage to your outer bottom can be accepted without serious risk.

If the efficiency of the hunt is such that drifting is your only chance, plan out your course of action for at least two days ahead.

If the hunting craft do not hear you for a long time, they may lose faith in the original report, or bad weather may set in.

Your object should be to increase your distance from your original position as much as possible without moving your motors. Do not use your anchor if you can avoid doing so, as the sound may give you away, but rest on the bottom with several tons negative buoyancy when the tide is adverse, and "balance" along it when tide is favourable. Avoid drifting into the vicinity of tide races, or you may find yourself forced to the surface before you can get the boat under control, or carried to bottom hard enough to damage yourself. Tide races are usually to be found in the vicinity of rocky and uneven bottom.

Your worst enemies in depths of less than about 30 fathoms are ground swells and rocky bottoms.

At Night.—If nothing has been heard in your vicinity for some hours, it is probably safe to come to the surface and ventilate the boat, but do not work your motors unless you intend definitely to escape on the surface.

(*See also* "Night" under (*a*).)

(6) *Traffic Noises.*—These may be of great assistance in covering your own sounds, especially if several merchant ships are in the vicinity, but should only be used with caution unless very loud.

Remember the instruments in the hunting craft can probably distinguish between reciprocating engines and a submarine's motors; therefore be careful not to use much power. Noises of slow reciprocating engines probably come from merchant ships, and, unless they are very close, advantage should be taken of their presence to come to periscope depth and note the position of any hunting craft in sight.

II.—THE LIMITS OF ACCURACY NOW OBTAINABLE COMPARED WITH THOSE REQUIRED FOR A SUCCESSFUL ATTACK.

Instruments.

No description of the instruments used in submarine detection by hunting units will be attempted here, as suitable descriptive pamphlets have been, or will be, issued. The instruments will simply be enumerated and a brief statement given of their capabilities:—

(1) **The Fish** is for use underway with engines stopped. Can be used when anchored in a tideway, except for about one hour on each side slack water. Can be towed at any reasonable speed; can hear submarines about 4 miles when engines of towing vessel are stopped; with amplifier this range is increased. Indicates direction of sound, with a probable error of 5° to 10°, if sound is distant. If sound is close, directional quality disappears. Requires about one to two minutes after engines are stopped for an observation.

Is short-lived on account of multiple wire cable.

(2) **The K-Tube** is for use when drifting, with engines stopped or when anchored in a tideway. No towing model is available as yet. Instrument must be streamed for each observation, and then taken on board before getting underway again.

Can hear submarines as follows:

Speed Submerged Submarine.	
Knots.	Distance, Yards.
0·6	2,500–3,000
2·0	8,000–10,000
4·0	15,000–20,000

Indicates direction of sound with probable error of 5° to 10°. If sound is very close directional quality disappears.

Requires five to eight minutes from signal to stop engines until observation is obtained and instrument is on board again ready for going ahead.

Instrument is very simple, sturdy, and reliable.

Efficiency is not interfered with by water noises of the surface in rough weather.

(3) **The S.C. Tube** is for use when stopped, when drifting, or with engines stopped.

Instrument is always in place ready for use.

Can hear submarines as follows—depending on state of sea and speed of vessel :—

Speed of Submerged Submarine.

Knots.	Distance, Yards.
0·6	500– 700
2·0	1,200–2,500
4·0	2,000–4,000

Indicates direction of sound with probable error of less than 5° at all ranges.

Requires about two minutes from signal to stop engines to get observation and be ready to go ahead again.

Instrument is simple and sturdy; never gets out of order.

Efficiency is interfered with by water noises and by excessive motion of vessel.

Not suitable for use in rough weather.

(4) **The Trailing Wire** is for towing at slow speeds to detect a submerged submarine, and especially a submarine resting on the bottom. Contact of the wire with the submarines gives instant indication of the contact.

Theoretically, with perfect station keeping, and allowing an error in the bearing given by hydrophone of only 5° each way, the best we can achieve is to locate the submarine within a circle whose radius is one-tenth of the base, and to do this she must not be far from the apex of the triangle. That is to say, with two vessels half a mile apart, the radius of the circle would be 100 yards. In practice, allowing for the inaccuracy of even the best instrument, we cannot say the radius of this circle is at present less than 200 yards. As the radius of destruction of the largest depth charge we have is only 70 feet, a very considerable number would be required, even if they could all be dropped the instant the position was fixed. Owing, however, to the uncertainty of what the submarine may do, and the time taken by even a T.B.D. to reach the place and drop charges, the original 200 yards is considerably extended. It is

evident, therefore, that considerable accuracy, a close approach, and a quick attack are necessary to success. To take an extreme case, if we could approach to 200 yards with our base vessels 1 cable apart, and successfully use some instrument which would then give us direction within 5°, we could locate a submarine within a circle whose radius was covered by the danger radius of a depth charge, and we could bombard her with these with every chance of destroying her. It is the bridging over the distance between 1,000 and 200 yards on which, therefore, we should now concentrate.

As an illustration of the above, a series of diagrams are attached. Figures 1, 2, and 3 show the area in which a submarine may be, if bearings are correct within 5° either way, and the base is accurately kept. The circle has a radius of one-tenth of the base, *i.e.*, for a half-mile base it would be 100 yards. From these it appears that the submarine must not be too far from the apex of an equilateral triangle. In practice, such accuracy is not at present obtainable.

Figure 4 to the same scale shows the effect of errors in bearings and distances of the base vessels combined with a possible error of 10° either way in the bearing of the submarine. This is more in accord with practical conditions of working and shows that we can hardly count at present on a circle of less radius than 200 yards with a half-mile base.

Figure 5 shows the area in which a submarine may be three minutes after location in a circle of 100 and 200 yards' radius, whose course is known approximately and whose speed is ½ knot (blue) or 3 knots (red).

Figure 6 shows in *black* a submarine located in a circle of 100 yards' radius, her speed known to be 3 knots and approximate course estimated. In *green* is shown the position she might occupy if she maintained her course and speed for two minutes, and the position of 22 depth charges 200 feet apart which, if they could all be dropped at that instant, would give a reasonable chance of destroying her. In *blue* is shown the course of a 30-knot T.B.D. supposed to arrive on the spot in two minutes, and the positions in which she would have to drop depth charges allowing for her own speed and that of the submarine as the three lines gradually extend further out. In *red* is shown the corresponding course of the T.B.D. and of two 10-knot trawlers, the latter arriving in five minutes and taking the inner line. It is quite clear that any such manœuvre is impracticable, and, if practicable, would be useless, for any change in the submarine's course or speed would save her.

It would be better to steam in wide curves with H.S.S. out than to use depth charges.

Figure 7 shows in *black* a submarine located in a circle of 200 yards' radius going dead slow and stopping, average speed half a knot and course estimated approximately. In *green* is shown the area she would be in under these conditions in two

minutes from the time she was located, and the position of 32 depth charges 200 feet apart which, if they could all be dropped at that instant, would give a reasonable chance of destroying her. In *red* is shown the course of a 30-knot T.B.D. arriving in two minutes and of two 10-knot trawlers arriving in five minutes, and the positions in which they should drop their depth charges. In practice the T.B.D. would make a circle round the spot at 200 yards' radius, dropping depth charges at 200 feet intervals and firing the inner thrower as quickly as possible, then with the trawlers drop others inside the circle. This is a practicable evolution and would give a good chance of destroying the submarine, but requires the use of a large number of depth charges.

The general conclusions to be drawn from these diagrams are that considerable accuracy and careful plotting are necessary, in conjunction with a base which should be reduced before the attack to at most a quarter of a mile, if the instruments can be trusted at that distance. In order to ensure accuracy, it would be advisable to eliminate possible errors, *e.g.*, to signal the base angles in degrees rather than the bearings by compass. Errors due to deviation and to giving the nearest point or half-point, are serious, but it requires considerable practice to keep a zero bearing on the other base ship, and the staff which can be accommodated in a trawler is probably too small for other than rough methods. Moreover, these rough methods are good enough for chasing. It is only when closing near enough to make a successful attack that accuracy and a short base are important.

III.—FORMATIONS AT PRESENT IN USE.

For the first stage—finding a submarine—there is general agreement that line abreast is best, the distance apart depending on visibility for signalling and on hydrophone range, and varying from 2 to 4 miles. On the one hand, the longer the line the wider the area covered, and on the other, the further the ships are apart the longer it takes them to get into chasing formation. To some extent the latter can be overcome by forming the line of two or more chasing units.

For the second stage—chasing a submarine which has been found—several formations have been tried. These may be divided into two classes; fixed formations in which all vessels alter course together, and line formations which wheel or form approximately at right angles to the direction of the submarine.

Of the former, five or six pointed stars, squares and triangles have been adopted according to the number of vessels. Of the latter, straight lines and lines with the flanks drawn back or advanced have been tried. Experience has shown that small numbers are best, the most favoured at present being three.

This therefore brings the fixed formation to a triangle, while on account of the greater ease in station keeping it is probable the straight line will outlast the curve.

It may be taken then that for chasing a submarine it is probable the unit will consist of three vessels disposed either in a triangle or a straight line. In the case of the triangle, bearings and distances will remain constant and course will be altered together; in the line abreast, bearings and distances will change and course be altered by forming to the new direction. In the triangle the location of the submarine is carried out mainly by the advanced face, and in the line the "cut" will usually be obtained from two vessels, the third vessel in each case acting as a check on the other two. To some extent therefore the two formations are much alike, the difference being as to the position of the third vessel. The main point of difference in working is the method of altering course, and as to whether the length of the base should be fixed. Practical experience will decide whether one formation will be eventually adopted to the exclusion of the other, or whether both will be modified; no hard and fast rules can be laid down. A consideration of the diagrams seems to show, however, that theoretically it will be necessary in the third stage—closing the submarine—to reduce the number of vessels to two, and to be in a position to vary the length of the base: probably also it may be found desirable to allow one vessel to make a slow approach while the other remains stationary. If this should prove to be the case in practice, the two formations for chasing will become one formation for closing.

IV. TYPICAL INSTRUCTIONS AND METHODS OF WORKING.

The following are typical instructions which have been issued for the two systems of formation. The "triangle" at Portland, the "line" in the Mediterranean:—

a Triangle Formation.

The unit consists of three trawlers fitted with "Fish" hydrophones, and a T.B.D. or P. boat as supporting ship.

Should a Submarine be heard by Day.

Hearing ship at once takes following action:—

1. Turns toward the sound.
2. Hoists numeral flags denoting the bearing of that sound.
3. Hoists black flag at the main and black ball at triatic stay.
4. Goes to "action stations."
5. Hoists cone over the red flag at the main (hunting signal).

Remaining ships :—

(1) At once close at utmost speed to half a mile from the hearing ship and take up "hunting formation."

(2) Get out Fish without signal if not already out.

(3) Go to "action stations."

(4) Hoist black ball at triatic stay and conform to stopping signals.

(5) Hoist cone over the red flag at the main, and subsequently signal "submarine heard" when they also hear the enemy submarine.

By "hunting formation" is meant the formation of an equilateral triangle.

The Senior Officer will usually direct the ship furthest from the hearing ship to retire and form the apex of the triangle, he himself forming up abreast the hearing ship, thus presenting a base towards the direction of the sound heard, and signal the new compass course.

Should the centre or Senior Officer's ship himself hear a submarine within two points of the course of the division he will probably order Nos. 2 and 3 to retire, thus himself forming the apex of the triangle towards the submarine. By this means the triangle will be formed in the quickest way.

The immediate steps to be taken by the division are to form the equilateral triangle with all possible speed.

Once the black flag is hoisted by the finding ship she herself directs the "stopping" signals, and others conform to them until such time as the Senior Officer himself takes over control of the hunt.

He, however, will not do this until he himself is in hearing touch with the submarine, and has hoisted the black flag.

Stopping by time interval ceases automatically directly a hunt is in progress.

Once this formation has been assumed the division will remain in the triangle, keeping relative bearings and distance half a mile apart, all turns being made together by blue pendant compass bearings.

Quick and accurate signalling of bearings is essential. To save time the compass pendant will be omitted, and only the two numeral flags denoting the bearing will be hoisted. If no bearing is obtained the "negative" is to be immediately hoisted.

The Senior Officer's ship will plot these bearings on the instrument provided, and so handle the division by blue pendant turns as best to overtake the submarine, if possible keeping a base of the triangle towards her, and getting her ahead on an overtaking course.

This gives the best base for getting an accurate cut by cross bearings.

In practice it is found that successive plots will not be sufficiently accurate to enable the course of the enemy to be plotted, but they will probably enable a rough forecast to be made as to his movements.

It is important, in the early stages of the hunt, to press on at utmost speed and not to have too frequent stopping intervals, as the speed of trawlers gives so little in hand for overtaking.

Probably 10 minutes between stops will be best at first, gradually reducing this as the hunt closes. All ships must proceed at their utmost speed between the stops, and should endeavour not to let their safety valves lift when they stop, as the noise confuses the listeners.

A "stand by" should, if possible, be given to the Hydrophone Officer before stopping, so as to let him make his switch and get his motors in step.

With a well-trained operator the correct bearing should be picked up in under 40 seconds.

In the earlier stages, and in hunting on a faint sound, the stopping periods should be sufficiently long to give a fair chance of listening, whilst still keeping sufficient way on the ship to keep headway on the hydrophone.

Accurate station and bearing are of importance, and ships must do their best to maintain relative bearings and distances. A glance at the compass when the first course signal is made, and a bearing of the leader, will easily show the relative bearing to be taken up and maintained when in hunting formation.

Every encouragement should be given to Hydrophone Officers to communicate to each other by semaphore, as by comparing notes much information may be obtained.

The Hydrophone Officer should be given every assistance from the bridge, by informing him of the presence, bearing, and nature of any surface craft that may appear, so that he may allow for and eliminate them when listening.

Supporting Ship.

Immediately the black flag is hoisted by any ship she will at once close to the apex of the triangle remote from the hearing ship. Should the wing ships both be directed to retire, thus placing the base nearest to her, she should close the nearest ship of that base, always keeping steam on for full speed.

Once in hunting formation, the supporting ship will conform to the movements of the triangle, stopping and starting with them and keeping close to the ship she first closes.

She must be ready at any moment to proceed at utmost speed should she be called upon by the Senior Officer to depth-charge an area.

The hunt proceeds until the Senior Officer considers it worth opening fire with the Sutton Armstrong bomb-throwers. By hoisting distinguishing pendant 5 flag the ship or ships addressed should commence a slow, deliberate fire on the plotted position of the submarine.

These bombs do not carry sufficient high explosive to seriously damage a submerged submarine unless, by good luck, they were burst practically in contact with her.

They may, however, make her realise she is being accurately followed, which will tend to shake their moral, in which case she might be brought to the surface or decide to bottom, if in sufficiently shallow water. Either of these would be an advantage. In any case quick and decisive action in the early part of the hunt should tend to bring it to a satisfactory conclusion, whereas a long-dragged-out hunt is more likely to be inconclusive, due to traffic interference or other causes.

Should the Senior Officer consider he has sufficiently accurately followed and located the submarine, he can at any time call up the supporting ship to depth-charge that area, but this should not be done until reliable plots are obtained within 1,000 yards.

It will always be advisable for the Senior Officer to get the supporting ship close to him shortly before he intends to use her, so as to give her the shortest run before bombarding, and consequently giving the least interval for the submarine to change her position during that run.

By hoisting red burgee 5 flag the supporting ship will close him at full speed and stand by to run out on a line of bearing as indicated by a compass signal; when hoisted, she will commence bombarding the area, when the red burgee 5 flag is hauled down.

Whilst throwing out the supporting ship, the Senior Officer should have "M" and "N" bent on and ready to hoist either side, so as to direct her to starboard or to port on the line she is running out.

It must be observed that the point at which to commence bombarding should never be the last plotted position of the enemy submarine.

Due allowance must be made for her estimated travel during the interval which elapses whilst running out the supporting ship.

Taking a general case, and allowing 1,200 yards for the latter to cover at 18 knots, she will do this in two minutes. The submerged submarine, in this time, may be expected to cover, say, 200 to 300 yards at an average speed of 2 to 4 knots.

At least 300 yards beyond the plotted position should, therefore, be allowed for before hauling down red burgee 5 flag.

Method of Bombarding an Area (*see* Figures 8, 9, and 10).

When red burgee 5 flag is hoisted by the trawler conducting the hunt the supporting ship will close her at full speed and prepare to release depth charges.

Directly a compass bearing is made she will run out on that line of bearing at utmost speed, keeping a careful watch on the conducting trawler, who may, by means of "M" or "N" flag, require to quickly direct her to starboard or to port; she will resume the original course directly either of these is hauled down.

Whether the bombardment should be carried out turning to starboard or to port must be governed by circumstances, and depends on which way the enemy is estimated to be swinging; this decision can only be arrived at at the last moment, but the procedure in either case applies equally well.

If the Senior Officer of the Division particularly wishes the supporting ship to do it either way he would, whilst she was on the run out, sound one long blast on his steam whistle if required to bombard to starboard, and two long blasts if to port.

It is, naturally, of first importance for the supporting ship to get to the point of bombardment in the minimum time, but once at this position the speed during the release of depth charges should not exceed 16 knots, otherwise they will be released too far apart, giving too extended a pattern.

Immediately red burgee 5 flag is hauled down commence bombarding in the following way, releasing up to 20 depth charges.

Drop the first depth charge and fire both throwers simultaneously, at the same time dropping a 10-minute calcium light and putting the helm hard over to starboard or to port as decided. Start a stop watch (destroyers stop the inner engine).

Continue releasing successive depth charges immediately the preceding charge fires, *i.e.*, about 10 seconds interval when set at 100 feet, and if set to a greater depth than 100 feet, still release them every 10 seconds. Reload throwers at full speed, and fire them when loaded, which should be in about three minutes. Continue the turn until the light or the position of the first explosion is four points before the beam, then ease the helm to 10°, *i.e.*, after altering course 24 points (destroyers again start the inner engine).

When the light bears four points abaft the beam, again put the helm hard over (destroyers again stop the inner engine).

With sloops, which carry a greater number of depth charges, the expenditure of 20 should be exceeded as considered justifiable, depending on the likelihood or otherwise of success.

It is probable that if 20, laid in this manner, produce no result, it is not worth dropping more; also you may want them badly on another occasion.

A few "dummy" runs will be required to practise this turn, and will enable the depth charge party to be carefully drilled by stop watch.

The foregoing method produces a "close" field of bombardment. If a more "open" field is considered advisable both engines in destroyers may be kept going ahead throughout the run.

Figure 8 shows the method in principle only, and is purely theoretical.

Figure 9 shows the actual, plotted results of trials carried out in H.M.S. "Ambuscade," stopping the inner engines as in Figure 8; speed of approach, 18 knots.

Figure 10 shows the actual, plotted results of trials carried out in H.M.S. "Ambuscade," with both engines going ahead throughout the run; speed of approach, 18 knots.

It is of the greatest importance to carefully conform to this spiral, which produces a pattern giving the maximum chance of encircling and damaging the hunted submarine.

Every preparation should be made to ram or engage her should the bombardment drive her to the surface.

If the 20 charges have been fired without apparent result, stop engines to enable trawlers to listen.

The Senior Officer of the Trawler Division may also consider it worth while releasing charges from the trawlers themselves, and will dispose and signal to them as necessary to do so.

The subsequent procedure must depend on circumstances. It will probably be best for the supporting ship to close the nearest trawler, and conform to their movements as during the hunt.

Experiments have recently been carried out with depth charges and calcium lights, the latter being thrown overboard immediately the depth charge is dropped.

The lights burn very well and are not affected by the explosion of the depth charge, and thus indicate to any ship in company the exact spot where the attacking ship has dropped her charges.

The calcium lights should be given flotation by being tied to a piece of wood.

Should the Hunted Submarine "Bottom."

If the submarine is definitely heard grouping down and stopping she may be attempting to "bottom."

Should all sound be lost a Dan buoy should be immediately dropped by each ship of the division by signal from the Senior Officer (LQ).

The steps to be taken under these circumstances depend so much on locality, weather, and other circumstances, that it can only be left to the discretion of the Senior Officer in each individual case.

It may be generally expected, though, that the position of the triangle of Dan buoys is unlikely to be within 500 yards' radius of the submarine.

Every attempt should be made to get the submarine quickly on the move again, either by running the supporting ship to bombard an area, as previously described, or by the division themselves dropping depth charges.

Once a submarine has securely settled, as time goes on there is less chance of getting her on the move, and although she cannot remain on the bottom indefinitely, many circumstances may arise which will enable her to slip away.

In any case the position should be watched for at least 48 hours, either by lying stopped with S.C. tubes in action, Fish at short stay, or by patrolling slowly round the locality.

The supporting ships, or even trawlers, cannot, however, risk lying about stopped too long or drifting at slow speed in the supposed vicinity of a submarine, and this must be taken into consideration.

Various methods of locating the position of a submarine on the bottom are being experimented with, and certain locating devices will shortly be issued.

Should these prove successful it is anticipated that they will very considerably reduce the area of the "possible position," even if they do not actually indicate the exact situation of the submarine on the bottom.

By Night.

The procedure for hunting by night will be exactly the same as by day, except for signals; the division, being in double quarter line, is nearly in hunting formation, and thus should be able to form more quickly.

(b) Line Formation.

The unit is a subdivision consisting of three vessels, of which, if possible, No. 1 should be fitted with W/T, P.G.S., P.D.H., S.F., or Plate hydrophones and four depth charges. No. 2 vessel should be equipped similarly to No. 1, but not necessarily with W/T. No. 3 should be equipped with portable hydrophones, S.F. or Plate hydrophones, a P.D.H., if available, and should carry at least six depth charges or paravanes.

The division consists of two subdivisions, with, if possible, a Senior Officer in an additional craft, preferably a torpedo boat or fast trawler, similarly equipped to the No. 1 vessel of the subdivision.

The formation will be in two columns, each subdivision forming a column, the lines of the column being usually at right angles to the original line. In making out the forming signal, attention should be paid to so ordering the movements that the vessel nearest the submarine is moved in that direction. For example: In Figure 11, supposing that the flotilla has been

moving from north to south, and that the submarine was heard by Nos. 1 and 2, the probability is that the submarine is not in the direction from which the line is coming. Therefore, No. 2 should be thrown out to the southward and No. 3 to the northward of the line, No. 2 being nearest the supposed direction of the submarine.

No. 1 will always be on the original line of the search, Nos. 3 and 5 moving to one side of the line, and Nos. 2 and 6 to the opposite side of the line. Nos. 3 and 5 and Nos. 2 and 6 will take up their correct bearing from No. 1 and No. 4 respectively.

Fixing is carried out by as few craft as possible, in order to minimise signalling (and therefore delays) and to obviate interference with hydrophone work. In this operation most skilful handling and the most careful attention to rapid and accurate signalling are essential to success.

One of the following two general methods may be employed :—

(i) A subdivision or unit should plot the course of the submarine and direct the movements of a division of drifters so as to station them ahead on the estimated path of the submarine. When the drifters are considered to be in position they are ordered to shoot nets, in the expectation of forcing the submarine up or, at any rate, of disclosing her presence by the functioning of the indicator buoys and the movements of the pellets. Experience may prove that it is advisable to station the main body of the division about 4 miles ahead, the divisional leader stationing himself about 1 mile ahead, in the possibility of his being able to get his rapid shooting nets across the track.

(ii) Three vessels are employed, two of which must have directional hydrophones, the third vessel (No. 3) not necessarily having directional hydrophones (though the latter are advisable), and carrying at least six depth charges.

No. 1 and No. 2 fix the position of the submarine, and No. 1 plots her course and stations No. 3 ahead of her track. When the submarine passes under No. 3, the latter is ordered to go ahead and drop depth charges. It requires very skilful handling on the part of the Senior Officer in No. 1 to place No. 3 in the correct position, and must depend on accurate observations with the directional hydrophone, and on rapid and accurate signalling on the part of all three vessels.

The proposed method of stationing No. 3 is as follows :—

At the commencement of the search, No. 2 should station herself roughly on the beam of No. 1 at a distance of 1 mile, carefully conforming to any alterations of course and speed of

No. 1. No. 1 should steer to get in the track of, and close to, the submarine. No. 3 should gradually station herself a quarter of a mile on the bow of No. 1, on the opposite side of No. 2. At each stop No. 2 and No. 3 signal bearing of the submarine as soon as possible, and change it immediately a new bearing is obtained. No. 1, as soon as bearings from No. 2 and No. 3 are received and his own bearing observed, will hoist "Z" flag and proceed immediately on his new course, Nos. 2 and 3 carefully observing the direction. No. 1 will continue to complete his plot, and then will make a course signal and correct his course accordingly.

As soon as good directional observations are obtained, and the submarine's position by plotting appears to be under a mile distant, the signal "B" flag numeral pendant" should be made, on which No. 2 closes to half a mile, and No. 3 draws ahead to two points on the bow of No. 1. When the course of the submarine is obtained signal "KI" should be made, on which No. 2 moves to a quarter of a mile on the bow of No. 1, and No. 3 takes station ahead.

No. 3 will then be moved by course and speed signals (the speed may be prearranged to save signalling), and she will discontinue to use her hydrophone and prepare to drop depth charges. If No. 3 is fitted with S.F. hydrophones, she will observe on which side of her the submarine appears to be, and may slightly alter course without orders to get across the path of the submarine. When the stopping signals are made, as No. 3 has not now to get her hydrophone down, she will go astern and may delay stopping for about 10 seconds, and continue on her course while No. 1 and No. 2 are getting their hydrophones over, and she should endeavour to keep her head steady, so as to be ready to proceed at once on her original course.

After signal "KI" has been made, No. 2, in addition to hoisting bearing of submarine, will show "M," "N," or "Q" flags, to indicate whether No. 3 is to the right of, to the left of, or in line with, the bearing of the submarine, as observed in the directional hydrophone. When observations of the submarine's present position and the plot indicate that No. 3 is across her path, No. 1, as soon as No. 2 hoists "Q" flag, will make signal "R" flag, on which No. 3 goes ahead on last compass bearing (or on compass bearing as signalled by No. 1), and will drop two depth charges at short intervals as soon as he is at full speed.

The object of ordering No. 2 to close when good bearings are obtained is that the longer base is not necessary when the submarine is near, signals are read more easily at shorter distances, and, in the event of the submarine altering course, No. 2 can wheel round more rapidly into the new position on the beam of No. 1

If No. 1 alters course, indicating an alteration of course on the part of the submarine, No. 2 will automatically resume station on the beam, and No. 3 will drop back on the opposite bow of No. 1, and will resume taking bearings to assist in the fixing. The same procedure of signalling of "'B' flag numeral pendant" and "KU" will be again carried out. It is possible that No. 3 will be stationed ahead several times before he is actually placed over the submarine.

By this system it will be seen that depth charges are not expended unless there is a very good chance of securing a hit; wasteful expenditure has the additional disadvantage of placing the submarine on his guard.

V.—POINTS WORTH REMEMBERING.

Enemy submarines make considerable use of their hydrophones, and when going slow or with engines stopped can hear enough of what the hunting vessels are doing to make a very good guess as to their movements.

Submarines are known to use sidelights (usually the red light) at night to induce merchant vessels they wish to attack to alter course. Also to use sails in the daytime as a disguise. Careful scrutiny of anything of the kind is therefore most advisable.

The distance a submarine can be heard depends largely on her speed; listeners should, therefore, be particularly careful to note the speed of her engines, or they may report her further off than she really is, and you may overrun her.

A submarine proceeding submerged can probably continue under weigh as follows under favourable conditions:—

Speed.	Hours.
1½ to 2 knots	60
5 knots	12
7 knots	3
8 to 9 knots	1½

In moderately rough weather it is advisable to keep to windward of the submarine, as water noises are less with the sea aft than ahead.

Avoid overrunning a submarine. Noises astern cannot be heard nearly so well as those on the beam or ahead.

When attempting to close a submarine which is balancing, and therefore moving only very slowly, or which may have gone to the bottom, stop and listen for long and *irregular* periods, and, if possible, let one vessel advance while the other listens, so as to catch the sound of a submarine who may be endeavouring to synchronize her movements with those of the hunting flotilla.

When it is desired to mark the position of a submarine, drop a Dan buoy, and also a drifting buoy, which, in order not to hold the wind, should float low in the water.

If it is desired to anchor near a submarine on the bottom without her knowing it, a hemp cable should be used, and the anchor should be lowered by hand, if possible, or two vessels should anchor simultaneously, and, after an interval, one should weigh and steam away. Any vessel at anchor waiting for a submarine should keep her gun manned.

When a vessel is waiting at anchor or drifting near a submarine on the bottom, extreme caution is necessary to avoid making noises. Do not throw things about the deck or against the hull of the ship. Do not break up coal or use a hammer: any noise is certain to give you away.

As to dropping depth charges on oil patches. If the submarine is supposed to be on the bottom, regard must be had to the fact that the oil takes some time to rise and the depth charge to sink. Allowing for these factors, an approximate position on the tideward side of where the oil is rising at which to drop the depth charge set for the depth of water is $d \times c \times 2{\cdot}8$; where d = depth of water and c = surface current. For example:—In 50 feet of water with a 3-knot tide, the depth charge should be dropped $50 \times 3 \times 2{\cdot}8$, or 420 feet on the side from which the tide is coming. If air bubbles instead of oil are rising, the multiplying factor is $1{\cdot}1$ instead of $2{\cdot}8$, and in the example given the distance would be 165 feet.

Figure 1.

At end of
C.B. 791.

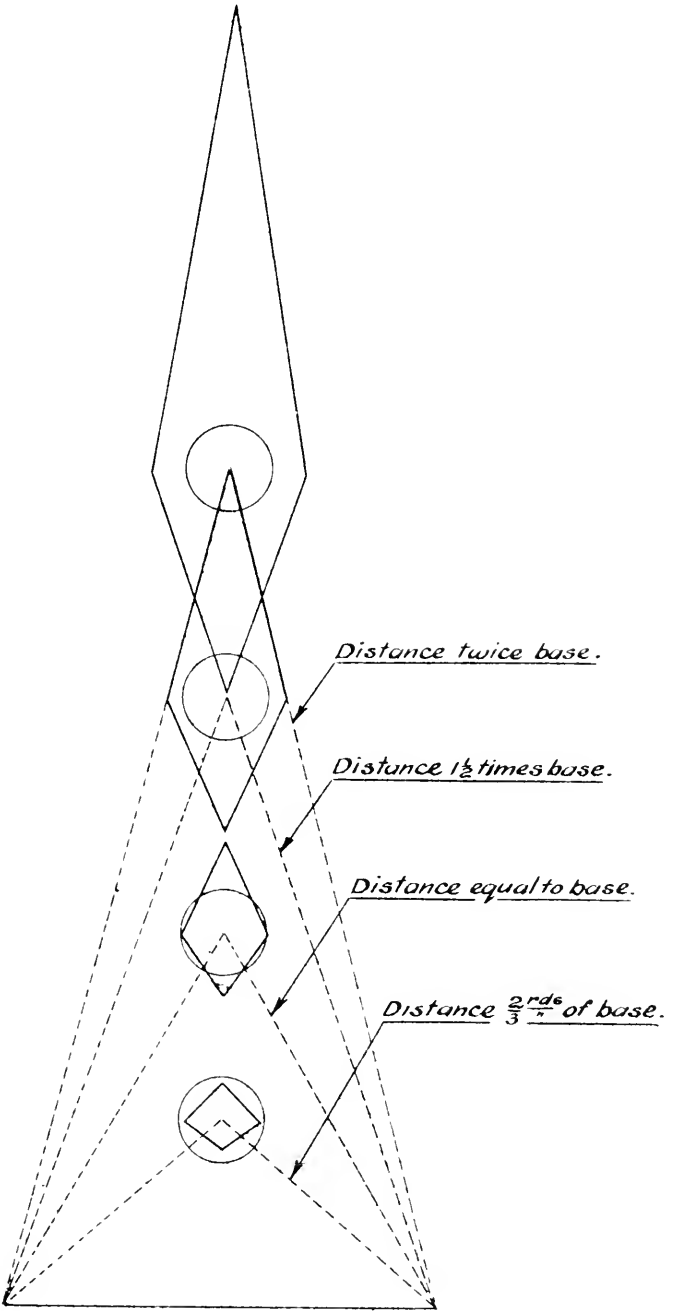
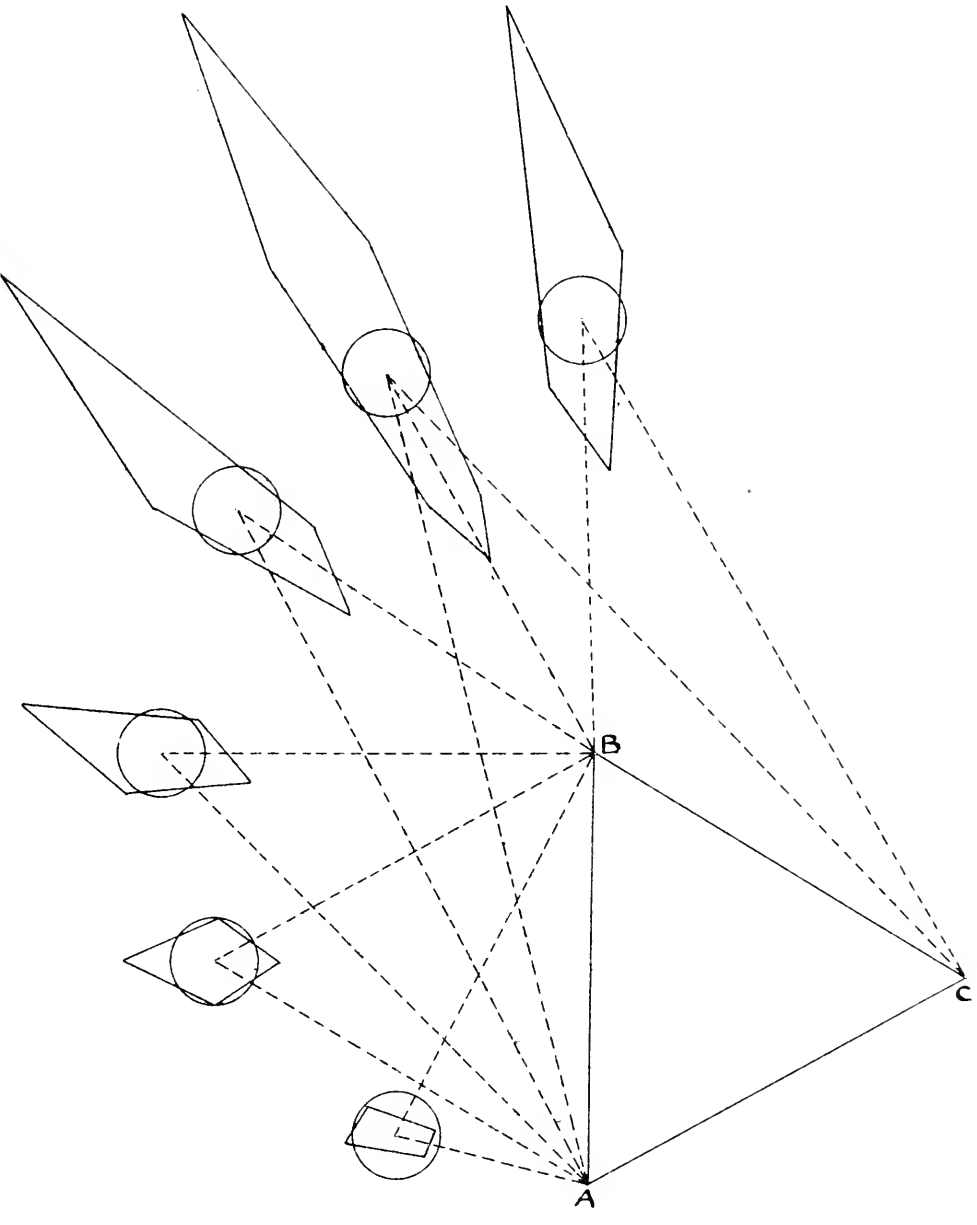


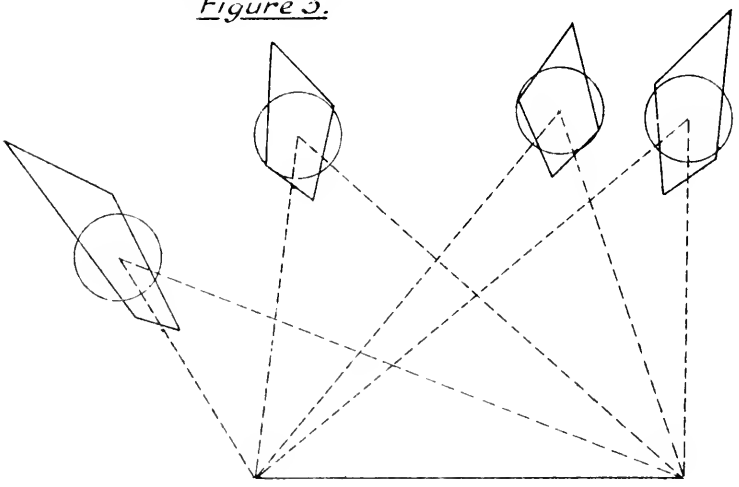
Figure 2.

At end of
C.B. 791.



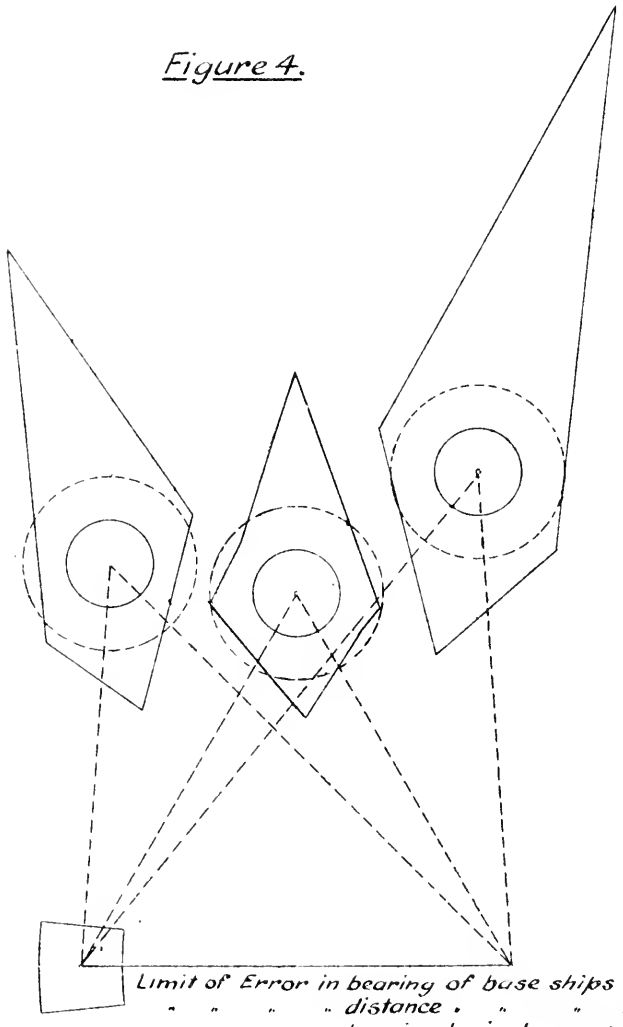
Distance from B equal to base.

Figure 3.



At end of
C.B. 791.

Figure 4.



Limit of Error in bearing of base ships ½ point.
" " " " distance . " " 10 %.
" " " " bearing by instruments 10 degs either way.

At end of
C.B. 791.

Figure 5.

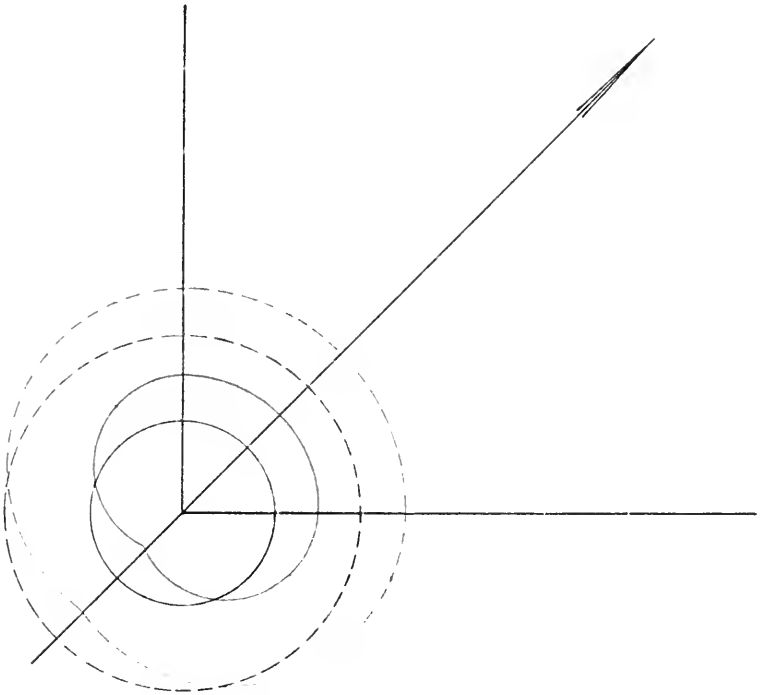
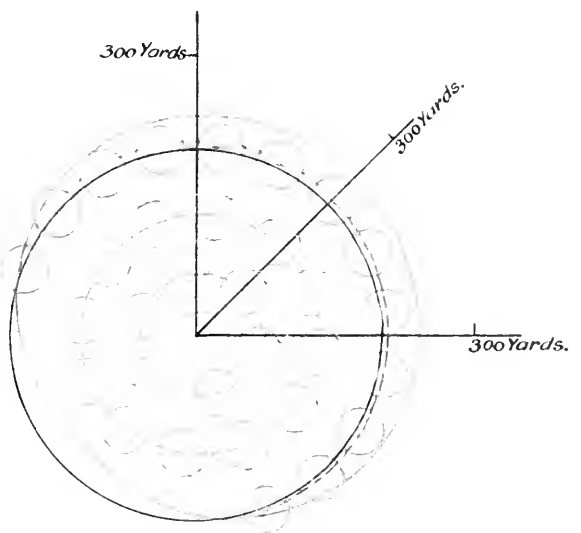


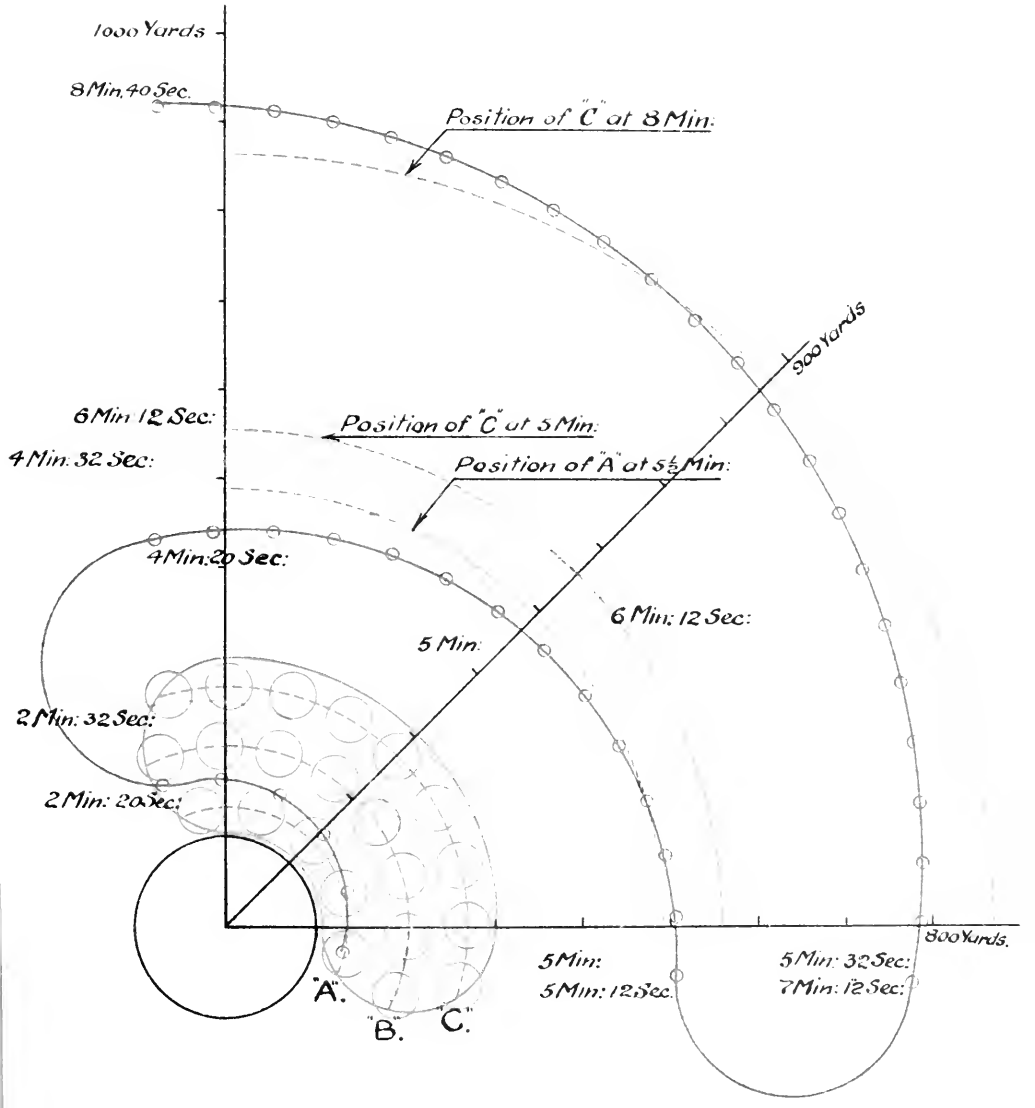
Figure 7.



Ordnance Survey, May, 1918

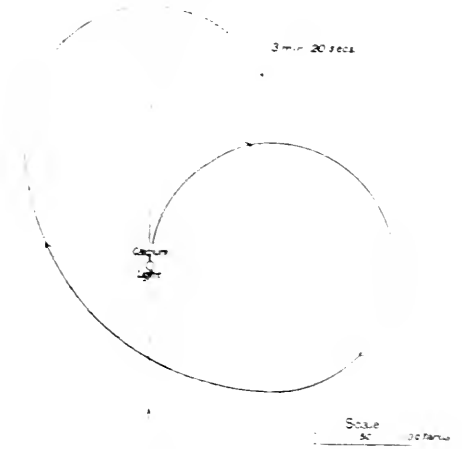
At end of
C.B. 791.

Figure 6.



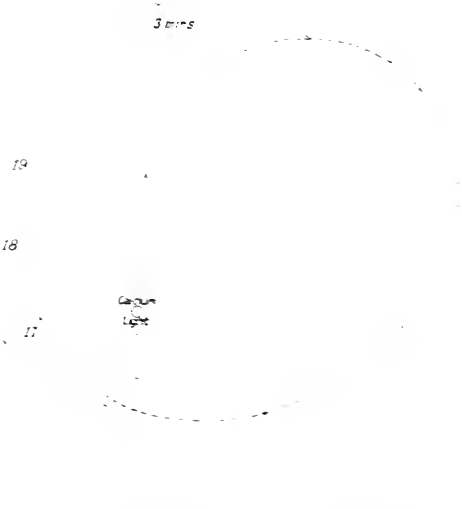
Ordnance Survey, May, 1918.

FIGURE 8.



COURSE OF BOMBARDING SHIP. SPEED 16 KNOTS.

FIGURE 9

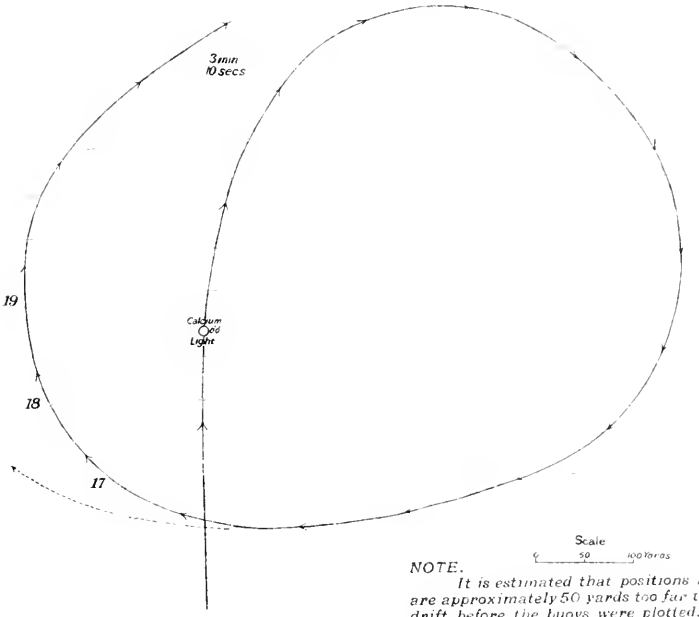


COURSE OF BOMBARDING SHIP. SPEED 18 KNOTS.

NOTE.

It is estimated that positions 17, 18, 19 onwards are approximately 50 yards too far to the right owing to drift before the buoys were plotted. The approximate course would have been in the direction of the peaked line.

FIGURE 10.



COURSE OF BOMBARDING SHIP, SPEED 18 KNOTS.

NOTE.

It is estimated that positions 17, 18, 19 onwards are approximately 50 yards too far to the right owing to drift before the buoys were plotted. The approximate course would have been in the direction of the pecked line.

FIGURE 11.

North.

Search Formation in black. Hunt Formation in red.

Ordnance Survey May 19