O. N. I. Publication No. 17

Confidential

Data on Submarines

A collection of papers reprinted from various sources and revised to date

November, 1917

OFFICE OF NAVAL INTELLIGENCE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

OFFICE OF NAVAL INTELLIGENCE.

OCTOBER 17, 1917.

The articles contained in this pamphlet are mostly reprints of publications the editions of which are exhausted. They have been revised as far as necessary in order to make them conform to the most recent instructions issued by the department. Nothing in them is to be considered as an order; they are to be regarded solely as circulars containing information that may be of use. The information contained in this pamphlet is confidential.

ROGER WELLES,
Captain, United States Navy,
Director of Naval Intelligence.

SUBMARINES.

MILITARY CHARACTERISTICS—TACTICAL USE—METHODS OF DEFENSE AGAINST THEM.

SUBMARINES.

MILITARY CHARACTERISTICS—TACTICAL USE—METHODS OF DEFENSE AGAINST THEM.

By Commander LUKE MCNAMEE, United States Navy.

(Revised by the Bureau of Ordnance, October, 1917.)

DEFINITIONS.

The term "submarine" as herein employed is defined as a vessel of war designed to operate either on the surface or completely submerged and having as its principal weapon of offense the automobile torpedo.

Originally vessels of this type were divided into two classes, "submarines" and "submersibles." Those terms arose with the building of the first Labeuf submarine, the *Narval*. She was called a "submersible," as distinguished from the French submarines of that period. The distinguishing features of a submersible were (1) two methods of propulsion, (2) a great reserve of buoyancy in the light condition, while "submarines" had only a single method of propulsion (electric) and 3 to 5 per cent reserve buoyancy. The two types to-day have merged into one. We do, however, have single-hull submarines and double-hull submarines that are sometimes distinguished in the service by the terms "submarines" and "submersibles." In addition it may be stated that the so-called "submersible" has a ship-shaped form of hull somewhat like that of a torpedo boat, while the "submarine" is generally of the spindle form, the cross section being a circle, with a nonwatertight deck built on top of the spindle.

A submarine is in light condition when all of its water-ballast tanks are empty and its cruising bridge rigged.

A submarine is in the awash condition when it is sealed up and has only those water-ballast tanks empty which are habitually kept full when running submerged, or, in other words, when only the forward, main, and after ballast tanks are empty. The fore and after trimming tanks and the auxiliary and adjusting tanks are filled to an exact amount of water, so that when the ballast tanks are filled the submarine will be trimmed for diving without further adjustment. The quantity of water in the trimming, auxiliary, and adjusting tanks is so small in comparison with the capacity of the ballast tanks that from all appearances the submarine is in the light condition; its draft is somewhat increased, but the speed is not materially reduced. German submarines, however, in the awash condition show only the conning-tower. In the awash condition engines are kept running with the air intake of the engine room open, or the conning-tower hatch open, to supply air to the crew and engines.

A submarine is in the submerged condition when its ballast and trimming tanks, together with the adjusting and auxiliary tanks are filled with such quantity of water that the boat is properly trimmed for running submerged with a reserve of buoyancy from zero to 800 pounds.

MILITARY CHARACTERISTICS.

Military characteristics will for convenience be considered under the following heads:

(1) Mobility.
(2) Offensive power.
(3) Defensive power.

(1) MOBILITY.

Mobility broadly considered includes the following: (*a*) Motive power, (*b*) radius of action, (*c*) reliability, (*d*), habitability, (*e*) communication.

(*a*) MOTIVE POWER.

Submarines in general have two methods of propulsion. On the surface steam or internal-combustion engines are used and when submerged electric motors operated by storage-batteries. In our Navy the older types have gasoline engines, these were abandoned in the E class for four-cycle fuel-oil Diesel engines, and in the K, L, and M classes, our latest development, for the Nuremberg two-cycle heavy-oil engine.

The latest (1917) British boats of the fleet type are designed to operate on the surface with steam turbines, Yarrow boilers are installed capable of raising steam in five minutes. It is known that some if not all steam types carry in addition a Diesel engine for recharging the batteries.

As far as known all submarines now in any service operate submerged with electric motors. Experiments are being conducted in our own and foreign navies to develop greater submerged speed. These experiments aim at the use of the same system submerged as that employed on the surface and involves the need of an air supply for the engines. Highly compressed oxygen is a possible solution of the difficulty, or a telescopic air tube of sufficient length to reach the surface, while at the same time insuring safe immersing.

Under present systems high speed in both conditions seems impossible due to the necessity for two separate sets of propelling machinery. On limited displacement high surface speed is obtained only by sacrificing space and weight for motors and storage batteries. Disregarding the feasibility of operating with but one system of propulsion it has been estimated that to obtain a submerged speed of 20 knots it would be necessary to have power for a surface speed of 25 knots, which combination would require a vessel of 4,400 tons surface displacement and a horsepower of 10,000. The construction of such a vessel is by no means impossible. A British submarine has been recently launched that is designed for a surface speed of 25 knots on 3,000 tons displacement. The submerged speed is not stated, but the present tendency of European navies is toward high surface

speed at the expense of submerged speed. British boats (1916) were reported as having 24.5 knots surface and 8.5 knots submerged speed. Electric storage batteries in our service are of the lead-acid type, either Gould or Exide batteries. Edison (alkaline) batteries have been used so far only experimentally. For military reasons batteries should be of a rugged type that will stand charging in a minimum of time. The engine and the motor power are usually designed so that the batteries can be charged in six hours after a two-hour discharge, with one engine, or in half this time using two engines. Increase in battery power at the expense of engine power would increase this time, which would be highly undesirable. Boats with two engines have the advantage of mobility while charging their batteries.

(*b*) RADIUS OF ACTION.

The table below indicates the radius of action of all submarines now in our service, under construction or projected. Displacement, speed, armament, and fuel capacity are also given.

It will be noted that the maximum radius of any submarine is not much in excess of 3,000 miles. By using fuel for ballast the radius of the "K" class could be increased to about 5,000 miles. The submerged radius at 8.5 knots is about 25 miles. In the "K" class this would be 60 miles at 3 knots and in the "E" class about 75 miles at 5 knots. The recommendation of the General Board for fleet submarines (1915 appropriation) called for: displacement, 1,000; speed surface, 18–20; submerged maximum for batteries, giving radius of 120 miles at 5 knots; surface radius, 3,000 miles at 14 knots.

The length of cruising radius desirable depends on the type under consideration. Fleet submarines should have the radius of the fleet. Coast-defense and harbor-defense submarines are limited in fuel capacity by their size, but it is desirable that all submarines should have a fuel capacity commensurate with their provision supply and habitability.

There are many types of the German U-boat. The type most common has the following reported characteristics:

Displacement, 850 tons; speed, surface 16 knots, submerged 10 knots; radius, surface 6,000 miles, submerged at 10 knots 70 miles; battery, one 4-inch and one 3-inch; torpedo tubes, four 20-inch. The German admiralty reports a submarine recently (February, 1917) as having made a voyage of 55 days without touching a port or receiving supplies. U-boat cruisers, five in number, are reported as of 2,400 tons, three 6-inch guns, and cruising radius of 12,000 miles.

Great Britain has (January 1, 1917) two submarines of 4,000 tons displacement built for the purpose of extending the cruising radius. The British "E" class, like the German "U" class, has many types, the most common being of 800 tons and with practically the same characteristics as the corresponding German "U" boat. A British boat escorted a troop ship from Australia to Liverpool and return, a distance of 38,000 miles, without a breakdown.

The requirements of commerce destroying may be expected to lead to an unheard of cruising radius for German submarines.

United States ships, Oct. 1, 1916—Submarines (Class Sm.).

Name.	Displacement (*g*).	Speed radius.				Armament.		Capacity fuel tanks (gallons).
		Surface.	Submerged.	Fuel (*e*).		Guns.	*Torpedo tubes.* Torpedoes(*i*).	
				Surface.	Submerged.			
	Surface. Submerged.	*Full* Cruising.	*1 hour.* 3 hours.	*Full.* Cruising.	*1 hour.* 3 hours.			*Normal.* Maximum.
A 2-7 (a)	*80* 123	*7* 5	*5.0* 4.0	*250* 440	*5* 12	.....	*1* 3	*750* gas. 750
B 1-3 (a)	*145* 170	*8* 7	*7* 4	*600* 1,000	*7* 12	.....	*2* 3	*1,800* gas. 1,800
C 1-5	*240* 273	*10* 8	*9* 8	*600* 800	*9* 24	.....	*2* 4	*3,900* gas. 5,100
D 1-3	*288* 337	*12* 9.5	*9.5* 8	*900* 1,150	*9.5* 24	.....	*4* 4	*6,000* gas. 7,850
E 1-2	*287* 342	*(b) 12.5* *(b)* 1C	*11* 9	*1,900* 2,090	*11* 27	.....	*4* 4	*5,200* oil. ?
F 1-3	*330* 400	*(c) 12.2* *(c)* ?	*11* 9	*1,344* 2,500	*11* 27	.....	*4* 4	*5,000* oil. ?
G-1	*400* 516	*(d) 12.5* *(d)* ?	*10* 8	? 3,500	*10* 24	.....	*2* 4	*12,300* gas. 16,000
G-2	*375* 481	*14* ?	*10.5* 8.5	? 3,500?	*10.5* 25.5	.....	*4* 4	*10,700* gas. 14,100
G-3	*430* 500	*14* ?	*9.5* 8.5	? 3,500?	*9.5* 25.5	.....	*2* 4	*13,500* oil. ?
G-4	*370* 452	*14* ?	*9.5* 8.0	*980* 3,200	*9.5* 24	.....	*4* 4	*8,700* gas. 19,400
H 1-3	*358* 434	*14* 10	*10.5* 8.5	*1,680* 2,500	*10.5* 25.5	.....	*4* 8	*7,500* oil. 13,375
K 1-8	*392* 520	*14* 12	*10.5* 8.5	*1,680* 3,150	*10.5* 25.5	.....	*4* 8	*8,600* oil. 21,980
L {1-4 (f) {9-11 (f)	*450* 548	*14* 12	*10.5* 8.5	*1,680* 3,150	*10.5* 25.5	One 3-inch	*4* 8	*9,500* oil. 23,000
L 5-8 (h)	*451* 527	*14* 12	*10.5* 8.5	*1,680* 3,150	*10.5* 25.5	One 3-inch	*4* 8	*13,800* oil. ?
M-1	*488* 676	*13.5* 11.5	*10.5* 8.5	*1,680* 3,150	*10.5* 25.5	One 3-inch	*4* 8	*10,000* oil 28,400
N 1-3	*347* 414	*13* ?	*10.5* 8.5	*1,500?* 2,500?	*10.5* 25.5	One 3-inch	*4* 4	*5,800* oil. ?
N 4-7	*331* 385	*13* ?	*10.5* 8.5	*1,500?* 2,500?	*10.5* 25.5	One 3-inch	*4* 4	*6,000* oil. ?
O 1-10	*520* 629	*14* ?	*10.5* 8.5	*2,499?* 3,000?	*10.5* 25.5	One 3-inch	*4* 8	*10,000* oil. ?
O 11-16	*485* 566	*14* ?	*10.5* 8.5	*2,499?* 3,000?	*10.5* 25.5	One 3-inch	*4* 8	*10,000* oil. ?
Schley {60 {61	*1,106* 1,487	*20* ?	*11.5* 9.0	*1,440* 3,000	*11.5* 27	Two 3-inch	*4* 18	*21,900* oil. ?

NOTES.

(a) These vessels are obsolete and of little military value except possibly the moral effect to be derived from their presence in bays to which they are more or less confined.

(b) The *E-1* has recently been reengined with 360 total H. P., while originally she had 500 total H. P. She has not standardized with her new engines, so actual full power speed is not known. The value 12.5 K. may be considered as approximately correct until speed curves have been determined. This speed has been attained on recent runs.

These remarks apply to *E-2* except that her new engines have not been installed. She is now out of commission and it is impracticable to even approximate a date of completion for this vessel.

(c) The F class are not in active service. They are to be reengined with 480 total H. P. instead of the original total of 800 H. P. Their speed with new engines will approximate 12 knots.

(d) The two forward engines of the *G-1* have been removed, thus reducing power from 1,200 to 600 total H. P. New speed will approximate 12.5 knots. This vessel is not in active service, pending delivery of new crank shafts. Date of completion indefinite. This vessel has but two effective torpedo tubes.

(e) This radius is calculated upon fuel capacity and consumption. However, the actual radius of all our submarines is dependent upon other factors which have yet to be coordinated. The radius of action as given on fuel is very apt to be misleading, since the storage of lubricating oil is not balanced with fuel oil, nor has supply of battery water been considered. When more accurate information is obtained it will be possible to make a table showing radius for *fuel, lubricating oil, battery water*, etc. The radius will necessarily be limited to that secured from the least of the factors (by same reasoning that speed of a fleet is equal to speed of slowest vessel.

(f) Information relative to these and subsequent vessels based on design data, since reliable actual data is not at hand.

(g) In speaking of displacement the Submarine Force and the Bureau of C. & R. invariably refer to surface displacement. The submerged displacement means nothing unless the surface displacement is known, then submerged displacement minus surface displacement divided by submerged displacement multiplied by 100 gives % of buoyancy.

(h) The *L-1, 2, 3, 4, 9, 10*, and *11* have been recently delivered. The *M-1* is shortly to be delivered. Delivery dates of remainder of this list are indefinite. However, none of them are expected before the first of 1917.

(i) *Torpedo tubes* and torpedoes= *Number of torpedo tubes on boat*, and number of torpedoes carried by boat.

(c) RELIABILITY.

Under this heading may be considered (1) safety, (2) seaworthiness, (3) mechanical efficiency.

(1) *Safety.*—Submarines of the spindle or single-hull type are built to stand immersion to a depth of 200 feet; larger boats with double hull, 150 feet. Our regulations permit in practice only 100 feet. Until the maximum depth is exceeded there is no difficulty or danger to be anticipated. Beyond that depth the boat is liable to be crushed in, admitting water at the seams that would cause her to fill and sink. The maximum depth may be exceeded through carlessness of the steersman, improper trim that can not be overcome by the horizontal rudders, too quick diving especially in long boats where the bow may reach too great a depth before the boat is straightened up, or lastly due to negative buoyancy caused by injury. Boats operating in the presence of an enemy would probably carry very little positive buoyance, as in case of accident or stoppage of the motors it might be dangerous to come to the surface.

In shoal water there is always danger of striking bottom. The consequences of such an accident is minimized in a submarine by her great strength of hull.

Another danger is that of collision. The periscopes at best give imperfect vision for navigation, which defect is greatly increased in thick weather. Boats totally submerged always run a risk more or less serious in the proximity of other vessels when they rise to the surface. The risk is either that of being rammed or rising under a moving vessel.

Storage batteries are a constant source of danger. When charging they give off hydrogen gas, which needs only admixture with the air to make an explosion compound that may be set off by a spark from any source. Any sea water coming in contact with the acid of the batteries generates chlorine gas that would necessitate the promptest action in coming to the surface to save the crew from asphyxiation.

The air contained in the hull is the normal supply for the crew for short periods of submergence. When this air becomes foul it causes exhaustion and dulls the faculties of the crew. As the greatest vigilance and alertness are needed at all times this effect can be regarded as one militating against safety. The air can be renewed by releasing it from air flasks at one end of the boat and utilizing the air compressors to pump it overboard at the other end.

If necessary at any time to increase buoyancy, water ballast can be reduced by forcing it out under direct air pressure from the flasks, by direct use of the pumps, or by reducing weight by letting go anchors and cables or special weights devised in certain types for this special object. As the greater the depth the greater the pressure against which water must be forced out, any means of reducing water ballast may fail and endanger the boat. A special compartment that may be released from the rest of the boat has been fitted to some types. This has sufficient buoyancy to rise to the surface and offers a means of salvaging the crew. Few boats, however, have any such arrangement. Cruising awash in rough weather with ventilator hatch open may endanger the boat if a heavy sea comes on board.

There comes a time when any crew becomes exhausted after continuous submerged work and it is necessary for the boat to come to the surface, seek port, or lie on the bottom. It has been found impracticable to rest at the bottom in bad weather at depths of less than 20 fathoms due to the sounding of the boat. Boats on the surface in rough seas find it difficult to submerge.

Submarines operating on the surface in shoal waters usually carry a quantity of water ballast to insure refloating in case of accidental grounding. In operating near the mouth of rivers submarines are liable to sink suddenly due to loss of buoyancy in fresh water. These conditions are referred to as "holes" in the water. The safety of a submarine in the presence of an enemy lies principally in its ability to quickly submerge, low normal visibility, and in some cases armor for hull protection. The German boats are reported as completely submerging from awash in less than one minute.

It may be said, in general, that all dangers to submarines are more apparent than real and that modern large boats with experienced crews are essentially safe.

(2) *Seaworthiness.*—The seaworthiness of a submarine is in general satisfactory. Coast and harbor defense types, while not as seaworthy as the larger types, are yet much superior in this respect to surface craft of the same displacement. Experience has shown that even when well below the surface submarines are affected by rough sea and swell, causing the boat to roll and affecting the control in a vertical plane. With only 6 feet of water over the top of the conning tower the boat is so much affected that the control is most uncertain. Boats of the diving type under such conditions find great difficulty in submerging. The conclusion is that in a heavy sea or swell the boat must be kept at least 10 feet below the surface, making its use in water of less than 30 feet depth impracticable. When 10 feet below the surface conning or aiming a torpedo is only possible by the use of a periscope of sufficient height to project from 2 to 4 feet above the surface.

(3) *Mechanical efficiency.*—The machinery of submarines is not in itself mysterious or complex. Engines, batteries, motors, compressors, and pumps are common in other ships and in industrial plants on shore. The restricted space militates against proper attention and overhaul, and lack of experience in the personnel detracts from its efficiency. The failure at a critical time of any part of the machinery may be so serious that all effort is now toward designing the most rugged types.

(*d*) HABITABILITY.

Submarines are now designed with a view to maintaining the crew without undue physical stress to the limit of both surface and submerged endurance.

The severest test on personnel appears to be that of being towed. Nine days appears from tests to be near the limit of endurance under average conditions, though there are records exceeding this. On the other hand, boats operating under their own power have less difficulty in this respect, though there is reason to believe that our boats of older types under these conditions can not maintain efficient crews to the limit of their fuel endurance.

The question of recuperation after a sea trip depends in a great degree upon the weather encountered and the training of the personnel. Habitability is such an essential military characteristic that it must be taken into account in determining displacement even if the increased tonnage is not required for other reasons.

German submarines stay away from their bases from 10 to 20 days. Two weeks is the average time. After a trip of this character it usually takes about the same period to overhaul and prepare for another cruise. Overhauling is done by relief crews, which gives the regular crews time to rest and recuperate.

(*e*) COMMUNICATION.

Submarines depend for communication at the surface on visual hand signals, blinker lights, Very's night signals, and radio. In submerged condition the submarine bells and Fessenden oscillator are available. Two periscopes are installed to permit necessary vision when submerged; one of these is for use in steering and the other for obtaining a view around the horizon. These periscopes are designed to magnify about one power. The periscope tubes are, in the latest designs, of the housing telescopic type and electrically operated and controlled. They are usually installed one forward and one abaft the conning tower and thus afford an enemy a means of judging of the direction in which the boat is heading. This objection is obviated in other types by placing them close together.

Undoubtedly the best periscope is the "Goerz." It is of German invention and make, and since the breaking out of the European war good periscopes are difficult to obtain. This difficulty has been severely felt in the British Navy.

The problem of recognition signals is one most difficult of solution. A submarine coming suddenly to the surface is as apt to be a friend as a foe. The British letter and number their boats. The Germans, Italians, and Austrians rely on being able to recognize their own and have given up marking as a measure of secrecy.

The submarine bell transmits signals in the Morse code. Under favorable conditions with the boat submerged and perfectly quiet, signals have been sent and received a distance of 8 miles. With engines operating this distance is reduced to about 1½ miles.

The Fessenden oscillator is efficient for Morse code to a distance of 9 miles and may be used as a telephone to a distance of 400 yards. The objection to all signaling in submarines is that it can be seen or heard by an enemy as well as by a friend. Effort is now being made to project sound waves in only the desired direction.

No range finders are installed, but there are graduations in the field of the periscope that give the range approximately. Gyrocompasses with repeaters are now being installed in our boats and in those of most of the belligerent nations. Magnetic compasses are practically useless when the boat is submerged.

Radio signals can be sent to a distance of 50 to 100 miles. The disadvantage in radio is that in some types the engines must be stopped to receive a message. This is on account of the noise and vibration of internal-combustion engines. The radio antennæ must be rigged after coming to the surface and unrigged prior to submergence. The difficulty of communicating with submarines is a heavy handicap in their tactical use, but one that is receiving much attention from inventors and will likely be soon overcome.

(2) OFFENSIVE POWER.

Considered as a military weapon the offensive power of the submarine rests on its ability first to gain close contact with the enemy by making use of its mobility and invisibility; and secondly, on ability to inflict damage, which will depend on the efficiency of its torpedo armament.

The armament of submarine boats, which originally was one torpedo tube placed in the bow, has now reached the point where the latest boats designed abroad carry 4 bow torpedo tubes and 4 broadside tubes, 8 in all, with 16 torpedoes. This equipment is combined with a further armament consisting of two 6-inch guns and two 3-inch anti-aircraft guns. Twelve mines with special launching tubes are carried in addition. The bow torpedo tubes, in some types, are of the revolving-chamber type, which permits quicker loading. Boats fitted with only bow tubes are compelled to bring the boat's course to the bearing of the target, which may at times be inconvenient and dangerous. This is not true of broadside tubes, which greatly increase the area over which torpedo fire can be delivered. It can be readily seen that a boat holding a course direct for an enemy from a position on the bow is in a most unfavorable position to escape in case the enemy attempts to ram, whereas if the torpedoes could be fired from broadside the submarine would gain additional time to turn still farther away or dive.

Considering an attack on an enemy of inferior armament, such as merchant craft with possibly but one gun mounted aft, or no guns at all, the submarine's gun may be considered as a truly offensive weapon. It would likewise serve a purpose in attacking small patrol or torpedo boats. As there is always the danger of capturing the hull of the submarine and thereby making it a modern practice of submarines is to submerge when-

Against vessels of superior armament the offensive power is the torpedo. Since most armed vessels have sufficient speed to escape a submerged boat if the periscope is sighted outside of torpedo range, the attack must usually be made by stealth.

A high surface speed enables the submarine to take advantage of her low hull and absence of smoke to gain a position ahead of the approaching enemy and then submerge to await favorable moment for attack. The modern 21-inch torpedo with which the latest foreign boats are equipped carries probably 500 pounds of trinitrotoluol. The destruction resulting from the explosion of such a charge against any ship's side would undoubtedly sink her. Our submarines are equipped with 18-inch torpedoes with explosion charge of T. N. T. of about 250 pounds.

Experiments are being made with a view of designing a short-range torpedo of high speed with very heavy charge of explosive. These are probably now in use abroad. It is said to be possible to design a short-range torpedo of a speed of 45 knots, to carry 1,000 pounds of explosive.

Considering the great strength of hull of the submarine it is possible that protected by its invisibility it may in the future be used as a ram. With a suitable bow it might in this way prove a dangerous weapon even when its torpedo supply is exhausted. It is recalled that the *Castine* was sunk when accidentally rammed by a submarine going at a low speed and that the boat itself escaped with very slight damage. When equipped as a blockade mine layer, as are now many foreign boats, the submarine will add to its equipment this truly offensive weapon which may have a decisive effect in fleet actions that take place on soundings.

(3) DEFENSIVE POWER.

The defensive power of the submarine is dependent upon submergence which effectually protects it from gun fire and makes it invisible to the enemy. Compelled to stay on the surface, destruction in the presence of a surface boat of superior armament would appear inevitable.

The latest submarines in use abroad are reported as having an upper hull plating of 2 inches and an armored conning tower of 3 inches. It is considered that such vessels are invulnerable to gun attack of calibers of 3 inches or less.

The submarines of our Navy carry no armor.

The defensive power of invisibility in the submarine is also manifested at night in the awash condition. The low hull and absence of smoke has enabled them in tactical exercises to pass through the picket lines without detection.

Submarines when threatened with attack can submerge in from 30 seconds to 3 minutes and escape either by their submerged speed or by resting on the bottom till nightfall.

In our Navy the average time of submergence from light conditions is 3 minutes and in awash condition about 20 seconds less.

Three-inch guns mounted on submarines may be considered as a defensive weapon against patrol boats, and the 6-inch guns mounted now on the largest, against destroyers or even light cruisers.

It is not believed that such guns would ever be used effectively against an armed vessel if it were possible to escape by submergence.

TACTICAL USE.

The tactical employment of submarines in time of war might be broadly considered under the general headings of offensive and defensive use, but as the best defense is in all cases the tactical offensive, and as the term "defense" is confusing when considered in connection with strategic employment in harbor and coast defense, it is considered best to treat the subject of tactical use under three different heads which refer to a more or less arbitrary classification by types.

These three types of submarines are: (*a*) Harbor defense, (*b*) coast defense, and (*c*) fleet submarines.

HARBOR DEFENSE SUBMARINES.

This term is applied to older boats of low speed and small armament that are considered of little value away from the vicinity of their bases. In our service it is applied to the "A," "B," and "C" classes. The use of these boats is regarded as somewhat equivalent to that of a controlled mobile mine field. It is a matter of interest that the Italian Government is at the present time building submarines of 30 to 40 tons carrying two 18-inch torpedoes. The motive power is electricity and the radius of action about 100 miles. No other foreign navy is known to have adopted such a type for any purpose, and their utility is very doubtful.

The limited submerged radius and speed of harbor-defense submarines do not permit them to operate far from the harbor which they are defending. Boats of this type will depend more than any other on stealth for success in making the approach. For this reason they should operate in accordance with a plan which would allot to each boat a certain zone to be covered, and once dispatched on her mission and submerged, she can be considered as outside of communication. Any attempt at coordination between submarines in this position by use of a submarine bell would serve as a warning to the enemy.

These zones should be selected to cover all courses of approach to the harbor and the boats should be so disposed that each can cover its own zone while well outside of gun range of the harbor fortifications.

A harbor-defense group having received warning from scouts or shore stations of the movements of the enemy off the coast would proceed to the entrance, where each boat would take up its station in the center of its zone, anchor in awash condition with radio up, and keep a lookout for the enemy.

By subdividing the total area outside each harbor into numerous small squares and using short code words to designate squares and directions, scouts in touch with an enemy can keep the submarines informed as to his movements.

The waiting submarines, having ascertained that the approach of the enemy to the harbor, would weigh anchor, and upon appearance of smoke disconnect radio and submerge, keeping periscopes exposed.

A submarine, through her periscope, should be able to see the masts of a large vessel in clear weather a distance of 7 or 8 miles. Such observations have been made with 4 feet of periscope exposed. All boats should remain in position until the movements of the enemy are definitely ascertained. By the arrangement of zones, the enemy must pass close to one submarine. The other boats

should move toward a point that will intersect the enemy's course, keeping him under observation, with just enough periscope to escape detection.

When approaching torpedo range, when periscope may be sighted, boats should submerge entirely and porpoise at intervals for a few seconds to obtain bearings. Once inside torpedo range periscopes should be kept exposed and all speed used to close the distance to the minimum before firing. If there is but a single enemy great care should be taken to avoid discovery until the last minute, as the probability of a hit will be small unless the range is very short. It should be possible for a submarine to get within 200 yards before firing. If the enemy is in formation his ability to escape is much less and the chance of a hit is much greater. As the danger of periscopes being destroyed by the concentrated fire of the enemy is also great, boats would be justified in firing torpedoes at a greater range, but they should close as rapidly as possible and continue to fire until torpedoes were exhausted.

It will be difficult for a group of submerged boats to coordinate an attack as there will be risk of collision. Such risk must be taken, and boats by keeping a sharp lookout for other periscopes and ringing the submarine bell continuously may reduce the danger to a minimum.

Having fired their torpedoes, boats should submerge totally, and reload their tubes if they have spare torpedoes. During the period of reloading they should run at such depths as would enable them to pass under the enemy's vessels; or if the depth of water permits, they can rest on the bottom till the reload is finished. It is important that selected zones should afford sufficient depth of water to permit submarines to lie on the bottom without danger of collision with deep-draft surface vessels.

When reloaded, boats should return to the surface and resume the attack. All means of offense being exhausted, the group should return to the harbor submerged or under cover of darkness. The tender should be ready to replenish torpedoes and recharge batteries.

The tactics employed at night are the same as that for surface boats. If bright moonlight, submerged work is possible and highly effective. Under such conditions the tactics would be the same as those described, except that periscopes would be kept up continuously.

COAST-DEFENSE SUBMARINES.

The distinction between a coast-defense and a harbor-defense submarine lies in the former's greater submerged and surface endurance, greater speed, and superior habitability. All submarines in our service not classed as harbor-defense boats may be regarded as coast-defense submarines. Taking our "D" boats as the most inferior of this class, we find that they have a demonstrated radius of about 1,000 miles and are self-sustaining for a period of about 10 days. Their submerged radius is 35 miles at 8 knots and about 75 miles at 5 knots. Their torpedo armament consists of four 18-inch tubes in the bow capable of taking any 18-inch torpedo now in service.

20652—17——2

In considering the tactics of coast-defense submarines it is assumed that they would be concentrated in groups at certain bases on the coast. On information from shore stations or scouts that the enemy has appeared approaching our coast, the group or groups nearest would proceed to intercept, using highest reliable surface speed (10 knots for "D" class and about 11 knots for "E" class).

Cruising formation should be column, distance 1,000 yards. Boats should be in awash condition with radio up to intercept any information that may be sent broadcast or directly to them.

On sighting the smoke, boats should submerge and take further observations only through the periscope. The problem that confronts the group commander is to bring his group into contact with the enemy and within torpedo range at the same time. To insure this, individual boats must conform to the general movement, and as signals will be impracticable when near the enemy column "follow-the-leader" tactics appears the only practicable method of insuring coordination. Once within maximum torpedo range the group should be *on the bow* of the enemy formation. If the distance is 1,000 yards, each boat can attack without risk of collision with neighboring boats, when it judges that the moment has arrived.

The proper bearings on which to fire torpedoes with the maximum chance of hits against an enemy in any formation is the same as for surface boats and has been considered by the Naval War College under the section devoted to destroyers.

As in the case of harbor-defense submarines, boats that have exhausted their means of offense should proceed with the same precautions to the designated base.

Should the attacking group discover the enemy at anchor, landing troops, or establishing a base, and with submarine defense yet unprepared, the attack might be much simplified. The enemy's patrol and pickets could probably be passed at night, and the most serious obstacles to success would be nets and mines with which the enemy would probably protect himself. Sharp net-cutting false prows are now being fitted to submarines designed to cut any wire used for nets. Propellers are protected by guards that prevent fouling, so that mines would appear to be the greatest danger. In spite of this risk, which would have to be taken, it is believed that a determined attack by submarines would stand a good chance of success.

FLEET SUBMARINES.

Fleet submarines may be defined as submarines having the formation, speed, and radius of the fleet and capable of accompanying it, ready for duty under all conditions of weather. Such submarines might obtain supplies from the fleet, but they should be as habitable and mobile as any of the fleet units.

In attack the tactics of such a group would be the same as that already described for coast-defense submarines, but as a unit of the fleet the problem for the commander in chief is how best to coordinate this attack with that of his other forces.

Assuming that submerged speeds will not be in excess of 12 knots, submarines can gain contact with the enemy only by stealth or stratagem. The task of the commander in chief is so to maneuver that the enemy will be drawn into submarine water. The problem is somewhat similar to that of drawing an enemy over

a mined field with the difference that the submarines being mobile can assist in the necessary maneuvers. If we consider a fleet speed of 16 knots and submerged submarine speed of 12 knots we have a combined speed of 28 knots available on opposite courses for changing the bearing of the group from its own battle line.

In the surface condition if the boats have a speed of 16 knots, there is a total speed of 32 knots available for this purpose.

A submarine may be sighted in the awash condition at a distance of 12 miles. By keeping on the offside abreast of their own ships they could keep concealed much longer but would be equally delayed in getting into action. It would seem wise then when two fleets are seeking action and are in scout contact that the submarines should be advanced to battle ranges about 15,000 yards in the direction of the enemy. The commander in chief with the assistance of the group commander should maneuver his forces in such a way that the bearing of the enemy from the flagship would always pass through the group; with 32 knots speed available for this purpose and boats still awash such maneuvers would be simple.

A group of destroyers, one for every three boats, should accompany them to act as observers and communicating vessels. When the enemy vessels are made out by the destroyers the submarines should submerge, periscopes up, and follow the motions of the destroyers which should still maneuver to keep them on the enemy bearing from the commander in chief's flagship. If the enemy desires to attack, it will be necessary for him eventually to approach the submarine area. No signals should be permitted except that destroyers might hoist a number indicating the range of the enemy and his direction. These might be read through periscopes. The utmost care should be observed to insure that the enemy does not sight a periscope until the moment for attack arrives. This signal could be made with the oscillator when the enemy is within torpedo range, when all boats advance at full speed, periscopes up. Outside of 6,000 yards there is no chance of seeing a periscope. Within that range an occasional porpoise of a few seconds would give small chance for discovery.

With boats paralleling the enemy's formation, each ahead and on the bow of its target, and the range at time of driving home the attack, 2,000 yards or less, the chance of success would seem very great.

The above tactics, while apparently defensive in character, are really offensive, since they involve only maneuvers necessary to bring about the submarine attack.

In any tactical situation there is usually a position of advantage to be gained by maneuvers, which, if necessary, should be fought for. This advantage may have reference to sun, spray, smoke, or silhouette. A fleet with submarines, knowing the probable intentions of the enemy in this regard, may be able to anticipate his movement toward a certain area and utilize the time during approach to place a group of submarines in position to meet him.

Fleets meeting for battle are sure to be forced into column, once gun-fire ranges are reached. It should not be impossible for a faster force to maneuver in such a way as to bring the enemy into column at a predetermined position. If groups of destroyers are placed across the path of this column in such a manner that they will confront the enemy steaming on courses parallel to our line and in

either direction, the enemy may be forced to maneuver under fire or suffer torpedo attack.

In some cases one or two submarines, detached for the purpose, might permit their periscopes to be seen, and thereby induce the enemy to turn away toward other groups lying in wait.

Fleet submarines should carry 10,000-yard torpedoes. The chance of hitting a single target at such a range is very small, but the chances of hitting some vessel of a formation are good. Submarines should always endeavor to close the range to the possible minimum, but if discovered and the enemy shows evidence of turning away, torpedoes in range should be discharged at once.

Enemy vessels discovering a submarine close aboard and ahead will likely attempt to ram. Under such circumstances the boat's best maneuver is to keep the periscope up and endeavor to steer a safe course past the vessel without turning away. An attempt to dive to a sufficient depth to pass under the keel would be hazardous.

It may shortly be possible to design a fleet submarine capable of maintaining a submerged speed of 20 knots. Assuming that such a boat would have ventilators extending to a height of 25 feet above the hull, she might in battle submerge to a depth of 20 feet and still be able to draw air for combustion from the surface. If we assume a fleet in action accompanied by 30 such vessels, they might assume a position of comparative safety on the disengaged side of the battleships and at the decisive moment pass through the intervals and steer for the enemy's column. It is difficult to see how such an attack could be met except by immediate retreat. The possibilities of a real fleet submarine have been but dimly realized, and it is possible that another great fleet action may contain a surprise. It is reported that both the British and German commanders regret the absence of their large submarines in the Jutland battle.

METHODS OF DEFENSE AGAINST SUBMARINES.

We will consider methods of defense under the heads of (1) Ports and anchorages; (2) Single vessels, armed and unarmed; (3) Vessels in formation; (4) General.

(1) *Ports and anchorages.*—In order to afford a refuge for vessels to repair and refit, safe ports and anchorages must be provided. Without safety in port, naval operations would be difficult and commerce impossible. Many devices have been brought forward in the present war to accomplish this end, some of which are known and others still kept secret. Each harbor or anchorage requires a special treatment to satisfy its peculiar needs, but the defense usually consists of booms, nets, mines, and active patrol vessels. In addition, batteries mounted on shore and seaplanes are frequently employed.

Booms are effective in denying surface craft entrance to a harbor at night. This applies to submarines in light condition. Nets for this purpose are of heavy wire cable $\frac{7}{16}$ inch to $1\frac{5}{8}$ inches in diameter, with about a 12-foot mesh. They are made in suitable lengths from 600 to 1,500 feet and of a depth such that a submarine can not pass under them. The ends are supported by buoys and the weight of the net taken by buoys or barrels secured at points in sufficient numbers to support the weight. Heavy moorings, 2,000 pounds or over, hold the ends of the net in position.

A gate, usually tended by a tug to haul aside one end of the net, permits passage for friendly vessels.

Mines moored at different depths to cover any possible depth of submergence of the submarine are very effective. Unless controlled they are dangerous to friendly vessels that may be out of their course, and are liable to go adrift in bad weather.

German submarines are fitted to lay mines and carry from 12 to 24. These are frequently laid in the approaches to harbors or off the mouths of navigable rivers. The latest type have a clock device for regulating the time that the mine watches. The mine field is arranged in groups with several time settings, usually two hours apart. It is very difficult for mine sweepers to be sure that they have them all. A constant service of effective mine sweepers appears to be the only protection against this menace.

Whatever defense is used the service of patrol vessels, day and night, is necessary to preserve the integrity of the defenses against an enemy who will be active in attempts to remove or destroy them. Submarines caught in a net may escape if not promptly dealt with by the patrol boats. The type of net described, however, is designed more to prevent submarines entering a harbor than as a means of catching them.

Batteries mounted on shore with searchlights are a good safeguard against night surface operations. A submarine in shoal water can be readily detected and followed by an aeroplane.

(2) *Single vessels (armed).*—A single vessel sighting a submarine should open fire at once and maneuver to avoid torpedoes. If the submarine bears more than six points on the bow and within 1,000 yards the ship should turn away. If the torpedo can be seen it will probably be best avoided by backing, since it was probably fired on the estimated speed of the ship.

If the submarine is within six points of the bow, greatest safety will likely be found in heading directly toward it and endeavoring to ram. To insure his own safety he will likely keep his periscope out of water so as to see to maneuver. In any case the smallest target will be presented to him and if the torpedo has been fired a skillful use of the helm may enable the ship to avoid it.

The position of the submarine relative to the ship should be plotted and the vessel maneuvered to pass outside of any position circle that the boat may reach in any elapsed time.

Merchant vessels approaching any area where submarines may be expected should have lookouts especially qualified by keen vision, experience, and reliability stationed in the tops and in the eyes of the ship. A high position is favorable for sighting distant boats before they become awash or submerge and low positions for obtaining a sky background for detecting boats that are in the intermediate zone 6 to 9 miles away and particularly hard to detect against a sea background when seen from a high position. No chances should be taken. It should be assumed that a German torpedo has a range of 10,000 yards and the ship maneuvered to keep outside that range from any position the submarine could reach.

At all times in possible submarine areas the ship should proceed at maximum speed, changing course at least 15° every 10 minutes. At night, if dark or in thick weather, a straight course may be steered at best speed. No lights of any kind should be shown and no whistles sounded. Radio operators should listen in constantly for possible messages or warnings, but no radio signals should be sent. If the ship is sighted by a submarine, an alarm should be sent by radio at once giving latitude and longitude. Possibly a patrol boat is in the vicinity and may assist evasion. As a submarine can submerge from light condition in about 90 seconds and from awash in about 30 seconds the chance of making a hit with gunfire is small. For this reason it is all the more necessary that guns should be kept loaded with gun crews at hand ready to fire at once. The puncturing of the exterior hull or conning tower of a U boat will have little effect. It is necessary to pierce the spindle-shaped interior hull to disable her. The destruction of the two periscopes would deprive her of vision while submerged, but would not otherwise endanger her. Machine guns at close range might be effective against periscopes by breaking their lenses. Nothing lighter than a 3-inch gun is considered effective against a U boat except at close range. It must be remembered that they have two periscopes, one about 8 feet and the other about 20 feet in height above the hull. These are telescopic and self-housing and are elevated and depressed by an electric motor within the hull.

It must not be assumed that because the radio masts are up that they will have to be unrigged before diving. These masts fold down along the starboard side of the deck and are operated from within the boat.

It is not considered advisable for an armed vessel of even moderate draft to attempt to pursue a submarine with a view to its destruction. Such work should be left to torpedo boats and special light-draft patrol boats.

Patrol boats.—The particular enemy of the submarine is the patrol boat or submarine chaser. They are divided into three classes according to the service they are disposed to render. The *inshore* patrol consists usually of 50-footers of at least 20 knots speed and preferably 30 to 35 knots, armed with a light gun and several machine guns. They are intended for use near harbors and channels where submarines may be expected to serve the purpose of locating and tracking them. They are too weak to attack a large submarine single handed by gunfire and must rely on numbers or the support of larger boats. They may, however, if the submarine is submerged, use depth charges to advantage.

The *intermediate* patrol serves the same purpose in extending the area under protection. Boats assigned to this rôle have a speed greater than submarines and a larger displacement, radius, and armament than inshore patrol boats.

The *offshore* patrol consists of correspondingly heavier and more powerful boats, such as destroyers.

When a submarine is discovered near shore, or where a number of patrol boats are available, the nearest boat proceeds at top speed to the point where it was seen to disappear, notifying the other boats by radio. When over the spot it hoists a flag; the other patrols assemble on this boat and each runs a retiring search curve on the assumed submerged speed to cover all possible courses that the submarine could take on the limit of its submerged endurance or in the time remaining before

darkness. Each boat is on the alert to open fire the instant the periscope is sighted. Whenever a patrol vessel has reason to suppose she is over the submerged location of a submarine—and effort should be made to reach such a position—she should drop one or more depth charges. It may be possible that the submarine has remained near the spot where first sighted and is resting on the bottom awaiting darkness. It is most probable that it will proceed slowly while deeply submerged to a distance of but a few miles and then await darkness to escape. If the microphone is installed it may be used by either the submarine or the patrol. The sound of propellers can be heard through the water a great distance by the use of this instrument. The receiver or a number of them is immersed in some position outside of the boat. Specially trained men can detect the peculiar noise of a submarine propeller and also the hum of the electric motors. The allies at present are reported as using a number of blind men for this purpose—their sense of hearing being usually highly developed. It is possible to tell not only the proximity of a submarine but its approximate direction.

It is reported that a number of German submarines have been sunk by destroyers because of the noise the Diesel engines make when they come to the surface at night to charge batteries. On a calm night or to leeward this noise can be heard for miles. A destroyer drifting along at slow speed hears the noise, makes for it, and when near turns on the searchlight and opens fire. It must be remembered, however, that submarines having two engines can charge batteries while under way on the surface in the daytime. Submarines in any case will always endeavor to maintain their batteries fully charged and will usually have ample opportunity to charge them while lying to or patrolling in daylight. Only after a prolonged submerged run, as after being chased, will it be necessary to charge at night. Steam turbines are not open to the objection of noise and this has been used as an argument for their substitution for Diesel engines in several navies. The English, French, and Japanese all have some boats operated by steam.

The class of submarines usually found in shoal waters and in the vicinity of harbors are of a small type, reported to be 80 or 90 feet in length. These boats are better adapted to work around nets and mines and have been successful in reaching inner harbors, such as Boulogne and Cherbourg, and did much damage. Small patrol boats would be most effective against this type. Any submarine that could cross the Atlantic would likely be compelled on account of its size to operate only in the steamer lanes well offshore.

SINGLE VESSELS—UNARMED.

For unarmed vessels, defense against submarines will consist in high speed, frequent changes of course, selection of unusual routes, invisibility at a distance, use of a smoke screen, timely sighting of submarine by vigilant lookouts, and in the last resort of ramming.

It is possible that a submarine might be deceived by quaker guns mounted on the bow and stern. If the submarine can be made to remain submerged, the greatest danger—that from gunfire—will be eliminated.

Invisibility at a distance is important, and freight carriers of moderate tonnage could be designed with low freeboard, folding masts, oil engines with no smoke

pipes, and exhaust carried under water. Vessels of the whaleback type would seem most suited. Speeds should be in excess of 15 knots, and preferably higher, though this would likely not be advisable on account of reducing cargo space. It is believed such a vessel would stand an excellent chance of passing through a submarine blockade undetected.

Smoke apparatus, for use both on board and as floating free of the ship, are now supplied to a number of allied vessels. All United States vessels with armed guard are so equipped, and the purchase of this type of apparatus has been opened to all United States vessels through the Department of Commerce.

If the vessel has a speed superior to the surface speed of the submarine, she may, of course, escape if the boat is discovered in time. Submarines in light condition have been seen at a distance of 12 miles, and periscopes, or rather the wake made by them, have in rare cases been made out at distances of 8 miles. These are very exceptional cases, but indicate the necessity and great advantage of vigilant, efficient lookouts.

A submarine suddenly coming to the surface ahead or on the bow might be rammed. Such an attempt should at least compel the boat to maneuver to avoid collision and spoil the aim of his torpedo. It would reduce the torpedo's target to a minimum.

A shotgun loaded with buckshot, or even rifles and revolvers, might be able to break the lens of a periscope that was close aboard.

Dummy periscopes are sometimes attached to mines for the purpose of destroying vessels that attempt to ram. A German U-boat destroyed a British destroyer by such means, the mine in this case being towed about 100 yards astern of the totally submerged submarine.

The use of dummy periscopes, even when unattached to mines, would have a very disorganizing effect on an enemy, and suggests a possible use of this device in battle.

VESSELS IN FORMATION.

In the British grand fleet great stress is laid on the avoidance of submarines and mines, and orders on the subject are kept on the bridge. There are three different conditions:

(*a*) When in cruising formation.
(*b*) When in approach formation.
(*c*) On or during deployment.

For each of the above there is a different procedure for distance submarines and for one discovered close-to.

During (*a*) captains are authorized to turn out of line, if in column. It is usually best to turn toward the submarine. The leading ship turns toward the submarine not more than 4 points if the submarine appears up to 6 points from ahead. She can turn more later, but only 4 points at a time. The ship next astern will also turn, and following ships will either follow No. 2 or turn toward submarine, according to judgment of captains, as far as the next flagship, which ship will handle its subdivision by signal. The danger zone is from right ahead to 5 points

on the bow, and if the submarine is within 3,000 yards your own or some other ship is in danger. A periscope, as a rule, can be seen only 2,500 to 3,000 yards. A submarine has been seen at a distance of 12 miles, so a distant watch must be kept as well as one close-to. If a submarine is seen at distance, ships will be maneuvered by signal to avoid it. No risks are to be taken. It must be assumed that the enemy has 10,000-yard torpedoes.

The orders are that there shall be an officer and a signalman aloft and an officer and six men on each side of the bridge or submarine lookout. They are to be on watch for one hour only so as not to be tired. In battle, lookouts are kept by crews and officers of intermediate batteries.

The submarine lookouts also keep a lookout for mines. If one is sighted the ship will act in the same way as if a submarine was sighted close aboard. If the situation permits, orders will be given to fire a Very star into the water—green to starboard, red to port—close to the ship. Ships will try to sink mines by small-arm fire. It is not thought that ships of the Grand Fleet ought to be bothered with mines if cruisers and destroyers are protecting the fleet.

If in line of division columns and both cloumns turn toward a submarine the one to port must keep clear of the starboard column. It is thought that a 4-point turn will make a submarine dive.

If in battle formation, it is important not to break the column, and ships must not turn out to avoid a general submarine attack, but if a torpedo is seen, captains may alter courses to avoid it, getting back in position as soon as possible.

Eternal vigilance is the price of safety and no chances must be taken. If a distant submarine is sighted it should be plotted and the ships maneuver so as to keep out of the danger zone.

GENERAL.

The most effective defense against submarines is undoubtedly an energetic offensive against them by every possible means that will compass their destruction.

A German U-boat commander is quoted as stating that the greatest danger to which they were exposed in the English Channel was that of being rammed. They never knew when they first rose to the surface that there was not some vessel at hand ready to ram before they could see her and submerge. He also spoke of the transportation of British troops across the Channel. He said they were so absolutely enveloped by destroyers that a submarine could not show herself without being sunk.

The French submarine *Foucault* was sunk by an aeroplane. The Austrian aviator at a height of about 2,400 feet sighted the submarine under water and was able to follow it. When it came to the surface he started a very steep descent and opened fire with a machine gun. The submarine replied with an antiaircraft gun, but was unable to make a hit. The hydroplane continued the descent until it was able to drop a bomb from an altitude of about 100 feet. It was thought that the submarine either lacked the necessary time for submersion or was under the impression that the plane on account of its steep descent was not under control. Small dirigibles are now in use along the English coast to search for submarines.

Trawlers and small steamers are sometimes used as decoys. These vessels conceal submarines that remain awash under their quarter. When an enemy submarine comes to the surface to attack the decoy, the hidden submarine submerges and attacks the enemy at short range with torpedoes. Auxiliary sailing ships with concealed batteries are also used to delude the enemy.

The new Admiralty design for patrol boats calls for a boat of 120 feet length, 17 feet beam, 6 feet draft, and displacement of 90 tons, constructed of steel. The speed is about 20 knots, cruising radius large, and so designed as to have excellent sea-keeping qualities. She will carry a crew of about 30 men and will mount two 5-inch guns. The cost per boat will be about $80,000. A smaller boat is deemed of little value.

Microphones are used in the British and French Navies as a means of detecting the presence of submarines. The French have found that it is better to have the microphones in series and trawled over the stern like a patent log. In a ship not under way the presence of a submarine can be detected within a distance of 5 miles. Training schools have been established for the purpose of using blind men in the use of this apparatus. A cruiser is employed, fitted for the purpose. Submarines circle about it, and by sound waves emitted from the propellers the operators are finally trained so that if a submarine is within a distance of 6 miles they can locate its bearing within two points.

The immunity of German submarines from attack by regular naval units is attributed to the use of hydrophones which give warning of their presence. It is quite possible to differentiate between the sound of their propellers and those of slow cargo boats.

Since the sinking of so many men-of-war by submarines both the Germans and the British have stopped placing vessels of military value other than torpedo boats on patrol duty.

Two British destroyers rammed enemy submarines at speed less than 10 knots. The submarines were not sunk, and the bows of the destroyers were damaged.

To meet the latest German methods of submarine warfare the British have adopted three schemes, as follows:

(*a*) To arm all merchantmen. They had not a sufficient number of guns for this, but intended taking land antiaircraft guns, which they now consider more or less useless.

(*b*) To have convoys with constantly changing rendezvous.

(*c*) To sow mines around German ports, forming a pocket, the outside of the pocket to be constantly patrolled by British ships.

As the method of destroying submarines that are under water, either on the bottom, entangled in nets, or pursued by patrol boats, is by the use of depth charges dropped on them or in their vicinity, it is of interest to know the quantity of T. N. T. and the distance of the explosion from the boat to ensure its destruction. It is believed that a pressure of 500 lbs. applied suddenly and locally would be sufficient for the purpose.

The following formula is of value in determining the pressure, distance, and weight:

$$P = \frac{3.17 W^{.68}}{D^{1.39}}$$

P = pressure in tons.
W = weight in lbs. of explosive.
D = distance in feet.
3.17 is applicable to Cast T. N. T.

For guncotton it would be 2.86. A bomb of 50 pounds of explosive should be fatal to a submarine at a distance of 25 to 30 feet, producing at 25 feet a pressure of approximately 1,000 pounds to the square inch, or a pressure of 500 pounds at 41 feet.

The United States aeroplane bombs carry 50 pounds of T. N. T. The depth charges are made in two sizes, the light, Mark I, 50 pounds T. N. T., and the heavy, Mark II, 300 pounds T. N. T. The effective radius of the latter is estimated as 75–100 feet. The Mark I are supplied to all vessels engaged in offensive against submarines; the Mark II only to vessels capable of 15 knots speed, as it is dangerous to the vessel itself to drop at less than that speed.

The following notes by Lieut. Daubin (Dec. 17, 1916) are considered of sufficient interest at this time to be produced in their entirety:

NAVY DEPARTMENT,
BUREAU OF STEAM ENGINEERING,
Washington, D. C., December 17, 1916.

Subject: Showing by diagrams the relative offensive value of submarines boats having different submerged characteristics and indicating how the offensive power and value of our submarines to be built may be directly increased by increasing the tonnage.

1. The following is quoted from a letter July 21, 1916, of the commander submarine force to the president of the Naval War College:

"A submarine is visible when on the horizon, and for about 3 miles beyond and 3 miles inside of this point, appearing as a buoy. When a submarine approaches near enough to have a sea background she becomes invisible and remains so until within about 3 miles of the observer. In general, a submarine is visible distant from 12 to 6 miles. To avoid detection it would be necessary to totally submerge before coming within the visible zone, and navigate totally submerged, or only show her periscope for a few seconds at long intervals."

2. Under favorable conditions for the enemy a submarine must submerge when the enemy is 12 miles distant. This distance, 12 miles, must be run submerged. It is true there is an invisible zone for the submarine from 6 to 9 miles from the enemy, but once submerged time would not be taken to blow tanks, etc., and come to the surface, knowing that within a few minutes another dive would be required, and knowing also that the exhaust or noise of the engines of the submarine would be detected by the enemy. The 12 miles is run at varying speeds, depending upon the course and speed of the enemy, the average speed will be about 8.5 knots per hour. When within 3 miles of the enemy the submarine makes numerous porpoises to get the exact bearing of the enemy; in all events the enemy will detect either the wake or the periscope before the torpedo can be fired; detection will probably occur in the average case at 2 miles. The enemy immediately puts her helm over to escape.

3. A submarine's offensive power depends upon three features:

(*a*) Surface speed and radius combined with sea-keeping qualities.
(*b*) Submerged speed and radius.
(*c*) Torpedoes carried and ability to fire them submerged.

A submarine's defensive power depends upon one feature—(*a*) submerged speed and radius.

4. A submarine's surface speed and radius combined with sea-keeping qualities enable her only to get within 12 miles of the enemy. The 12 miles must be navigated submerged. The final test of the submarine's offensive power to deliver an attack rests entirely upon her submerged characteristics, and her ability to fire torpedoes submerged when within range of the enemy.

...ther the attack submerged, whether successful or not, a submarine must have power in her battery to enable her to immediately make attack submerged on another ship of the enemy near by, *or* power in her battery to enable her to run submerged and escape, as she can not escape by surface navigation.

6. To illustrate the value of submerged speed and radius, assume two types of submarines with characteristics as:

Type P–1: Tonnage about 400 to 500, submerged speed and radius similar to our present coast-defense type, viz, 1 hour at 10.5 knots, or 3 hours at 8.5 knots.

Type P–2: Tonnage about 800 to 900, submerged speed and radius, 1 hour at 12.5 knots, or 6 hours at 8.5 knots.

Assume also—

(*a*) That each type carries a 30-knot torpedo, range 2,000 yards.

(*b*) That submarine has submerged 12 miles distant from enemy and makes the approach at varying speeds, averaging about 8.5 knots per hour, until at a point 2 miles from the enemy, *on any bearing*, when enemy sights her and attempts to escape.

(*c*) Speed of enemy, 15 knots.

7. Fig. I, first case, Type P–1. After submarine has run submerged for 10 miles at 8.5 knots she has 31 per cent of her battery power and can now make 6.4 miles at a speed of 10.5 knots per hour. She carries a torpedo which she can fire, which is good for 1 mile at 30 knots. Fig. I shows that the enemy, speed 15 knots, having sighted the submarine and started to escape, can be approached within 1 mile and a torpedo fired; that the maximum danger zone for the enemy or the maximum attacking zone for the submarine is equal to 63° either to the left or right, according to which direction the enemy tries to escape, making a total danger zone, O, equal to 126 °, and the enemy's zone of safety equal to B, or 360°—126°=234°. See Fig. II.

Fig. I, second case, type P–2: After submarine has run submerged for 10 miles at 8.5 knots she has used 19 per cent of her battery power and can now make 10 miles at a speed of 12.5 knots per hour. Torpedo carried for same range and speed as used for type P–1. The enemy's danger zone, O, is increased to twice 80° or 160°, the enemy's safety zone, B, is reduced to 360°—160°=200°. See Fig. II.

Note that in either case the enemy can be intercepted if she takes a course within her danger zone, but can not be intercepted if she takes a course within her safety zone.

8. By the same method as used in Fig. I the danger zone and safety zones for enemy's ships of 12, 15, 18, and 20 knots were calculated when attacked by submarines of types P–1 and P–2. See Figs. II, III, IV, and V. Following are the facts shown by these figures:

	Speed of enemy.	When attacked by submarine having 10.5 knots for 1 hour or 3 hours at 8.5 knots.		When attacked by submarine having 1 hour at 12.5 knots or 6 hours at 8.5 knots.	
		O, danger zone for enemy.	B, safety zone for enemy.	O, danger zone for enemy.	B, safety zone for enemy.
	Knots.	*Degrees.*	*Degrees.*	*Degrees.*	*Degrees.*
Fig. 2	12	162	198	246	114
Fig. 3	15	126	234	160	200
Fig. 4	18	102	258	140	220
Fig. 5	20	76	284	95	265

9. Thus the military value *for offense* of the submerged characteristics of the two types of submarines is illustrated when operating against enemies of different speeds.

10. But the submarine must have power in her battery after the first attack either to deliver another attack submerged or to escape. In Fig. I, first case, the attack was delivered at the end of 12 minutes after initial submergence, submarine P–1 has used 59 per cent of her battery power, and she now has left a radius of 10.4 miles at a speed of 8.5 knots per hour for another attack or to escape. In Fig. I, second case, the attack was delivered at the end of 16 minutes, submarine P–2 has used 45 per cent of her battery power, and she now has left a radius of 28 miles at a speed of 8.5 knots per hour for another attack or escape. Or, *after the attack*, submarine P–1, having originally 3 hours at 8.5 knots, or 25.5 miles, has 10.4/25, her original value is equal to 31 per cent, while submarine P–2, having originally 6 hours at 8.5 knots, or 51 miles, has left 28 miles at 8.5 knots, or is equal to 28/25.5, equal 109 per cent, or more than the *original* value of submarine P–1 for another attack.

11. The following table shows the value of battery power remaining after the original attack:

	Speed of enemy.	Battery power remaining after initial attack is made.			
		Submarine P–1, having 1 hour at 10.5 knots or 3 hours at 8.5 knots.	Submarine P–2, having 1 hour at 12.5 knots or 6 hours at 8.5 knots.	Submarine P–1, per cent of original value.	Submarine P–2, per cent of original value of P–1.
Fig. 3	15	10.4 miles	28 miles	31	10
Fig. 4	18	12.7 miles	31 miles	50	121
Fig. 5	20	14 miles	37 miles	55	145

12. The foregoing figures and tables illustrate the greater value of submarine type P–2 (800 to 900 ton submarines, submerged speed and radius 1 hour at 12.5 knots, or 6 hours at 8.5 knots) over that of type P–1 (500-ton submarines, submerged speed and radius 1 hour at 10.5 knots, or 3 hours at 8.5 knots) for an initial attack upon enemy's ships, and the value of the submarines for another attack or escape after the initial attack.

13. If submarines with greater submerged characteristics are desired, greater battery power is necessary, hence larger submarines.

14. The surface and submerged speeds and radii of a submarine should determine the displacement of the vessel. For every B. H. P. required to drive the boat at its rated surface speed so many pounds of engines and auxiliaries are required, *if the installation is to be reliable.* Similarly for every E. H. P. required to drive the boat at its rated submerged speeds, so many pounds of battery and motor are required. If it is attempted to obtain more E. H. P. per pound of motor and battery than good engineering practice sanctions, an unreliable motor and battery will result. The characteristics of the proposed submarines having been decided, the weights of the engine, auxiliaries, motors, and batteries to produce the speeds, and function reliably, can be determined. Having determined these weights, the tonnage of the vessel can be ascertained.

15. Other considerations affecting the motive power installation, are:

(*a*) The propeller design.

(*b*) The engine power for charging the battery.

It is desirable, from an engine viewpoint, to design a propeller that will require as few R. P. M. as possible to drive the boat at its maximum surface speed, in order that the required maximum speed of the engine may be low. It is common knowledge that slow-speed machinery is less liable to break down than high-speed installations. This same propeller must drive the boat submerged. The propeller will cavitate quicker submerged, i. e., at a lower speed, than on the surface. However, the weight and efficiency of the motor will vary with the R. P. M. of the propeller, since the motor must drive the boat submerged. It is desirable, then, to have as high revolutions of the propeller as possible for submerged work, since the motor will weigh less and be more efficient. But since the engine will be more efficient for surface work the lower the speed of the propeller, the propeller design must be a compromise.

16. Consider (*b*). The engine must not only furnish power for driving the boat on the surface, but it must also furnish the power for driving the generators to charge the batteries. For military reasons the engines must have power to charge the batteries in a minimum of time. The engine and motor power should be such that the batteries can be charged in six hours after a 10-hour discharge—with one engine—or half this time using two engines. If the battery capacity is increased, that is weight added to the battery, at the expense of the engine installation, thus reducing the engine power, it takes a time longer than six hours to charge the batteries, and the characteristics of the submarine become *unbalanced;* she becomes an inefficient weapon for offense or defense.

17. It is obvious then that if greater submerged speed and radius are demanded, the capacity, and hence the weight of the battery must be increased, and to balance this increase in submerged motive power, that is, to insure its availability, the engine power, hence the weight of the engines must be increased.

Summing up the above from an engineering standpoint, the following is logical:

(*a*) Determine the surface and submerged characteristics.

(*b*) For reliability the motive machinery (engines, auxiliaries, motors, and batteries), will weigh a certain number of pounds per horsepower.

(*c*) The military characteristics, i. e., speeds in conjunction with other desired characteristics, as hull strength, fuel oil carried, torpedo installation, will then determine the displacement of the vessel.

(*d*) The propeller design must be a compromise between that design most suited for surface speeds and that most suited for submerged speeds.

(*e*) The surface and submerged characteristics must be balanced if the submarine is to be effective.

18. Following are the speeds that may be obtained, with reliable motive machinery, in submarines of various displacements:

Maximum surface speed.	Normal radius surface.	Maximum submerged speed.	Radius in time.	Submerged speed 10 knots radius in time.	Submerged speed 8.5 knots radius in time.	Submerged speed 5 knots radius in time.	Displacement surface.
Knots.		*Knots.*	*Hours.*	*Hours.*	*Hours.*	*Hours.*	
15.5	4,000 at 12 knots	12.5	1	3	6	22	800–900
16.5	4,000 at 12 knots	12.5	1	3.3	6.5	24	1,000–1,100
17.0	4,800 at 12 knots	12.5–13.0	1	3.6	7.2	30.5	1,200–1,400
17.8	5,300 at 12 knots	12.5–13.0	1	4.5	8.5	36	1,600–1,700

19. Conclusions as follows are drawn:

(*a*) The surface speed of a submarine enables it to approach the enemy to the zone of visibility, distant 12 miles from the enemy.

(*b*) The zone of visibility must be navigated submerged.

(*c*) The power in the battery must be sufficient for the submarine to run about 10 miles of this distance at an average speed of 8.5 knots and the last 2 or 3 miles at its maximum speed in order to get within torpedo range of the enemy.

(*d*) After the attack there must be power remaining in the battery to attack another ship or for the submarine to escape submerged.

(*e*) Depending upon the submerged speed and radius of the submarine and the surface speed of the enemy, there is a danger zone for the enemy of a definite number of degrees.

(*f*) This danger zone for the enemy is increased the greater the submerged speed and radius of the submarine.

(*g*) The submarine having the greater submerged speed and radius has also the greater power left in her battery for another attack submerged or to escape.

(*h*) To increase the submerged speed and radius, the battery cubical contents and weight must be increased.

(*i*) If the battery power is increased, the power of the engines must be increased in order to charge the battery in a minimum length of time; consequently the surface speed is also increased.

(*j*) To obtain greater battery and engine power, the displacement of the submarine must be increased.

(*k*) For reliability of the engines the revolutions per minute must be kept low, which means that the revolutions per minute of the propeller submerged must be lower than full speed on the surface.

(*l*) The weight of the motor for submerged work decreases as the revolutions per minute of the propeller, submerged, increase.

(*m*) Therefore the design of the propeller for surface work and the design of the propeller for submerged work must be a compromise, and

(*n*) Therefore higher maximum speeds submerged in 1,500–1,600 boats than 12 to 13 knots are at present considered impracticable.

(*o*) The greater the submerged speed and radius of the submarine—i. e., the greater the displacement of a boat designed with balanced characteristics—the greater is the enemy's danger zone. Hence the larger the boat, with proper characteristics, the greater the military value.

20. Following is a table showing the submarines built, building, and recently authorized by Congress.

21. When the boats recently authorized by Congress have been commissioned, in 1919, the Navy will have:

Submarines under 570 tons displacement..... 99
Submerged characteristics: 1 hour at 10.5 knots; 3 hours at 8.5 knots.
Fleet submarines, 1,106 tons displacement..... 3
Submerged characteristics: 1 hour at 11.5 knots; 20 hours at 5 knots.
Submarines, 800–854 tons..... 3
Submerged characteristics:
One Lake: 1 hour at 11 knots; 4 hours at 8.5 knots.
One E. B. Co.: 1 hour at 11 knots; 5 hours at 8 knots.
One Government: 2 hours at 11 knots; 6 hours at 8.25 knots.

22. Following are notes on submarines made from the files of O. N. I.: Russia is building:

350-ton boats..... 6
900-ton boats..... 8
800–900-ton boats..... 5
1,000-ton boats..... 28

Germany is building in large numbers at present submarines between 750 and 800 tons.
Her 1917 program calls for 100 submarines.
Her 1918 program calls for 50 submarines.

In the summer of 1916 Germany had:

U boats under 300 tons..... 10
U boats about 400 tons..... 3
U boats about 800–1,000 tons..... 19
U boats about 1,350 tons..... 7

Before the end of 1916, 42 more submarines were due for commissioning.

Great Britain has 172 submarines in commission, of which 65 are under 600 tons and the 107 remaining are from 725 to 1,300 tons. She is building 17 fleet submarines 1,700–2,000 tons.

Class.	Displacement.	Surface. Maximum speed and radius.		Surface. Cruising speed and radius.		Submerged. Maximum speed and radius.		Submerged. Cruising speed and radius.	
		Knots.	*Miles.*	*Knots.*	*Miles.*	*Knots.*	*Hours.*	*Knots.*	*Hours.*
A 2 to 7									
B 1 to 3									
C 1 to 5	240	11.0	725	8.1	776	9.0	1	8.0	3
D 1 to 3	288	13.0	910	9.6	1,179	9.5	1	8.0	3
E 1 to 2	287	13.0	1,900	10.1	2,090	11.0	1	9.0	3
F 1 to 3	330	14.0	1,344	11.0	2,500	11.0	1	8.5	3
G 1 to 4	375–430	14.0	.....	11.5	3,500	9.5–10.5	1	8–8.5	3
H 1 to 3	358	14.0	.....	11.5	2,500	10.5	1	8.5	3
K 1 to 8	392	14.0	1,680	11.0	3,150	10.5	1	8.5	3
L 1 to 4	450	14.0	1,680	11.0	3,150	10.5	(1)	8.5	(2)
L 5 to 7	451	14.0	1,680	11.0	3,150	10.5	1	8.5	3
L 9 to 11	451	14.0	1,680	11.0	3,150	10.5	1	8.5	3
L 8	451	14.0	1,680	11.0	3,150	10.5	1	8.5	3
M 1	488	14.0	1,680	11.0	3,150	10.5	1	8.5	3
N 1 to 3	347	13.0	.....	.....	2,500	10.8	1	5.0	6
N 4 to 7	331	13.0	.....	.....	2,500	11.0	1	5.0	6
O 1 to 10	520	14.0	2,499	.....	3,000	10.5	(1)	8.5	(2)
O 11 to 16	485	14.0	.....	.....	3,000	11.0	1	8.5	3
Schley	1,106	20.0	1,440	14.0	3,000	11.5	1	5.0	20
60–61	1,106	20.0	1,440	14.0	3,000	11.5	1	5.0	20
1917 prog.									
18 E. B. Co	569	13.5	1,760	11.0	2,000	10.5	1	8.5	3
9 Lake Co	495	14.0	2,000	11.0	3,150	11.0	1	8.5	3
1 E. B. Co	854	14.5	2,000	11.0	2,400	11.0	1	8.0	5
1 Lake Co	800	16.0	1,665	11.0	3,150	11.0	1	8.5	4
Government 800-ton	800	16.0	.....	11.0	.....	[3] 12.5 11.0	1 2	8.25	6

[1] 54 minutes.
[2] 2 hours 42 minutes.
[3] Propeller design of Government 800-ton submarine has been modified to give the boat a 1-hour speed, submerged, of 12.5 to 13 knots. In the absence of trials of actual submarines of this type, the speed should be considered as only 12.5 knots for 1 hour, although the boat will probably make 13 knots submerged.

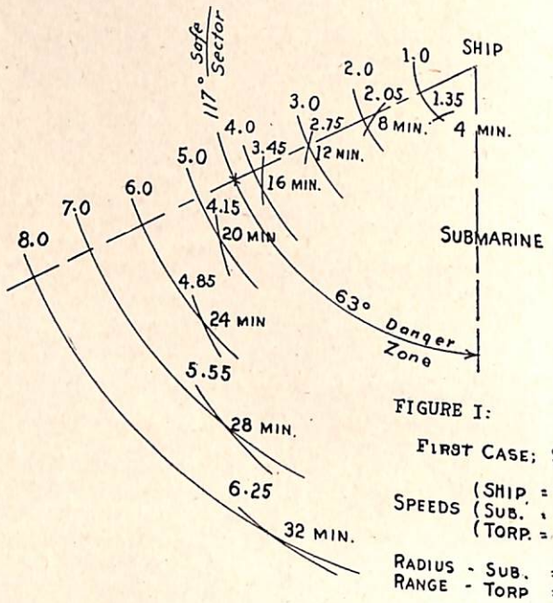


FIGURE I:

First Case: Submarine P_1

Speeds (Ship = 15 knots
(Sub. = 10.5 knots
(Torp. = 30 knots

Radius - Sub. = 6.4 miles
Range - Torp = 1.0 mile

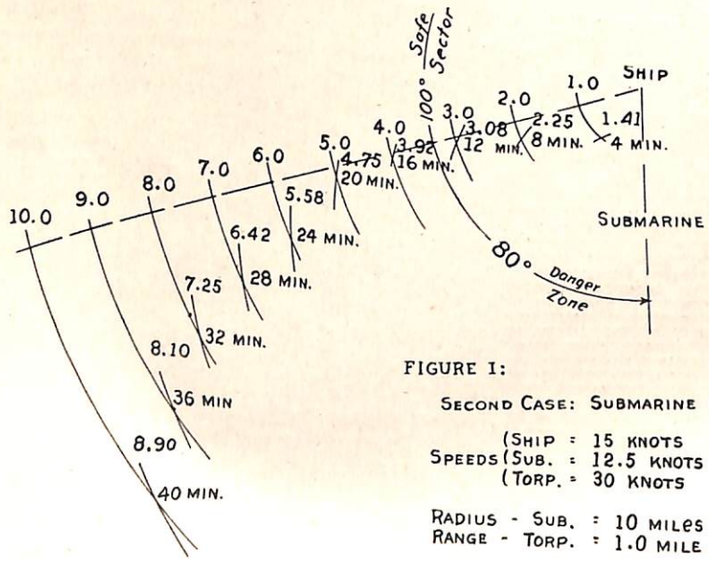


FIGURE I:

Second Case: Submarine P_2

Speeds (Ship = 15 knots
(Sub. = 12.5 knots
(Torp. = 30 knots

Radius - Sub. = 10 miles
Range - Torp. = 1.0 mile

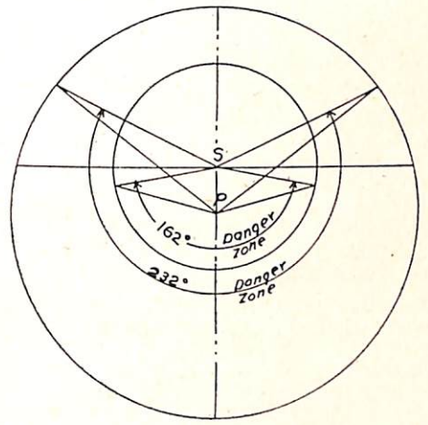


FIGURE II

Enemy = 12 knots

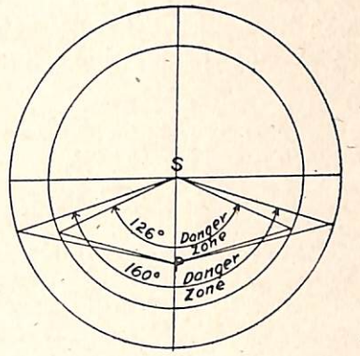


FIGURE III

Enemy = 15 knots

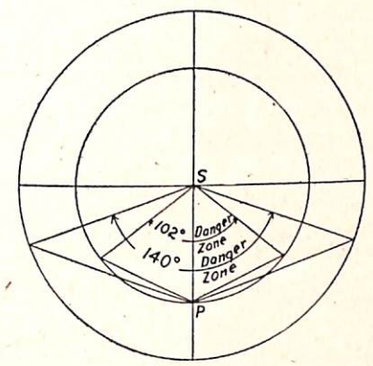


FIGURE IV.

Enemy = 18 knots

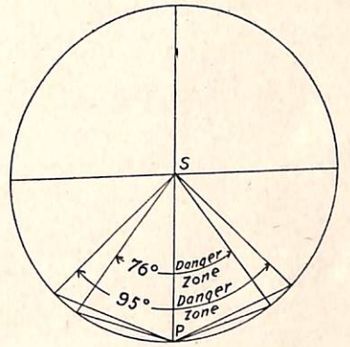


FIGURE V.

Enemy = 20 knots

Enemy at "S" sights submarine "P", distant 2 miles

Danger zone for enemy is increased when attacked by submarine having 1 hour at 12.5, or 6 hours at 8.5 knots.

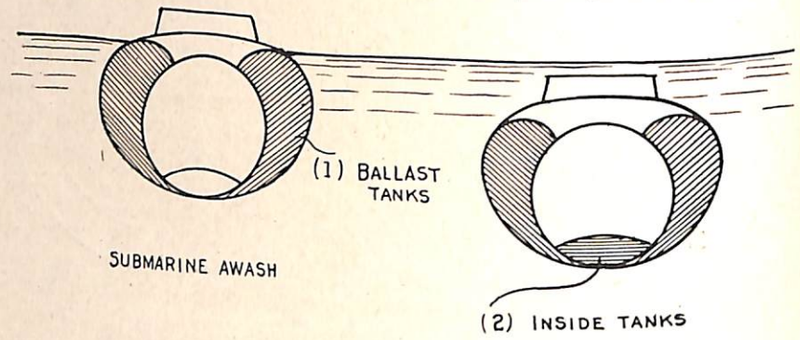
TORPEDO

20652—17——3

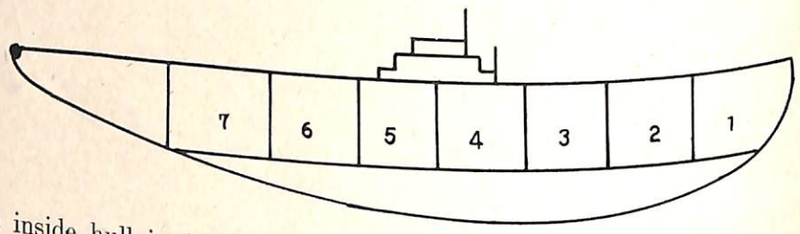
REMARKS ON SUBMARINES.

GENERAL DESCRIPTION OF A GERMAN SUBMARINE.

The German submarines are what are known as double-hull vessels; that is, there is a centrally located hull or spindle of heavy steel plating surrounded by an envelope of light steel plating. Between the two platings are compartments in



which ballast water and fuel oil are carried. Inside the heavy-steel hull or spindle all the machinery, battery, electric motors, torpedoes, and personnel to man the vessel are located. The ballast tanks between the two hulls are very large and hold sufficient sea water when flooded to bring the submarine to the awash condition. (1) By flooding the tanks within the heavy hull all buoyancy can be destroyed, permitting the submarine to sink to the bottom or just float in the water with practically no weight (2) at all.



The inside hull is divided into several compartments. Beginning forward, these compartments are:

1. Torpedo compartment: Torpedo tubes and torpedoes.
2. Forward battery compartment: One-half of storage battery; living quarters for officers and men.
3. Central operating compartment: All valves and other arrangements to control and operate boat on surface or submerged.
4. After battery compartment: One-half of storage battery; living quarters for crew.
5. Engine room: Diesel engines, pumps, etc.
6. Motor room: Main motors and main pumps.
7. Tiller room: In some of the submarine this after compartment contains also torpedo tubes and torpedoes.

The torpedoes carried by German submarines have a range of from 7,000 to 4,000 yards and run at speeds varying with the range set. Each submarine carries no less than 12 torpedoes. For a short distance the torpedo can be made to go at a speed of 40 knots an hour. For the maximum range the speed of the torpedo is seldom over 30 knots. The torpedoes to be fired are kept inside the tubes. It is but the work of a few moments to adjust the torpedo, close the tube, and fire the torpedo out of the tube with a charge of compressed air.

The torpedo after leaving the tube runs by means of compressed air stored in a steel flask inside the shell of the torpedo itself. This air is reduced from 2,250 pounds, the flask pressure, to about 500 pounds, then is heated by an alcohol flame and mixed with steam raised from a small boiler inside the combustion or mixing chamber. From here it is led into nozzles and impinges on the blades of a turbine which revolves at high speed or is led through the cylinders of an engine driving two propellers which turn in opposite directions in order to equalize the sidewise push of the propeller blades.

The torpedo is kept at a set depth by means of horizontal rudders controlled by appropriate means and regulated by water pressure, and kept straight on its course by means of a vertical rudder connected to a gyro. The tendency of the torpedo to turn is corrected by the gyro through levers acting upon an air-driven piston which works the rudder.

The war head or explosive charge varies from 250 pounds to over 500 pounds of high explosive. The torpedo needs only to make a glancing blow against a vessel to detonate the explosive charge.

If a torpedo has missed its mark it will usually sink. If a German torpedo is found floating, great care should be exercised in maneuvering near it. A gunner's mate, by swimming, might manage to unscrew the exploder, but this is a dangerous proceeding. Sinking by gunfire from a distance of not less than 150 yards is the safest method. Under no circumstances leave the torpedo before it is destroyed or sunk.

In order to hit a vessel that is underway with a torpedo the submarine must know or estimate within limits the speed and course of the target. The faster the ship is steaming the more difficult becomes the submarine's task. Frequent changes of the course also tend to upset the calculations of the torpedoist in the submarine.

The gun used by the submarine is about 4 to 6 inches, and is short; hence, of low velocity and short range. It is mounted on the superstructure deck, one abaft and one forward of the conning tower. It houses inside the nonwater-tight superstructure. Submarines will frequently submerge with the guns mounted and will not take the time to house the gun; and, further, this procedure insures quickly manning the guns after emerging. From 200 to 300 rounds are carried.

HOW TO RECOGNIZE A GERMAN SUBMARINE.

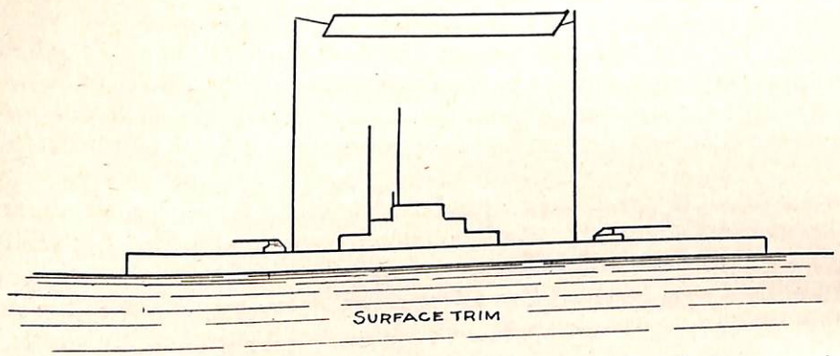
The German submarine is of about 1,000 tons' surface displacement. On the surface it can travel at the rate of from 16 to 18 knots an hour. While on the surface or in the light condition, its superstructure deck is exposed to a height of about 5 feet for a distance of 200 to 225 feet. The conning tower is about amid-

ships and appears in two steps. From the deck to the top of the conning tower is about 12 feet. Two guns are mounted on the superstructure deck, one forward and one aft. These guns are short and of about 4 to 6 inches in caliber. From the bow to the stern, leading over the top of the conning tower, are two stout wires used both as short-range radio wires and as protection against drags and nets. Radio masts for long-distance work, about 35 feet high, are stepped on the starboard side of the overhang and can be raised and lowered from within the boat. They are folded down before submerging.

These submarines have two periscopes of the housing type, one sticks out from the hull on the starboard side just forward of the conning tower, while the other sticks up from a point forward on the top of the conning tower. The upper periscope when up shows a length of from 15 to 20 feet and the lower a length of from 8 to 10 feet.

CAPABILITIES OF A GERMAN SUBMARINE.

The surface radius of these vessels is about 5,000 miles at 10 knots speed. The submarines of this type have main ballast tanks holding about 210 tons of water. When these tanks are filled the submarine sinks so that the top of the superstructure deck is only a foot out of water. The auxiliary ballast tank holds about 30 tons. When this is flooded the submarine can be submerged in order to show any desired amount of the conning tower or can be completely submerged. The condition described above with the conning tower exposed is called "awash condition;" when conning tower is beneath the surface the submarine is considered submerged.



The submarine in the light condition can become awash in one minute and can completely disappear in 90 seconds.

The submarine on the surface is driven by two Diesel engines, developing about 1,400 H. P. each. The air for engine is drawn in through the conning tower fair water, being conveyed to the inner hull at the top of the engine-room by a pipe leading under the superstructure deck. This pipe is closed by a valve before submerging. The engine exhaust is above and aft on the superstructure.

The exhaust, except when the engine is first started, is colorless and almost invisible.

Submerged the submarine is driven by two electric motors of about 500 H. P. each. The source of electrical energy is a storage battery of about 280 cells.

The submerged speeds are:

Full speed about 10 knots. They can maintain this high speed for not over three hours.

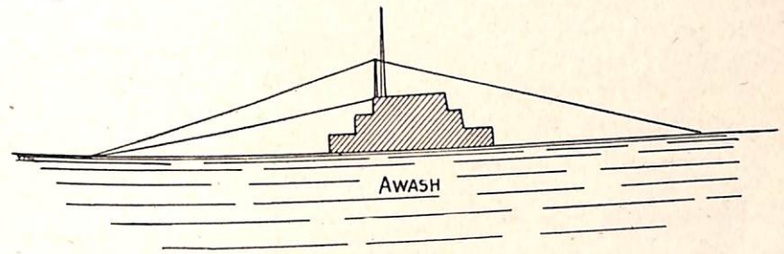
Moderate speed about 8 knots. They can maintain this speed for about 12 hours.

Low speed about 4 knots. They can maintain this speed for about 36 hours.

Steerage way about 1½ knots. They can maintain this speed for about 72 hours.

By means of the air purification and air renewal apparatus a submarine of this type can remain submerged for four or five days without coming to the surface.

The submarine will be painted a light green color and will be almost invisible against the sea background. When seen against the sky, their silhouette is most distinctive. Lookouts, therefore, should be stationed both as high and as near the water as possible; the former to discover submarines at a distance and the latter those near by.



Submarines will endeavor always to keep their storage batteries fully charged A high submerged speed, even for a short time, takes a great amount of energy out of the battery which can not be restored except by expenditure of several hours engine charging with the submarine on the surface. Therefore, submarines will run submerged at low speeds except in emergencies. While submerging, if chased by a patrol boat, submarines will run motors at high speed until safely under water, then will slow in order just to maintain steerage way at a safe depth. Submarines may endeavor to charge batteries at night, but unless it has been found impossible in the daytime to do this it is more likely that at night they will lie on the bottom, provided the depth should be from 12 to 25 fathoms, where all hands can go to sleep with a feeling of perfect security.

Charging batteries will be accomplished in the daytime in clear weather, where a good view of the horizon can always be had; if not possible in the daytime on account of large number of patrols, submarines will be forced to charge batteries at night or else run out of the danger area and recharge.

From a height of 12 feet a submarine in the awash condition can see on a clear day:

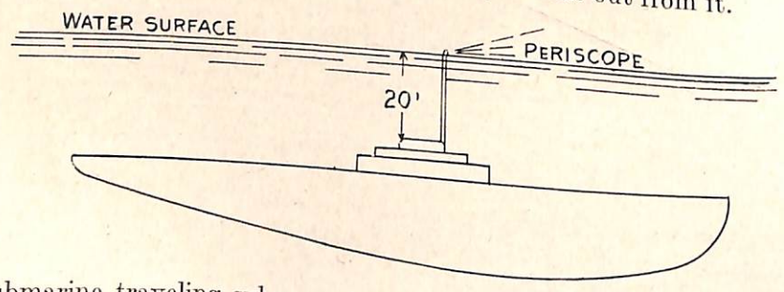
Smoke of a steamer	15 to 20 miles away.
A large vessel	10 to 12 miles away.
A patrol boat	4 to 5 miles away.

A submarine in the awash condition—that is, with main ballast tanks flooded—can be completely under the surface in 30 seconds. In 30 seconds a vessel with a speed of 40 knots can make only two-thirds of a mile a minute, and in 30 seconds could hardly turn and head for the submarine before it would be seen to disappear.

VULNERABILITY OF SUBMARINE FROM GUNFIRE.

The only vulnerable part of a submarine in the awash condition is the conning tower. This tower is only a small part of the space or fair water around it. A direct hit in the conning tower will not completely disable or sink the submarine, for the conning tower is completely shut off from the inner hull by means of a water-tight scuttle. It will, however, put the commanding officer out of action. The boat can yet be controlled from below, and sight is possible through the forward periscope. To use this latter periscope the boat must be brought within 6 or 8 feet of the surface of the water.

In the light condition the vulnerable part of the boat is at the water line. The superstructure is nonwater-tight and can be shot through without damage to the submarine's water-tight hull. The best point of aim is at the water line in wake of the conning tower, just where the after periscope sticks out from it.



A submarine traveling submerged or having laid on the bottom will not approach the surface with any part of its vulnerable self until it can raise the long after periscope from the conning tower and take a look about the horizon. It will therefore be in no danger of being rammed by any vessel drawing less water than 12 to 15 feet. If the periscope shows nothing within several miles, the submarine can then slowly emerge. In order not to make a commotion in the water, it will probably stop the motors and blow, with air, sufficient water from the auxiliary tank to enable it to raise the conning tower half or two-thirds out of water. Then the conning-tower periscope will be at a height of twenty-odd feet and a better look about can be gotten. Further, an officer or man can open the conning-tower hatch, provided the sea is smooth, and from on top of the conning tower can make sure no enemy vessel of war is in sight. Then the engines will be started for charging batteries. Upon starting up a cold engine considerable black oil smoke may be emitted. Vessels must look for this, for by this means a submarine may be discovered; a moment only and the exhaust becomes clear and invisible.

The submarine has two systems of radio. One system is always rigged and is good for a distance of from 15 to 20 miles. The other system requires time to rig

and has a range of several hundred miles. Submarines operating against commerce leaving United States ports will probably endeavor to keep in short radio communication with each other.

A submarine sighted by a patrol boat will probably submerge at once and will be well under before the patrol boat can arrive within gun range.

Submarines may operate by divisions and in pairs. A submarine tender of the *Deutschland* type may accompany them and lie outside of the patrolled areas.

Offshore patrols of the larger type should endeavor to locate the tender. The best time to discover tender will be at night when submarines are alongside refueling.

METHOD OF SUBMARINE ATTACK.

A submarine carries a limited number of torpedoes. The largest of the German submarines is said to carry only 12. It will be appreciated that a submarine operating at a considerable distance from its base will not use a torpedo unless a hit is assured. The submarine will prefer a station near where steamship lanes converge, where the depth is between 30 and 175 feet and about 100 miles from shore. During the daytime the submarine will remain awash with periscope up; observer at periscope and one on top of the conning tower. Upon sighting the smoke of a vessel the submarine will take its bearings and note whether steamer will come within a distance which would make an attack profitable. If the steamer is seen to be passing at some distance away, requiring considerable running on the surface at high speed to arrive at a position for attack, unless the steamer is known by the submarine to be an important one the submarine will not make the attempt, for to do so will expose it to discovery and besides uses up considerable fuel oil which it must endeavor to conserve.

After observing the vessel discovered for sufficient time to make certain that its course will lead it within easy torpedo distance the submarine will edge over awash, under engines at first and afterwards under batteries and motors, finally completely submerge and endeavor to get as near the path of the vessel as possible before it will have to fire its torpedo. In certain cases the submarine might note that the vessel was unarmed and that no patrol boats were in sight, then it might suddenly come to the awash condition with its deck above water, man a gun, and open fire at or near the vessel to stop it, directing it at the same time to abandon ship and stop the radio. If the vessel endeavors to send an S O S message the submarine might open fire upon the vessel to prevent a message being sent giving its position.

If the submarine refused to take the risk of coming to the surface and stopping the vessel, it would run completely submerged to a range of about 1,000 yards and fire a carefully aimed torpedo at the oncoming vessel from a position on its bow. If the vessel sees the submarine in time, it might, by quick maneuvering with helm or engine, avoid it; but such a chance is small at such close range.

This description shows the necessity for:

(*a*) Arming merchantmen and manning guns with trained crews.

(*b*) Convoying merchantmen with several fast vessels.

(*c*) A very quick method of sending radio emergency calls giving location of submarine.

(*d*) Necessity of always having radio operators on watch on every vessel, merchantman or patrol vessel.

(*e*) Necessity for having lifeboats and other means of rescuing always ready.

(*f*) Necessity for efficient and wakeful lookouts both aloft, on the bridge, and in low positions.

(*g*) Value of high speed of merchant vessels and frequent changes of course to confuse submarines and cause their torpedoes to miss.

SUBMARINE HUNTING.

The exact point where the submarine last disappeared is important and the patrol boat should drop a buoy at the spot and also, if land marks are in sight, fix the position on the chart. Then radio to base and nearest patrol vessels, giving accurately the location.

The submarine can not travel far from this locality without expenditure of battery capacity. It may

(*a*) Go to bottom and lie there, provided water is between 10 and 25 fathoms deep;

(*b*) Run in any direction at a speed of about 8 knots, gradually slowing to 4 or even 1½ knots, at a depth of about 60 to 70 feet.

It is unlikely that a submarine will continue the same course after completely submerging, but probably will turn through a fairly large angle and endeavor to elude the discovering patrol boat and those coming to its assistance. After submerging to avoid the patrol, if it is decided to still continue intercepting merchant vessels, the submarine will not travel far before it will come up near the surface and observe with its long periscope. Patrol boats must be on the keen lookout for this broach. The periscope as it emerges above the surface of the water will make a white wake which can be seen a mile away in ordinary weather. From an aeroplane this wake can be seen several miles away.

The radio message sent by the patrol should call to the vicinity a number of patrol vessels who must be on the lookout and be ready to open fire upon the periscope in case it comes within range of them.

The method to be used to destroy the submarine will be decided by the circumstances. One of the following methods might be employed:

(*a*) Sweeping for submarine on the bottom or dropping bombs on bottom within a certain area of spot where submarine submerged;

(*b*) Dragging nets or laying nets across most probable paths;

(*c*) Dropping depth charges set to explode at a fixed depth or when striking the bottom;

(*d*) Use aeroplane to locate and patrol boats to drop bombs or have trawlers and tugs lay nets.

These methods are described in another part of the manual.

The senior officer on the spot will assume charge and will decide the method to be used. In view of the necessity of the submarine to save its storage battery, for upon this its usefulness greatly depends, we may assume that the submarine will remain within a circle whose center is the buoy dropped by the patrol with a radius equal to the assumed submerged speed of the submarine, times the elapsed hours since discovery. This will narrow the circle to a probable radius of not over

12 to 15 miles within the next six hours. To find the submarine, therefore, a concentration of many patrol boats will be most effective with systematic search. Furthermore, the submarine will not go much beyond this circle unless it can do so on the surface, using its engine power, unless it feels that its safety warrants a large expenditure of its battery current. After discovery quick action must be taken, for a submarine located in daylight and hunted by the patrol will be likely to come to the surface at nightfall and use ite engines to run out of the dangerous area at high speed. Should the weather be sufficiently smooth it will run awash with only conning tower exposed. For patrol vessels to discover the submarine in this condition at night will require extreme vigilance. The submarine will be ready to submerge at the flash of a searchlight or the discharge of a gun, and after submerging will run a few miles and then come to the surface and proceed again on its way under its engines.

While thus running awash the submarine may be able to keep a gun ready for use against a single patrol boat suddenly encountered.

The patrol boat in the daytime upon discovering a submarine will send out its radio message promptly and head off the submarine at full speed, firing its available guns at the vessel as rapidly as accuracy permits. If near the submarine, machine-gun fire directed against the conning-tower periscope and against any of the crew on deck will be most effective. Ramming tactics will not be resorted to unless the patrol boat is especially constructed for that purpose.

At night gunfire should be used. A patrol boat may be able to get very close to submarines at night before being seen. An attempt, therefore, to approach as close as possible will be made before turning a searchlight on or firing guns. The submarine should be stalked at night and surprised; wait until the patrol boat is nearly on top of the submarine before announcing the boat's presence by searchlight and gun. Care must be exercised in using radio, for this may tell the submarine that patrol boats are in its vicinity.

A submarine knowing that it has been located, and therefore a certain measure of the possibility of surprise being taken away from it, may endeavor to reach a point as far away as possible by the next sunrise in order to use again the weapon of "surprise." The submarine may consider that as it has been seen and definitely located, all vessels likely to be attacked will be at once warned to keep clear of that vicinity. If sighted off New York for instance, it may decide to—

(*a*) Enter the Ambrose Channel and torpedo merchant vessels that have been arrested, unless it is known that nets bar the channel;

(*b*) Leave the vicinity and appear the next day off Philadelphia or Norfolk or day following that off Boston;

(*c*) Move farther out to sea on the steamship lane;

(*d*) Remain in the vicinity but go close inshore and lie on the bottom in shallow water, counting upon the daring of the act to mislead the patrol boats; or

(*e*) Move to the southward a definite distance and return at nightfall awash on the engines, to be again off the port at sunrise.

It has been claimed that the best and safest method of submarine hunting is to cover the locality with patrol vessels as quickly as possible. Do not give the submarine time to travel far from the locality in which discovered.

The following method of procedure is suggested:

1. Patrol boat making discovery radios locality and time of sighting submarine; drops a buoy at the spot and remains near it with distinctive flags flying. If close enough, use depth charges at once.

2. Remainder of patrol boats of the division assemble at once upon patrol making discovery.

3. Several aeroplanes and Blimpfs to be sent up from base to fly over vicinity in order to endeavor to locate submarine submerged, provided the distance offshore is within the radius of operation of these types.

4. Several pairs of destroyers with drags or sweeps arrive at the locality and drag for submarine, beginning at buoy dropped by discovering patrol.

5. Several pairs of trawlers arrive at vicinity and lay nets across probable paths of submarine.

6. Several pairs of tugs with towing nets sweep toward buoy from the circumference of a circle whose radius equals the probable distance the submarine has traveled in the elapsed time.

The patrol boats after assembling use retiring search method, assuming speed of submarine is 4 knots, and arriving in five hours on a circle whose radius from the buoy is 20 miles, distance apart not over 5 miles, remain on this circle until dark. Stop engines and use microphones to endeavor to hear submarine's engines.

The retiring search methods depend upon number of patrol boats available. It is based upon an assumption of submarine speed and limited to its most probable courses.

Starting at the buoy, patrol vessels will steer diverging courses and speeds to arrive on the circumference of a circle of radius 20 miles from the buoy and between two extreme courses. For instance, if discovered off New York, extreme courses will be buoy to Montauk Point and buoy to Delaware entrance.

If aeroplanes discover and drop calcium torches to make its progress, then

(*a*) Patrol boats steer along line of torches, dropping water bombs ahead of submarine. Keep guns ready to open fire if periscope should appear.

(*b*) Trawlers get a position ahead and lay their nets across the submarine.

(*c*) Tugs take position just inside of trawlers; lay net and drag slowly toward approaching submarine.

(*d*) Destroyers drag sweeps inside of nets and be ready with guns in case submarine is brought to the surface.

If aeroplanes can not locate submarine—

(*a*) Patrol boats continue retiring search method.

(*b*) Destroyers start and sweep on most probable course toward buoy, distance away depending upon the hour dragging begins.

(*c*) Trawlers lay nets in a loop between most probable courses.

(*d*) Tugs sweep with net in between nets layed by trawlers.

Search should continue until dark and even after if there is reason to suppose that submarine has remained in vicinity.

Submarine in daytime in clear weather will invariably remain submerged with only periscope exposed in the vicinity of patrol vessels. If nothing is in sight, the submarine will then expose its conning tower.

A submarine on the surface will never attack with gunfire a surface vessel of equal or greater gunfire.

Lookouts must be numerous and at all times vigilant. Guns must be kept constantly manned and loaded. The lookouts must become familiar with the appearance of enemy submarines with various amounts of hull or periscope exposed. Commanding officers must realize that the usual methods of lookout and watch are insufficient against the submarine, and only the concentration of the vigilance of the entire watch on deck can prevent a patrol boat from falling a victim to a torpedo, provided the vessel is considered sufficiently important to be sunk.

It should be borne in mind that the advantage in visibility rests with the observer the highest up from the water. Therefore to delay detection of your presence by the submarine, unrig all top-hamper possible and place the lookouts as high up as possible. The advantage derived from this precaution will increase with the roughness of the sea.

The first consideration in training for search operations is the training of efficient lookouts. Practice in this particular will train the eye to pick up objects a landsman would never notice. This can be done by tests in picking up buoys, beacons, various landmarks on shore, etc. Note should be taken of the atmospheric conditions at the time so that better judgment can be made of the visibility conditions on the various days in which you may be stationed on patrol.

ARMING OF MERCHANT SHIPS.

The best protection against a submarine on the surface is gunfire. All merchant vessels should be armed with guns of 4 to 6 inch caliber, so mounted as to cover as much of an arc of fire as the character of the ship permits. These guns must be manned by a trained crew. Common shell should be used as long as the submarine is above the surface; nonricocheting F–N (flat nose) shell should be used against submarines showing periscope only. Point of aim should be the base of the periscope.

MANEUVERING OF MERCHANT VESSELS IN PRESENCE OF SUBMARINES.

Merchant ships when steaming through dangerous areas should steam at top speed with guns manned and change course at least 15° every 10 minutes. Keep lookouts aloft with good binoculars, also lookouts as low down as possible. When periscopes or submarine are sighted, open fire at once.

Should submarine be sighted outside of torpedo range on starboard side, for instance, bring to bear on port side at once, turning toward submarine, and open fire—this for reason that if submarine has a mate it will probably be on the port side, and for the steamer to turn away from the submarine would place the vessel in danger from a submarine whose location is uncertain. Possibly submarine sighted showed itself on the starboard bow in order to drive the merchant ship away and into dangerous area of its mate.

After turning make a wide detour, plot submarine on a piece of drawing paper, with position also of merchant ship, draw circles from the submarine and from ship, using relative full speeds, then set course so that submarine can not arrive within torpedo range.

On discovering submarine, radio at once the location to patrol flotilla.

If at night, submarine will attack awash and will be very close before discovery. Probably upon discovery its torpedo already will have been fired; however, turn on searchlight and open fire. If submarine is forward of six points on bow, head directly for it. Keep up fire until submarine has disappeared, then proceed on course, else make a detour.

CONVOY OF MERCHANT SHIPS.

The most suitable vessels for convoy are:

(*a*) Destroyers.

(*b*) Torpedo boats.

(*c*) Fast light-draft patrol boats of about 500 to 800 tons displacement.

(*d*) Fast steam or oil engine yachts of from 500 to 1,000 tons displacement.

The escort must have several knots more speed than the vessel to be convoyed and should form ahead and on each bow of the merchant ship and maintain that position. Distance in daytime about 1,500 yards. The numbers of patrol furnished must depend upon patrol boats available.

Escort should follow course to be made good, merchant steamer to vary course, making irregular changes of at least 15° on either side of course to be made good.

Upon sighting submarine or periscope, patrol nearest will open fire and if so fitted endeavor to ram or drop water bombs. Radio steamer, and in daytime hoist warning signal. If at night fire red Very star. Searchlight will be turned on submarine by patrol nearest submarine only.

Steamer will maneuver as seems best to avoid submarine sighted and will open fire if submarine is visible and within range and clear of patrol vessel. If not, will remain dark and will steer wide course. The patrols will carry a stern light screened for merchant vessels to steer by. Merchant vessels will not depart too widely from its escort under any circumstances. After disposing of or losing sight of submarine, patrol will accompany convoy.

If submarine appears very close, endeavor to ram if forward of six points on the bow.

Patrol vessels returning will form a wedge formation, middle patrol at night to carry a white masthead light, distance between patrols about 800 yards. A submarine may take leading patrol with light for merchant vessel and endeavor to get within torpedo range, in which case other patrols, keeping dark, may be able to sink with gunfire or ram.

DEFENSE MEASURES TO BE USED AGAINST SUBMARINES.

The following methods have met with more or less success:

(*a*) The use of a large number of high-speed surface craft, capable of using the ram and more or less invulnerable from torpedo attack on account of small size and draft; armed with rapid-fire and machine guns and carrying a number of water bombs, designed to explode when striking bottom or at a set depth below the surface.

(*b*) The employment of drifting nets of light steel wire construction, designed to entangle the submarine and betray its position to patrol boats.

(*c*) The employment of stationary or anchored nets of heavy wire rope construction, designed to hold the submarine once entangled until it can be destroyed by means of mines or bombs.

(*d*) The employment of heavy towing nets of steel wire construction towed between two powerful tugs.

The net defense has not been used with much success upon the high seas, but only in restricted areas; for instance:

1. An anchorage can be completely inclosed by nets.

2. The entrance to a harbor can be completely closed by heavy steel nets together with booms. The net is opened to permit ingress or egress of friendly vessels.

3. The towing net and drifting net has a more extended use; they can be used in narrow straits or channels, or after the discovery of a submarine to inclose it and force it to run into the net or else come to the surface.

In the method of employing a large number of fast surface vessels of small displacement, some stratagems have been used which have proved profitable:

(*a*) Patrol boats have rigged improvised sails, causing them to appear like slow sailing vessels, and by this means have been able to get very close to a submarine on the surface and dispatch it by gunfire.

(*b*) Patrol boats have taken a position close under a large merchant vessel. In this way when a merchant vessel is overhauled by a submarine the patrol boat rushes out from her side at high speed and either rams or shells the submarine.

(*c*) Tramp steamers have been fitted with screened gun batteries. The tramp herself is actually a patrol vessel, and having decoyed a submarine on the surface within range dispatches it by gunfire.

Many more such "ruse de guerre" will suggest themselves to the officers on patrol duty and should be developed with energy and determination.

Patrol commanding officers must exercise great caution when desiring to ram a submarine periscope. Dummy periscopes have been carried by German submarines, consisting of small mines attached to a pole resembling a periscope, even to the green and white blotched painting to resemble the crest of a wave. Also both floating and anchored mines have been fitted with dummy periscopes to decoy surface vessels to employ ramming tactics.

AIRCRAFT.

The use of aircraft against a submarine has a particular value in locating either a submarine submerged or traveling with periscope only exposed. However, the aeroplane, by reason of its high speed, even if by chance it sights a submerged submarine, will have great difficulty in following it. Slow traveling lighter-than-air machines will be found of greater use and their employment should be conscientiously developed for both inshore and offshore work. Weather conditions are an important factor in the employment of aircraft.

Aircraft should be provided with calcium phosphide torches fastened to floats. The aeroplane or airship then can drop these torches to indicate position of submarine at intervals. The torches upon reaching the water will give off flame and smoke, and this will guide the patrol boats, trawlers, and tugs in their search.

A GENERAL DESCRIPTION OF DEFENSIVE MEASURES.

There are many types and designs of submarine defense nets in use by the allied forces. The various types naturally group themselves under the general designations of "trap nets" and "indicator nets."

Trap nets are planted as barriers across channels for the purpose of denying entrance to hostile submarine craft. There are different designs both as to size of wire rope forming the net and as to methods of planting and mooring. The wire should be sufficiently strong and the net so secured that a submarine running into it will be stopped. The latest design of heavy submarine trap net in use in the United States is of 12 by 12 foot mesh, with a jackstay of $1\frac{5}{8}$-inch wire rope and the net proper of $\frac{3}{4}$ and $\frac{5}{8}$ inch wire rope. The net is made in 600-foot sections and in depths depending on depths of water in which they are to be used. The sections are secured between heavily moored buoys and floated along their length by steel floats attached to their jackstay. Trap nets are maintained across the entrance to all important harbors in belligerent territories. They have been planted across important deep-sea channels, but the difficulties and expense of maintaining a heavy net in waters where it is exposed to the ocean weather conditions have rendered projects of this kind impracticable.

Indicator nets are light steel wire rope nets with a 12 by 12 foot mesh. They are not intended to stop a submarine, but serve merely as detectors, and may be used in combination with mines and bombs. They may be planted and moored in fixed positions, or they may be towed through waters where submarines are to be expected. The presence of a submarine which has fouled an indicator net is disclosed by the behavior of the net's floats or by some special automatic apparatus. The various automatic signals which have been tried include the releasing of flag markers, lighting lamps, sending radio calls, discharging bombs, etc. The automatic signals are of questionable value, and the principal dependence is to be had in the action of the net's floats. Mines used with this type of net are fired by being brought in contact with a submarine which has fouled and become enmeshed in the net. Indicator nets require the presence of armed vessels supplied with depth charges for destroying a submarine which has fouled the net.

Mines.—Contact mines can be suspended at various depths from tethered buoys or trailed from steam or sailing fishing boats. Vessels and boats on minefield patrol and elsewhere on the lookout for submarines and drifting mines should have rapid-fire guns and small arms always ready to open fire instantly. Probably also shotguns, firing buckshot, would be used, aimed at periscope; disabling the lens of a periscope would seriously cripple the submarine.

Depth charges.—Depth charges are made to explode at any depth of water desired. Their explosive effect will be sufficient to seriously damage the submarine even if a direct hit is not made. These bombs are dropped in such a manner as to anticipate the position of the submarine when the bomb arrives at the depth set to explode it. Depth charges are dropped one after another at close intervals along the estimated course the submarine has been seen to take.

A scouting aeroplane provided with some efficient method of showing the course and position of a submarine submerged (such as calcium phosphide torches

made fast to wooden floats) might readily lead a scout or patrol to a position most advantageous for attack with depth charges. The aeroplane should also be able to estimate depth of the submarine, and may successfully herself attack with aero bombs.

CLASSES OF VESSELS USEFUL FOR SUBMARINE HUNTING.

A submarine as at present constructed being very vulnerable to shell fire, the most effective way to overcome it is to cover the surface of the sea with guns.

Inasmuch as a submarine hides under the surface of the sea and without disclosing its position can launch a torpedo at an enemy ship, the size of the vessel to carry these guns should be the smallest minimum compatible with sea-keeping qualities. To hit a small vessel with a torpedo a submarine must approach it to a very short distance, increasing the chance of discovery, as the submarine while firing its torpedo must expose its periscope for a few moments. Speed is an essential characteristic for the vessel that is to carry the guns, yet high speed increases the length of the vessels, thus giving the submarine a larger target for attack. The vessel to carry guns to destroy the submarine must be a compromise type. The nations at war are utilizing many different vessels for this purpose.

Numbers are provided by utilizing a patrol boat of the following characteristics; these are called submarine chasers:

Displacement	tons	30
Length	feet	80
Beam	feet	12
Draft	feet	4
Engines	H. P.	500
Speed	knots	19
Cruising radius at maximum speed	miles	700
Slow cruising speed	knots	14
Cruising radius at slow speed	miles	1,500
Time possible to remain away from base	days	10

Armament, one 3-inch R. F. gun.

These vessels can be built in enormous numbers. They are most valuable for locating the submarine. Fast patrol boats of this type are most useful within 50 to 100 miles of a shipping port, to cover the sea along the shipping lane leading from that port. Due to their small size, they are not good gun platforms except in smooth water. They are, however, fast and handy and can not be torpedoed. They are equipped with radio, and, besides the 3-inch gun and ammunition, are provided with water bombs to drop upon the submarine when possible to observe its hull beneath the surface or to estimate with fair accuracy its probable location.

Patrol boats smaller than this type, but faster, with speeds of from 25 to 30 knots, are useful as inshore patrols to be used in a manner similar to the larger type. The smaller vessels, being of very high speed, might reach a submarine before it completely disappears beneath the surface.

A type of submarine destroyer of about 800 tons displacement would be of great value if developed in sufficient numbers. Its speed should be at least equal to the surface speed of enemy submarines—18 to 20 knots. It should offer the minimum target to a torpedo; therefore its length should be moderate and of shal-

low draft. Its cruising radius should be large. It should have sufficient beam in proportion to length to make it a steady gun platform. Its battery should contain several 5-inch guns. The radio should be powerful and rigged between two lofty masts. Observation kites should be provided, also an arrangement for dropping water bombs over the stern. The best system of submarine detectors and submarine signaling should be installed.

This type of patrol could be used to guard battleship fleets, convoy merchant vessels through submarine areas, and form the outside patrol force to hunt down submarines and their supply vessels.

The private yachts, having been taken over by the United States Government, have been classified in accordance with tonnage and speeds:

Class A: Over 1,000 tons. To be used as mother ships for small patrol vessels. Furnish quarters for officers and men. To lie at anchor in base.

Class B: 500 to 1,000 tons. To be used as flagship of outside patrol forces. Only the fastest selected. Appropriately armed.

Class C: 300 to 500 tons. To be used as outside patrol boats. Appropriately armed.

Class D: 200 to 300 tons. To be used as outside patrol boats. Appropriately armed.

Class E: 100 to 200 tons. To be used as intermediate patrol boats. Appropriately armed.

Class F: Under 100 tons. To be used as inshore patrol boats up to 50 miles of port.

FITTING UP PATROL BOATS FOR SUBMARINE HUNTING.

An intelligent lookout, as high up on the mast as possible, with good binoculars, should be in telephone or voice-pipe connection directly with the quartermaster or the man at the wheel in order to quickly "conn" the patrol vessel onto the course for ramming a submarine or approaching it for purpose of gunfire or "bombing," and, further, to direct the steering in order to avoid a torpedo whose wake has been discovered from aloft.

Means of dropping depth charges by mechanism operated from the bridge are in some cases provided; if not, there should be a single system devised by which the depth-charge operator at the stem can drop his charge at the moment directed by the bridge.

Powerful tugboats of from 500 tons up are employed to tow submarine nets and for sweeping. All tugs are armed. A submarine submerged has but little longitudinal stability; that is, but small force is required to cant the submarine dangerously. If the sweep should catch in a projection on either the bow or stern of the submarine underway, the force might be sufficient to up-end it, and thus destroy it. German submarines have all projections "guarded." A stout pair of steel wires run from bow to stern over top of the conning tower. This acts to prevent sweep from fouling conning tower or periscope.

Less powerful tugs of smaller tonnage are employed to lay drift nets. Torpedo boats and old destroyers are employed in sweeping with light sweeps and for convoy and patrol duty.

TACTICS OF PATROL BOATS.

Small patrol boats should anchor on station; their anchors should be buoyed and the boat made fast to a line for quick slipping.

In searching, patrol boats after concentrating at the point where submarine is sighted should employ the method of the retiring search curve. An accurate patrol formation can be much better maintained if compasses are accurate or their errors known. Frequent checks should therefore be taken. When operating in groups and the courses to be steered are known in advance, each group should, if time permits and before proceeding to station, obtain the compass error on these courses, if such errors are not accurately known.

Should any apparent error exist in the compensation of a compass, provided such compensation is installed, never tamper with or change any of the adjustments without first reporting the fact to the division commander or other superior authority and obtaining permission to do so. The compensation of all compasses should, if possible, be done by an expert.

It is equally desirable that some means be at hand for determining the speed of your boat. This can be done by the use of an automobile speedometer, geared to the propeller shaft, and calibrated to determine the speed in knots corresponding to the readings of the speedometer. If opportunity permits, it should be practicable to construct and install new dial graduations to read knots speed direct; but if this is not done, the speedometer will still be of considerable assistance in maintaining constant speed of revolutions of the propeller.

When steaming in company a line of bearing formation will be employed. At night the guide will carry a white light visible all around the horizon.

Searchlights will be used only after submarine has been discovered. It is easier to sight a submarine at night without the searchlight, but the light is required to illuminate the target after discovery to employ gunfire. Searchlights shall be turned off immediately the submarine has disappeared beneath the surface. Searchlights used indiscriminately are only confusing to friends and blinding to the man at the wheel.

Signals.—Radio signals are always efficient. Operators should be carefully trained to send and receive accurately and quickly. At night communication by "blinker" light with patrols in close proximity will be used. Unnecessary signals, radio or light, will not be made. As few signals as possible should be sent. Efficiency is shown more often through duty performed with but few signals. Filling the air with radio messages is both confusing and lubberly initiative. Commanding officers should read carefully their instructions and always act according to the spirit of the instructions. If instructions are lacking to cover an emergency, commanding officers must act upon their own initiative to further the general object and take the responsibility for their act being a wise one. Frequent requests for instructions from commanding officers of patrol vessels upon trivial subjects show a lack of initiative and a repulsive timidity to accept responsibility.

20652—17—4

Efficient patrolling involves a reliable method of communication. Every boat should be prepared to communicate by the following systems:

Wigwag—day and night.
Flag semaphore—day.
Blinker—night.
Shapes—day, to a limited extent;
and if equipped for same.
Searchlight flash, and
Radio.

The above systems require a knowledge of the dot-and-dash code, the semaphore code, and the special code for submarine destroyers using shapes.

For distant signaling both day and night a flashlight set can be easily rigged, using a storage battery, an automobile headlight, and a sending key to control the current.

GENERAL PRINCIPLES OF MANEUVERING.

The direct method should generally be used in assuming any new formation ordered. That is, each boat will proceed to her new position by the shortest route. For accomplishing the best results, relative bearings will be found most useful.

In general, compasses are not essential to good station keeping except upon the guide or flag boat directing the formation. Other boats should steer by the guide, using a dummy compass or steering pointers. To further explain the system, consider the proposition of keeping station in column. To keep the proper course, boats astern can steer by keeping the bow or jack staff on the stern of the boat next ahead, and the proper distance can be maintained by speeding up or slowing down on the engines. Assume now that the jack staff is moved to one bow so that the steersman when looking at it is looking along a bearing of 30° on the bow. If he keeps this jack staff on the boat next ahead, he will be steering a course parallel to that of the boat next ahead in a position 30° on her quarter, and if, at the same time, the engines are speeded up or slowed, the boat will reduce or gain distance from the one next ahead and the same as in column except that the operation will be a little slower.

If to the right or left of the proper line of bearing, proper position can be taken the same as would be the case in column by heading in toward it by bringing the jack staff above described as being on the bow, a little forward or abaft of the boat next ahead, as the case may be.

Of course the moving of the jack staff, as above, was done for illustration only. The same result can be obtained in a practical manner by the use of a horizontal batten rigged to swing in a horizontal plane around its rear end with range pointers placed upright in each end so that the steersman can sight over them and by the use of the rudder bring them in line with the boat next in formation.

Any line of bearing up to 45° on either bow can easily be kept by this method by following the rules enumerated below:

(*a*) The guide will establish the line of bearing by coaching the second boat in formation to the proper position, these two boats then forming a range for the guidance of the others.

(*b*) If ahead or astern of the line of bearing, head in toward the line a smal amount by bringing the steering pointers a boat's length forward or abaft the boat next ahead.

(*c*) If distance to next boat is too great, speed up, and if too small, slow down.

(*d*) When both distance and bearing are incorrect, use both methods of correction at once.

Boats should habitually use line of bearing formations except when proceeding in channels or restricted waters where column formation is necessary.

For keeping station in line abreast, or line 90°, similar methods can be employed, as follows, except that the rudder and engines are now used in the reverse order, since speed in line controls the position in line and the rudder controls the distance:

(*a*) Steersman keep pointers on boat next toward the guide, pointers being set to point abeam.

(*b*) If behind the line, speed up.

(*c*) If ahead of the line, slow down.

(*d*) If distance is too great, head in by bringing pointers abaft the boat next toward guide.

(*e*) If distance is too small, head out by bringing pointers forward of the boat next toward guide.

(*f*) If both distance and bearing are out, use both methods of correction simultaneously.

In maintaining patrol over a certain prescribed area, the vicinity of *aids to navigation* should be covered thoroughly, as the approaching submarine must sooner or later establish its position by observation of such aids to navigation. The area to be covered in the vicinity of such aids to navigation will depend upon daylight, darkness, and the state of the weather, and the importance of these areas depends upon their position. For lighthouses and lightships the area to be searched will usually be greater at night than at early daylight, and for this reason submarines would naturally endeavor to fix their position by observation of such lights before sunrise. They would also endeavor to obtain such a fix from lights the farthest away from port, which are out to sea or on some outlying headland.

The search should therefore be in the nature of a stationary patrol in such outer areas during the night, followed upon the approach of daylight by a retiring search in the direction of the harbor, bearing in mind the probability of the submarine proceeding on the surface during the night and submerged during the day.

As local conditions, such as the contour of the land, currents, shoals, etc., will govern the time it is safe for a submarine to proceed submerged with no periscope in sight, search should be most effective at points near the limits of the radii representing such submerged distance laid off from the center of the area the submarine must have passed through to obtain an observation and fix her position before daylight.

In case the submarine, to reach her destination, has to proceed through an area where the question of navigation becomes difficult, she would doubtless obtain

her fix early enough in the night to enable her to proceed during darkness and submerge with periscope out to the nearest safe point and arrive there at early daylight, abandoning the stationary night patrol farther out in time to reach the areas in question at that time unless sufficient craft are available to cover both areas at the same time.

ANTISUBMARINE WARFARE.

NOTES FOR THE USE OF NAVAL ARMED GUARDS.

ANTISUBMARINE WARFARE.

NOTES FOR THE USE OF NAVAL ARMED GUARDS.

By Lieut. A. H. Miles, United States Navy.

The submarine had no value as a war machine until the invention of the periscope. By the use of the periscope, partial invisibility was obtained in delivering the attack, thus giving the submarine the power of "ambush," or of making the *surprise* attack. The surprise attack is the reason for the submarine's existence, for without it, the submarine degenerates into a torpedo boat with all its limitations.

Thus, to combat the submarine, if we prevent it from delivering this surprise, we destroy its effectiveness. In the protection of merchantmen, it should be our aim to prevent the surprise, for it is known that if the submarine once located, by maneuvering, we have a fair chance of escaping the danger of being torpedoed.

By arming merchantmen, we keep the submarine submerged, thus confining it to low speeds of small radius and preventing it from using its guns as a surface vessel.

The main points to be considerd, then, are as follows:

A BRIGHT LOOKOUT.

By detecting the submarine when it shows its periscope while getting into position for firing, we can alter course to avoid the danger. If abaft the beam, the greatest safety lies in always turning stern to submarine and running away at highest possible speed. A slight alteration of the course will then avoid a torpedo coming from astern, a small target is presented, and the disturbed wake of the ship might probably deflect the torpedo from its mark. If sighted 2 points forward of the beam inside of 2,000 yards, it is preferable to turn toward him and proceed at top speed. This brings the submarine in danger of being rammed, and, if he fires, causes him to get off a hurried shot under unfavorable conditions, for it is well known that a successful torpedo shot from a submarine requires the boat to be steady on her course, at an angle near the horizontal, and not changing at the time in depth. By turning away, we at once relieve the submarine commander of the anxiety of being rammed, and he has a good opportunity of taking careful aim while you are presenting your largest target, i. e., the broadside. Moreover, by heading toward the submarine a small target is presented, and a torpedo could best be avoided by a small touch of the helm. Ram in the vicinity of the periscope, if possible, but if he dives, which is his most probable action, and you see no torpedo wake, alter course at once to bring stern to spot where he last is seen, and your safety is assured. Steam into the wind and sea whenever possible in satisfying the above tactics, for the sea will knock down his speed; he will be unable to use his gun on account of sea breaking over his low decks, and if submerged good periscope work is prevented by constant spray. In all cases, open with your gun, and having once gotten the

range, keep up a rapid fire as long as a target is seen. Keep the fall of shots slightly under rather than over, remembering that an over is a wasted shot. A submarine's best sustained submerged speed is not over 10 knots, and he can not keep this up for longer than two hours at most. After that, he is finished until dark, when he must rise to recharge his electric storage batteries. That is, if there are patrol vessels in immediate vicinity. The effective torpedo range for the present can be assumed to be 2,000 yards, and a torpedo's speed 36 knots. His best surface speed is 20 knots, and best submerged speed, 10 knots. At 7 knots his maximum duration submerged is about four hours.

Lookouts for submarines make the common mistake of only looking for submarines off on the horizon; this of course should be done also, but the most probable distances at which a periscope is likely to appear is from 300 to 800 yards from your vessel, from dead ahead to either beam. Orange-colored glasses should be used by at least one lookout when the sun is low, and a bright lookout kept down the sun path. Under ideal conditions a periscope can not be detected with naked eye at a distance greater than 1,500 yards, while with high-power glasses it *may* be detected at distances up to 6,000 yards. With whitecaps, it is difficult to differentiate between whitecaps and the feather from a periscope wake, but if watched closely can be distinguished from a whitecap by its persistence to the vision. A sea gull on the water might be taken for a periscope wake, but glasses will soon bring this out. Very often a flock of sea gulls will follow a submarine, and when flocks of these are seen the locality should be carefully searched with the glasses. Similarly, sharks will play around a stationary submarine when submerged, and when fins are seen in the water in dangerous areas they should be given a wide berth. Sharks also play about floating mines, and, too, floating German mines are made in some instances to resemble a shark's fin projecting above water. Do not pass between these, as mines of this variety are attached to each other by wire cable. Mines are sometimes fitted with dummy periscopes, so be careful not to ram one in mistake for a submarine. Beware of all floating objects on the water and give them a wide berth. The arc covered by the lookouts should be repeatedly swept and searched with high-power glasses. Lookouts should be placed as far forward in the eyes of the ship as possible, and at least one stationed as high aloft as possible. Two (merchant) should be on the bridge to cover from ahead to each beam, and two should be aft at the stern with efficient communication to the bridge. Lookouts sighting a suspicious object should call out the estimated distance and at the same time point with the arm in the general direction. Officers of the watch should take immediate action when a report is received from a lookout. It must be remembered that just because the officer of watch can not see anything at the time it is no sign that the object reported was not a periscope which in the meantime has disappeared. A skillful submarine commander will never show his periscope for more than 5 or 10 seconds before arriving at normal firing position. At firing position and while firing his torpedo he *may* show his periscope as long as 25 seconds. Officers of the watch should receive thorough instructions as to course of action to be taken in all cases.

A lookout should be sent high aloft just before dawn, and he should carefully scan with powerful glasses the horizon for submarines on the surface. Submarines

always lie on the surface at night and they may be located in this manner before they have a chance to submerge. In thick weather they may be suddenly encountered on the surface and most probably at a short range, when they could be seriously injured by gunfire. At nightfall assume that you have been tracked during the day and alter course at least four points for one hour before coming back to the original course. The original track can be regained in the morning if necessary. Steam off the quarter of another vessel if you get a chance; this will screen you from surprise from that bow at least. Remember that anything you can do to prevent the *surprise* will be a prime factor in the safety of the ship, and in this your lookout is of first importance.

SPEED.

The faster your speed the harder time the submarine will have in closing to make the attack, the more difficulty he will have in hitting with the torpedo, and the smaller the danger sector from ahead becomes. Consequently, see that the master and chief engineer fully realize the importance of this factor in the safety of their ship.

ZIGZAGGING.

In order to get in position to fire a torpedo it is a matter of great skill for a submarine commander to get at the right spot without detection, especially so on account of his low submerged speed and of the two unknown quantities, i. e., your course and speed, which he must know approximately in making his last totally submerged run to the firing position. Zigzagging makes this doubly difficult for him. He comes up to fire and finds that you are not where he expected to find you. He is out of range, probably, and has lost his chance of attacking because he now has not time or speed to catch up with you. If he sees or suspects you are zigzagging, it will make him give more periscope exposures and you have a better chance to detect his presence, thus considerably reducing the probability of surprise attack. Also, to hit with the torpedo, he must know fairly well your course and speed. Zigzagging, therefore, is very disconcerting to the submarine commander and should not be neglected in dangerous waters.

IF CHASED.

Hold him down with your stern gun. (Use smoke-producing devices; see Bu. Ord. Pamphlet No. 560, pp. 59–69, inc.) This operation can be repeated while help is coming; continue to harass him while sending out your S O S calls.

RAIDERS.

In the ocean trade routes or at sea assume no vessel to be friendly. If a sail be sighted, alter course to bring it abaft the beam, and if it closes, changes course toward you, or acts in any way suspiciously, bring it astern and make all possible speed until out of sight.

MINES.

Experience so far has shown that submarine mine layers never lay mines unless they can be sure of their exact position; this on account of danger to themselves. Consequently, safe navigation may be expected out of sight of land in so far as

are concerned. The fact that a mine field laid by a submarine has been swept is no indication that no mines are present, this because German submarines have lately been laying time mines, which come up at predetermined intervals unknown to us.

MESSING.

In especially dangerous zones have all hands continuously on deck at the guns, and arrange with steward to have meals served on deck. Never under any circumstances allow the number of men on deck to be decreased to less than one gun crew.

INFORMATION.

Confidential information should not be confided to any person whom it does not concern, nor should it be referred to in public places.

PORTS.

After being closed for the night, no port should be permitted open. Cases have occurred in which the passenger or member of the crew, in order to get air, has, after turning out his light, opened the port. Later the light was turned on and the port left carelessly open. Notices of caution should be posted conspicuously about the ship. Extreme vigilance is the price of a completely darkened ship, and frequent inspections by those in authority *must* be made. Pay particular attention to probability of unextinguished lights in locked storerooms.

WATER-TIGHT BULKHEADS.

These should be inspected for water-tight integrity, etc. They should be kept closed and dogged at all times at sea, day and night. All unnecessary doors, non-water-tight, should also be kept closed, for this might assist, at least, in keeping the ship afloat for a longer time while aid was coming. Fore and after bulkheads are a menace, because in the case of a torpedo the ship will probably take a list over on the holed side. Fore and aft bulkead doors should be removed.

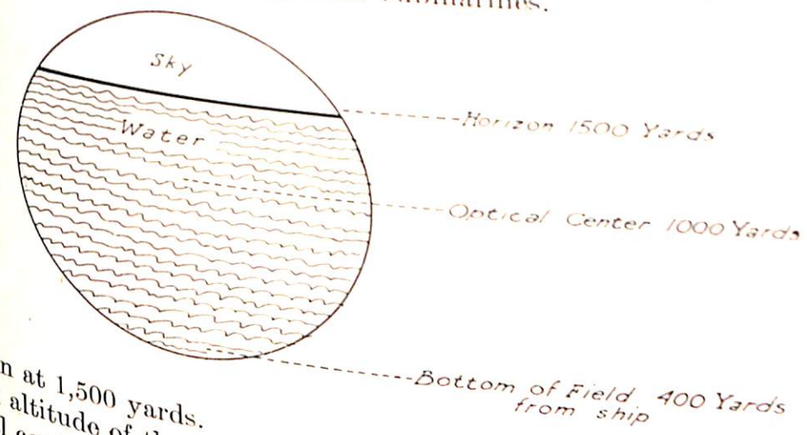
CLOTHING.

Members of armed guards should be careful that they have a complete outfit of heavy clothes, boots, rain clothes, and pea-coats. Woolen underwear is especially desirable to guard against exposure in open boats, particularly necessary in case of wet clothes due to rain or boat capsizing. In northern latitudes it is extremely cold even during summer months. New outfit of winter clothing now issued takes care of this. See Op. Nav. No. 5. General Instructions, issued under date September 22, 1917.

DEPTH CHARGES.

It is recommended that all ships be equipped with a howitzer firing a depth charge. A heavy charge landing in the water and exploding at a depth in the vicinity of a submarine is going to do serious damage, not only to the personnel, but to the delicate internal mechanism of the boat (such as gyro compasses, storage batteries, depth gauges, etc.). A leak might be started which would force her to the surface, in which case she should be destroyed by gunfire. If sub-

marine commanders knew that they were going to be greeted with a heavy explosion of this nature when once discovered, they would become very wary and make their totally submerged runs of longer duration, which in connection with our own zigzagging would be a large factor in preventing them from accomplishing the surprise attack which is, of course, the submarine's only reason for existence. It is quite possible that a hit may be made, in which case the submarine would be destroyed, while with the low trajectory gun alone, the chances are slim, indeed, of doing much damage. They are centering their attacks on merchantmen; here they must be met and combated. While keeping our shipping moving, we protect them and at the same time fight the submarines.



Horizon at 1,500 yards.
For an altitude of the observer of 45 feet.
Optical center at 1,000 yards from the ship.
Lower edge of the field at a distance of 400 yards from the ship.
The rule in practice is to fill one-quarter of the field with the sky and three-quarters with the sea, which, with a glass of 3° field and at an altitude of 45 feet, permits a view of the sea about 400 yards from the ship.
(The foregoing distances should read METERS, to be more exact.) The method presents a rough thumb rule of estimating DISTANCES quickly.

NOTE.—This article has been revised by Lieut. George Joerns, October 15, 1917, in order to make it conform to the present practice of the Navy Department.

MEMORANDA ON SUBMARINE LOOKOUTS.

MEMORANDUM ON LOOKOUT DISPOSITION.

By Lieut. George Joerns, United States Navy.

The report of Ives and Priest, "Submarine Base Experiments," is comprehensive and splendid. So far as possible its essential features will have to be articulated with military lookout disposition under actual working conditions.

The following are affected thereby: Fleet, convoy, armed liner, and armed merchantmen. The first three named are in the hands of competent officers already on the ground; the last named presents a serious responsibility and aspect.

It is assumed all merchantmen are armed or are to be armed. At present their armed guards are commanded by a chief petty officer. Guard consists of 18 men manning two guns, the usual armament.

Conditions have to be visualized, bearing in mind merchant personnel conditions; numerical strength of the armed guard; length of trip through the Atlantic danger zone, usually three days on a 10-knot ship; location of bridge and lookout stations; lookout and physical endurance curve of lookout personnel; visibility conditions, average in submarine zone; coordination of lookout and battery duty of the armed guard; possibility of a simultaneous attack by two enemy submarines operating in different quarters; extra compensation and reward; discipline; binoculars.

Merchant personnel conditions.—Mixed crews of varying nationalities and not a very high degree of intelligence. Numerically limited under the stress of commercial competition and because of certain pernicious features of the seaman's act, pernicious at least in relation to war and emergencies; *not* a fertile field for the rapid inculcation of military efficiency.

Conditions on the liners are better. On some of these certain of the crew hold the special rating of lookout, and as such are carried on the rolls with extra compensation to the extent of $1.25 per month. Rather munificient and probably a relic of the days of icebergs.

Numerical strength of armed guard.—As stated, usual strength—1 chief petty officer and 18 men of other ratings.

In danger zone chief petty officer's time fully occupied on the bridge, his usual control station, which under these conditions he should never leave except in case of absolute necessity. During hours of darkness he should sleep there on an extemporized cot or in the chart house on a settee if such be installed. Under the stress of a three days' run he and the master of the merchant vessel can very well alternate on full duty. The meals of both of them should be served them on the bridge. As master lookouts both should have working control and understanding of the lookout disposition. The proper spirit of cooperation can evolve this. Both are or should be equipped with the best glasses aboard ship. The strength of the remainder of the bridge force varies with the type of ship. The man at the wheel can be eliminated from consideration. The watch officers and their assistants are useful assets.

The two gun crews, totaling 16 men and 2 petty officers, certainly can not under prevalent working conditions come across with more than 8 lookouts at a time. This would give them 4 hours on and 4 hours off. From the standpoint of constant and continuing efficiency a 4-hour lookout watch is out of the question, absolutely so on the second and third days—and the enemy submarine usually puts in an appearance at such an unfavorable juncture.

Two hours on and 6 hours off is the easiest, so far as wear and tear on personnel is concerned. Its disadvantage is the minimum number of armed guard on lookout at a time. Naturally 1 petty officer and the armed guard commander, or master, are additions, making 6 reliable lookouts constantly on duty.

Length of trip through danger zone.—Usually three days for a 10-knot ship bound for France or England, and which is the basis of this memoranda. In case of vessels bound for Mediterranean ports new aspects come in.

Location of bridge and lookout stations.—Location of bridge varies with type of vessel. Some are forward, some amidships, and some even aft as in Great Lakes type of vessel.

Crow's nests also vary, some being higher than others. Every merchant vessel should be compelled to install a fore truck crow's nest, portable if need be, the man going on watch being hoisted to his station by block and tackle. The quick detection of an enemy submarine on the surface and before it can submerge for run to predicted firing position is thereby greatly enhanced. At present crow's nests are not high enough up for attainable efficiency. The lower crow's nests should not be discarded, but retained. Merchant personnel should man these. It is essential that whatever the lookout station of a member of the armed guard such member should be enabled to quickly get to his gun station as that gun goes into action. Slide down a backstay if necessary.

A member of the armed guard should be stationed in the eyes of the ship on the forecastle.

Physical endurance of lookouts.—The stress and strain of a run through the zone tells on men. They quickly recover. The most common surface sign is a puffiness under the eyes. The sun glare, wind, and a certain amount of mental tension varying with different mentalities all enhances the stress. Men become nervously alert, which is a good thing. The practice of giving them coffee at night-fall and at daylight in addition to that to be had at regular meals should be carefully watched. After three days the effect is bad. If under proper control, they go to sleep or lie down on deck when not actually on watch; if not, they chatter and keep others awake.

Visibility conditions.—These are a matter of common knowledge and vary.

Coordination of lookout and battery duty, armed guard.—This is important. A member of a gun crew who has as lookout discovered something to *shoot* at enhances the speed with which that gun gets into action. Seconds count in this game; and lookout disposition must be based on these essentials.

Simultaneous attack by two enemy submarines.—This has occurred in several instances and with the increase of the number of submarines operating against us may occur oftener than hitherto. In such contingency the armed guard is naturally fully occupied with its battery duty, and usually sole reliance must be placed on the merchant personnel or a part thereof. Accordingly they should be trained and so indoctrinated, especially as all attention is quickly focused in usually but one direction.

Extra compensation and reward.—Some of the steamship companies have offered and paid over the sum of $100 to the first lookout discovering a submarine. This at the beginning of the ruthless campaign and probably not now generally in force. The amount seems high, and the practice should be standardized and given the widest publicity among merchant personnel.

Discipline.—A lookout should be so stationed that he can not gossip with some one else or be otherwise diverted from the sector assigned to his surveillance.

Binoculars.—This subject has already been covered by a competent board. Some of the steamship companies, notably the American Line, have been very liberal in furnishing these for the use of the armed guard, while others at the outset of the war were rather parsimonious in that respect. The Navy is now taking care of that feature of it. A wide field glass should be favored. The old fashioned spy-glass is obsolete, and its use is a hardship—too tiring on the eyes.

So far as the armed guard is concerned, I should say in the case of a vessel bound for France or England, the lookout disposition should be as follows for a two-gun ship with a guard of 16 men, a chief petty officer, and 2 petty officers:

Having due regard for existing orders on the subject, full lookout disposition should be put on at longitude 20 west, as follows: For the first 24 hours from 20 west in, watches should be 4 hours on and 4 hours off, stationing 8 men as follows: Two men at or near after gun; watch sector from both beams to astern. They to have alarm contact with the forward control station and the forward control station to have the same with them. One man in the lower crow's nest forward, covering a sector of 180° on both beams to dead ahead. Two men forward on the forecastle in the eyes of the ship, one covering the sector from dead ahead to six points on the one bow; the other the same for like bearings on the other bow. Two men at or near forward gun each covering that sector on either bow assigned to him, towit:—from four points on the bow to abeam. This disposition leaves one man over who should alternate in two hour watches with the man stationed in the crows nest. The two petty officers to alternate in the supervision of these lookout watches, suppressing inattention, temporarily relieving those answering calls of nature, and enforcing discipline.

After 24 hours from 20 west shift watches to 2 hours on and 4 hours off in order to concentrate gun crews at their respective guns, which is essential. Borrow two men from after gun crew. (Do not take pointer, trainer, sightsetter, gun captain or first loader of after gun.) Send these two men of after gun crew forward for lookout duty with instructions to rejoin after crew when action commences. The watch at the after gun remains as before, splitting the sector. The watch forward becomes three men. Counting on the petty officers and the armed guard commander this constantly gives 7 naval lookouts; the crows nest and forecastle lookouts covering the 180 degree and six point sectors previously noted. Militarily this is the best you can accomplish for long runs. In short runs between European ports, switch back to 4 on and 4 off disposition. At all times use merchant bridge personnel to back up and reenforce naval personnel observation sectors. During winter months on northern runs where daylight is shortened, the four on and four off rule with its attendant maximum of 10 of the armed guard (master relied upon to alternate with chief petty officer) may seem desirable; but in the ultimate this four hour lookout watch looks strong but is weak. "Also don't get torpedoed while relieving the watch."

20652—17——5

At night, during darkness, reduce the watch to two men at each gun, calling all hands 20 minutes before dawn, the most dangerous time of the day. The hours of darkness increasing as the season advances will ameliorate all of the foregoing.

Gun crews should go to meals by gun crews and not scatteringly, lookout disposition being maintained as outlined. In fact, meals should be served at the guns from 20 west in.

The foregoing schedule should be reversed on the run out from England or France.

ORGANIZATION OF SUBMARINE LOOKOUTS.

By Lieut. C. C. Gill, United States Navy.

The following scheme for organizing, training, and equipping submarine lookouts is based on a study of experience gained by the French Navy, and is suggested for use by United States escort and convoy ships in transport service.

The defense of capital ships against submarines depends upon

THE LOOKOUT,
THE MANEUVER, and
THE GUN.

The lookout is the most important, as everything depends upon "seeing" the submarine. An efficient lookout by gaining 200 or 300 yards in sighting a periscope may save the ship.

Intensively trained and organized lookouts are more important even than skilled gun crews.

BRIDGE CIRCLE OF LOOKOUTS.

A circle of lookouts on the upper bridge or other sheltered place seated at mounted telescopes or binoculars, twenty (20) by day and ten (10) by night searching the following sectors: (The size of each sector has been determined by careful mathematical calculations. The lookout is "denser" for the more dangerous bearings from which attack is more likely to come.)

BY DAY.

No. 1. 0° to 20° named 10° sector.
2. 20° to 35° named 27° sector.
3. 35° to 50° named 43° sector.
4. 50° to 60° named 55° sector.
5. 60° to 70° named 65° sector.
6. 70° to 85° named 77° sector.
7. 85° to 100° named 93° sector.
8. 100° to 120° named 110° sector.
9. 120° to 150° named 135° sector.
10. 150° to 180° named 165° sector.
11. 180° to 210° named 195° sector.
12. 210° to 240° named 225° sector.
13. 240° to 260° named 250° sector.
14. 260° to 275° named 268° sector.
15. 275° to 290° named 282° sector.
16. 290° to 300° named 295° sector.
17. 300° to 310° named 305° sector.
18. 310° to 325° named 318° sector.
19. 325° to 340° named 332° sector.
20. 340° to 360° named 350° sector.

BY NIGHT.

No. 1. 0° to 35° named 17° sector.
2. 35° to 60° named 47° sector.
3. 60° to 85° named 73° sector.
4. 85° to 120° named 103° sector.
5. 120° to 180° named 150° sector.
6. 180° to 240° named 210° sector.
7. 240° to 275° named 258° sector.
8. 275° to 300° named 288° sector.
9. 300° to 325° named 312° sector.
10. 325° to 360° named 342° sector.

Note.—These bridge lookouts to be relieved every half hour during the day and every hour during the night. The bridge or vicinity of bridge is the best location for lookouts, as it is efficient both by day and night. It is handy both for maneuvering the ship and for directing the gunfire. For distances of less than 6,000 yards the bridge (45 feet) is preferable to the top for detecting periscopes.

The officer of the deck.—Charged with maneuvering the ship and keeping lookout from ahead to 30° on either beam.

Fire control officer.—In general charge of starboard lookouts. Search from 30° to 90°. In case anything is sighted on starboard, hand man the target bearing transmitter to indicator guns under forward bridge and keep them pointed at object sighted.

Assistant fire control officer (C. P. O.).—Perform like duties on the port side. Searching from 330° to 270° and operating port target bearing transmitter.

NOTE.—The target bearing transmitter to the indicator guns to consist of a revolving shaft with pointer and dials marked in degrees and connected to a repeating pointer and dial marked in degrees at the indicator guns below. The figures and points on these dials as well as on the azimuth scale marking the train of the guns to be marked with luminous paint. (It might be better to have the repeating indicating pointer director over the turning center of the gun and just under it another pointer attached to the gun and parallel to the bore. This arrangement would eliminate reading degrees. the object of the gun trainer being to keep the two pointers in alignment.)

Signal watch (4).—Search in 45° sectors covering from ahead to either beam.

Indicator gun crews (4).—Search in their respectively assigned 45° sectors covering from ahead to either beam.

Watch guns crews (4).—Search in their assigned 45° sectors covering 360°.

Fire control party and their searchlight party (8).—Search in assigned 45° sectors covering 360°.

Foretop watch.—(One officer and three men.) Search ahead in 20° sectors covering to 39° on either beam.

Forecastle lookouts (4).—Search in 45° sectors from ahead to either beam.

Quarterdeck lookouts (4).—Search in 45° sectors from either beam astern.

NOTE.—By this arrangement the circle of lookouts is backed by a number of panoramic lookouts duplicating all sectors and triplicating the more dangerous sectors. Instead of having so much duplication it might be better to decrease the size of the search sectors in the panoramic lookout system. The need for good communication service is obvious. Voice tube men should be well drilled and alert. Telephones are also useful. Noise and confusion are to be guarded against.

TRAINING LOOKOUTS.

Lookouts should be especially selected for alertness, keenness of vision (tested by surgeon), and coolness. Men liable to seasickness or incapable of concentrating their mind on an intense search should be replaced.

1. Lookouts should search through their assigned sectors by successive 2° steps, rather than by continuous sweeping. The time of covering a 20° sector by steps has been found to be about 40 seconds. Lookouts should always search in the same direction, from the forward to the after limit of his sector. When the after limit is reached he should quickly swing back to the forward limit, repeat the search from forward to aft, and so on.

2. For ordinary search using a glass with 3° aperture at a height of about 45 feet, fill one-quarter of the field with the sky. This gives a view of the water about 400 yards from the ship, with the optical center about 1,000 yards from the ship. Glasses should be pivoted and lookouts drilled to handle them in a seaway. Correct focus and adjustment are important. Telescopes are more fatiguing than binoculars. With telescopes a blinder on the "OFF" eye so that it can be

left open is helpful. Shades to cut off outside light are good and should be rigged so as not to chafe the wearer. The watch coming on should wait at stations for five minutes before relieving, in order to accustom eyes to light conditions.

3. Lookouts in making reports should first give the name of their sector (the bisector of the angle of search), then the object sighted, then its estimated distance, then whenever drawing ahead or drawing aft.

EXAMPLE.—Lookout at sector 55° sees a wake (or a dark point) drawing ahead, distant 100 yards, and reports:

55 a wake (or dark point).
It draws ahead.
Distant 1,000 yards.
(Then as it passes into the next sector.)
It passes to 43.
The next lookout picks it up and also reports:
43 a wake (or dark point).
It draws ahead.
Distant 800 yards (and so on).

4. No lookout should take his eye off any object sighted in his sector until the next lookout in adjoining sector announces it. As ship will probably make a quick change of course, lookouts will have to be alert in picking up objects as they pass from sector to sector.

Control officer should put his pointer on all objects sighted, and indicator guns should follow it ready to fire immediately the order is given.

5. Men at voice tube to top report all objects sighted by circle of lookouts to top, and repeat all information sent from top to bridge.

6. Lookouts should be instructed in methods of submarine attack. In the usual attack by a skillful submarine commander the periscope will be shown for short intervals somewhat as follows: Beginning at 4,000 yards, at which range an alert lookout can see a periscope, the submarine will show about 1 foot of periscope and observe for a period of about 30 seconds. After that the periscope will be shown at intervals of about 1 minute for a period of time diminishing to 10 seconds. From 2,000 yards to 1,000 yards only about 6 inches of periscope will be shown at intervals of about 1 minute for a period of time diminishing to about 5 seconds. At about 1,000 yards when the torpedo is fired the periscope will be exposed for an aiming period of about 25 seconds.

7. The above procedure, of course, is not absolute, but it may be taken as typical, and in the majority of attacks the periscope will probably be shown more rather than less.

8. This means that from the time the submarine can be seen to the time the torpedo is fired about 10 minutes elapse during which there are about 10 exposures of the periscope for gradually diminishing periods of time ranging from 30 seconds down to 5 seconds, except the last exposure for firing, which lasts about 25 seconds.

9. Rewards in the shape of money prizes, extra liberty, etc., should be given lookouts who pick up the largest number of objects during a cruise—record to be kept in a book passed on by cont

10. On the other hand, inattention to lookout duty should be severely punished. Strict discipline is necessary to avoid confusion. Relaxation should not be tolerated. Constant supervision of lookouts is necessary.

11. The entire crew should be impressed that if the lookouts are alert and see the periscope in time to permit report, maneuver, and gunfire before the torpedo can be fired then there is small chance that the attack will succeed.

GLASSES FOR LOOKOUTS.

Experience has demonstrated the superiority of glasses with high power over those in which illumination preponderates. The pointer's telescope has given good results, as it combines magnifying power with an appreciable field. But the so-called D.D. binocular used by the heavy artillery of the French Army and combining magnifying power with large field and stereoscopic effect has proved much superior to other types. After tests conducted by the battleship *Marabeau* to determine the comparative efficiency for sighting a periscope in the Mediterranean (smooth sea), the various types were graded in the following order:

The D.D. artillery glass effective for over 5,000 yards. The pointer's telescope effective for 400 yards. The quartermaster glass effective for 4,000 yards. The spotter's binoculars effective for 4,000 yards. Low-power binoculars effective for 2,000 to 3,000 yards. The naked eye could not be depended upon above 1,000 to 1,500 yards.

NOTE.—High-power glasses are not good for night work. Low-power night glasses should be used after dark.

Since the gain of two or three hundred yards in sighting a periscope may easily mean the difference between escape and destruction, it would seem important for escort and convoy ships engaged in the United States transport service to be supplied with either the D.D. French service binoculars or a similar type.

The characteristics of this glass are as follows:

Prismatic binoculars, long glasses, type D.D., made by The Huet firm, of France.

Used by heavy artillery ashore under the name of "Prismatic binocular, long glass, type D.D."

ADVANTAGES.

Easy and accurate adjustment both for separation of the eyes, scissor mounting, and for variation in the visual acuteness of the eyes.

Magnifying power, 12.

Field, 3° 35′.

Good illumination.

Wide separation of objectives which may be as great as 70 centimeters, giving powerful stereoscopic effect, which detaches periscope from the water and throws it into distinct relief. This also facilitates determining the course of an enemy ship.

Perfection of adjustment relieves lookouts of fatigue, and good results obtained stimulate interest.

Azimuth scale attached permits lookouts to give exact bearing of object sighted.

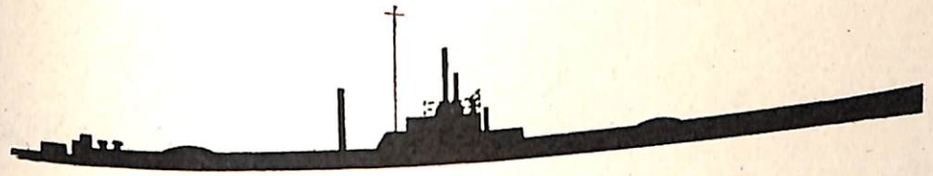
(At height of 120 feet a floating cask in a choppy sea was sighted and identified at 9,000 yards.)

(These glasses might be good for spotters.)

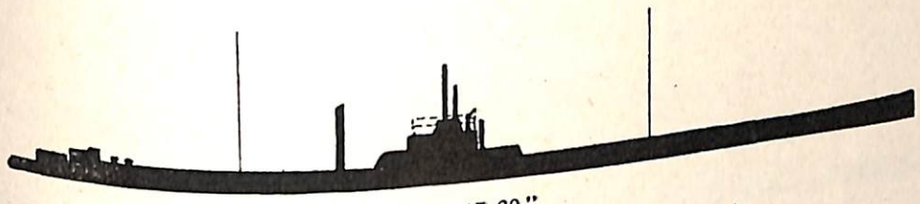
The number of binoculars required to equip the lookout organization would be:

Circle of lookouts	20
Officer of deck	1
Fire-control officer and assistant	2
Fire-control officer aft	1
Fore-top lookouts	4
Spares	6
Total	34

SILHOUETTES OF GERMAN SUBMARINES.

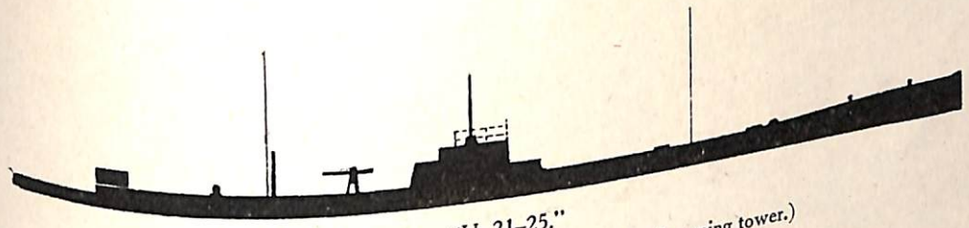


"U. 13–16."



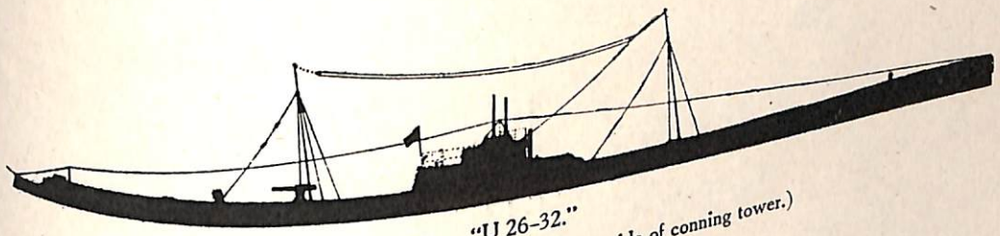
"U. 17–20."

(A gun may now be mounted on fore side of conning tower.)



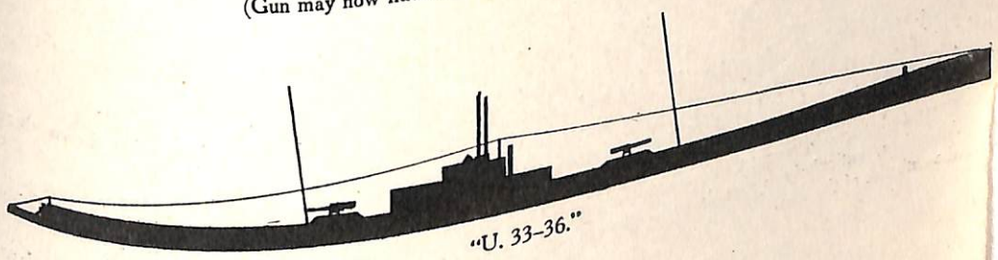
"U. 21–25."

(Gun may now have been moved to fore side of conning tower.)

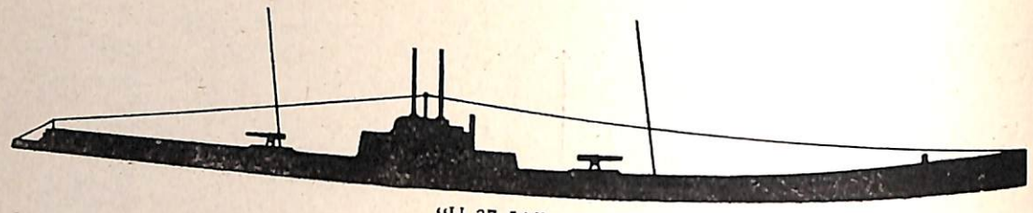


"U 26–32."

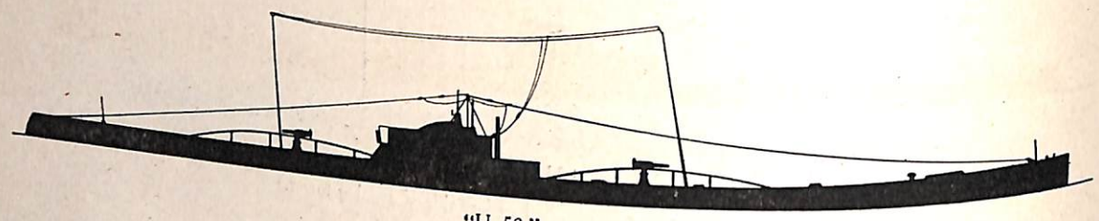
(Gun may now have been moved to fore side of conning tower.)



"U. 33–36."



"U. 37–54."



"U. 53."

"U. B. 18–29."

"U. B. 1–17."

"U. C. 1–15." (Very similar but 20 feet shorter.)

NOTE.

Masts, ventilators, and exhaust funnels are hinged or telescopic, and may be either up or down when the vessels are on the surface. One or both of the guns may be housed.

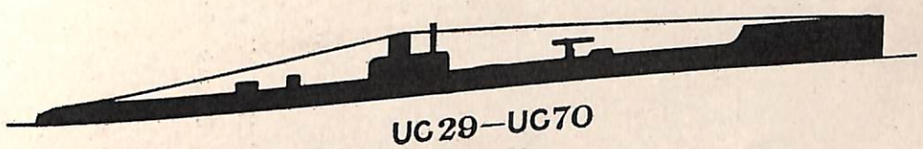
A German submarine has been seen underway, submerged to base of conning tower, with her masts up.

The block sketch of German submarines, class U. 26 to U. 32, may be accepted as perfectly reliable, being derived from a recent photograph, except that gun now may have been moved. The silhouette of U. 53 is reliable.

Alterations, particularly as regards periscopes and exhaust funnel, may have been made in some of the earlier classes since the outbreak of the war.

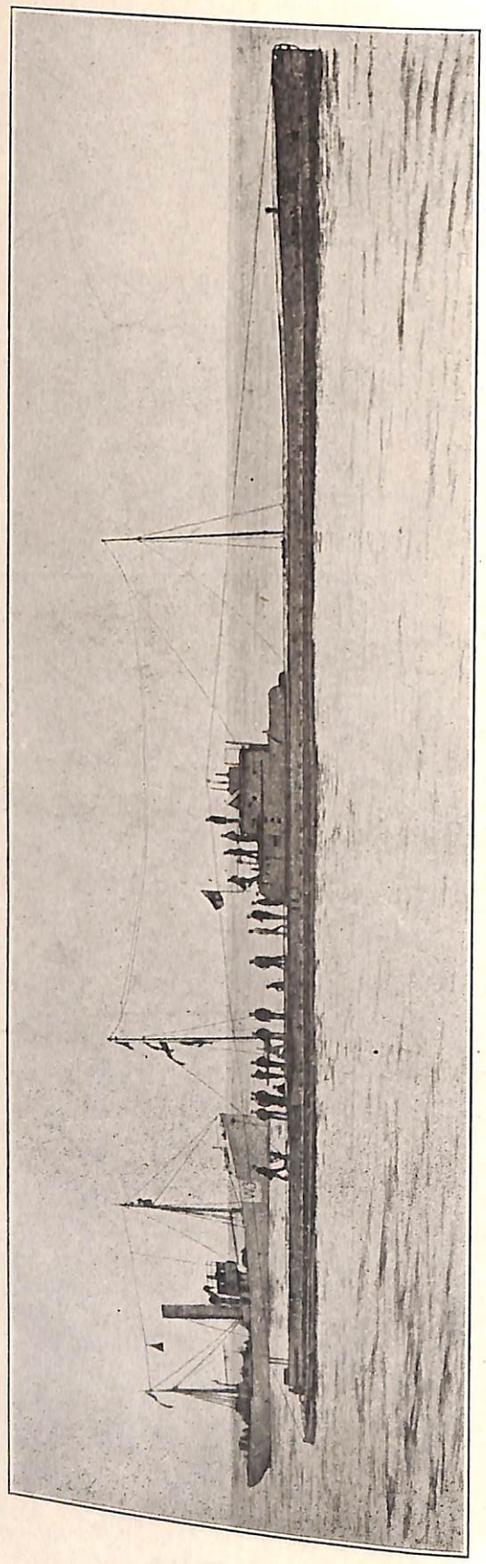
U43–U50

U52–U60



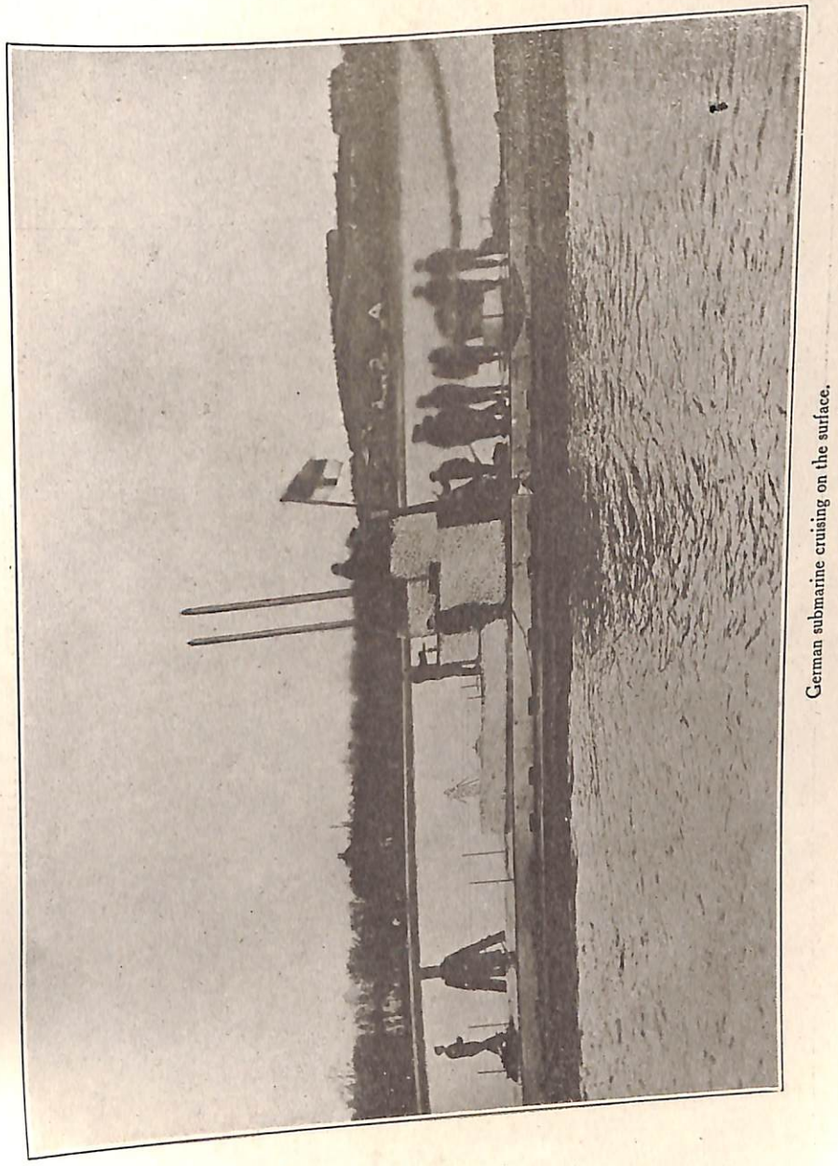
UC29–UC70

U-B-18-48

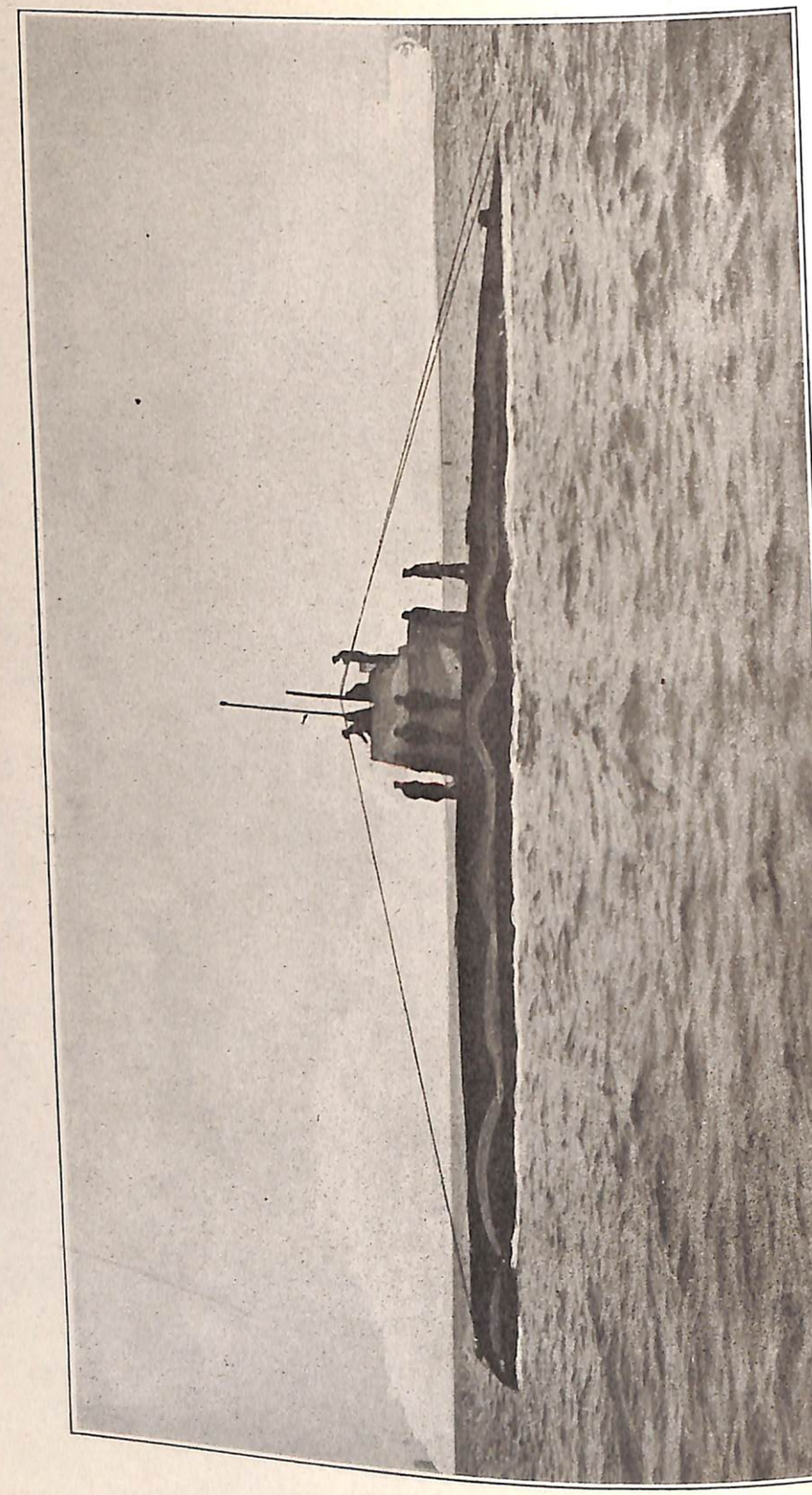


GERMAN SUBMARINE U. 28.

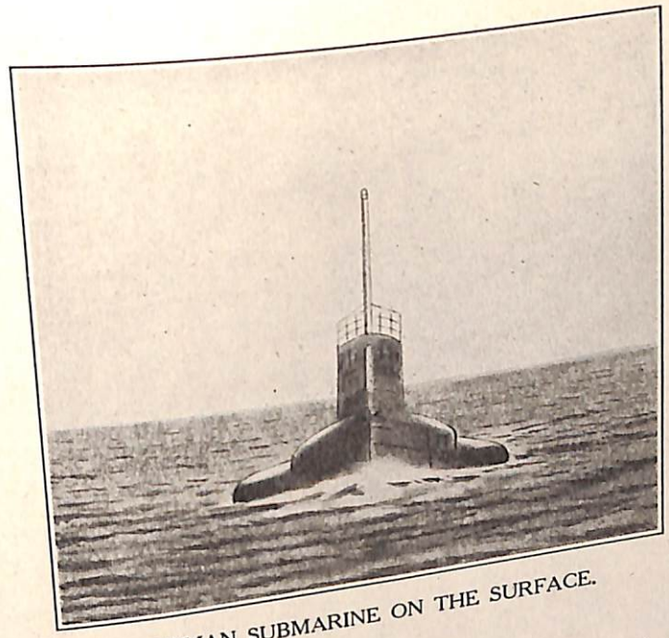
Length about 220 feet. Draught in surface trim about 13 1-2 feet.



German submarine cruising on the surface.



German submarine painted with wave line.



GERMAN SUBMARINE ON THE SURFACE.

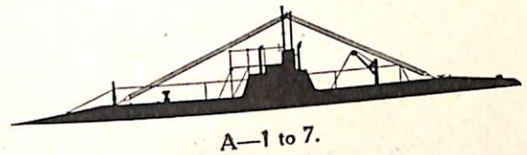
Bow view.

SUBMARINE SUBMERGED.

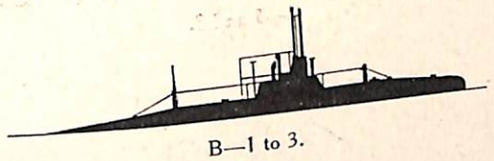
Only one periscope showing.

20652—17—6

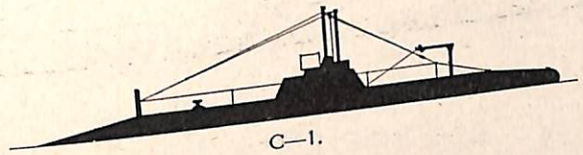
SILHOUETTES OF UNITED STATES SUBMARINES.



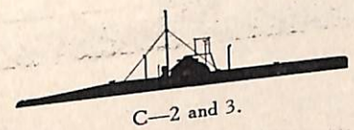
A—1 to 7.



B—1 to 3.

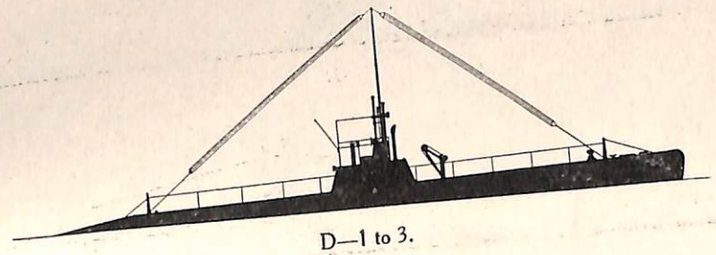


C—1.



C—2 and 3.

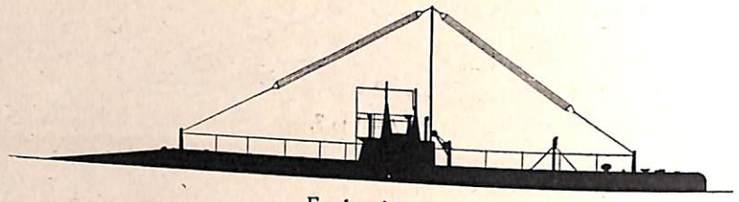
C—4.



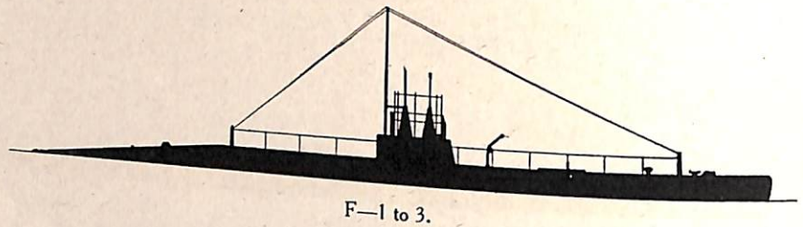
D—1 to 3.

NOTE.

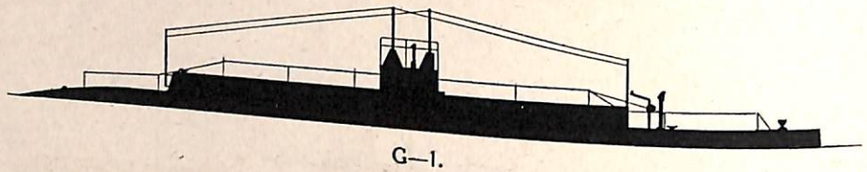
On all submarines, ventilators may be either housed or extended; anchor cranes, stanchions, and life lines may be stowed, and radio masts may be housed.



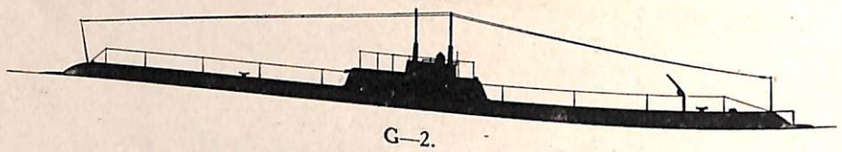
E—1 and 2.



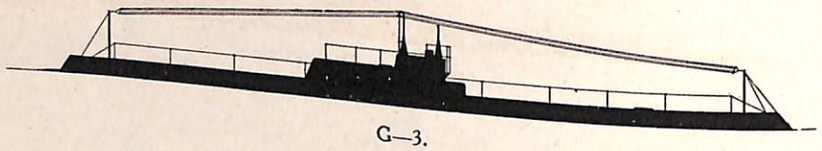
F—1 to 3.



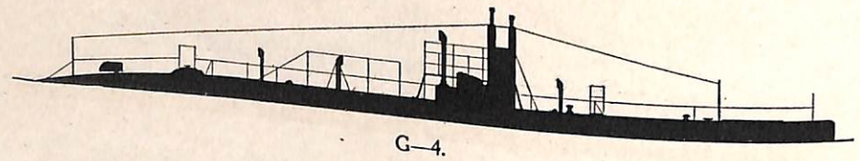
G—1.



G—2.



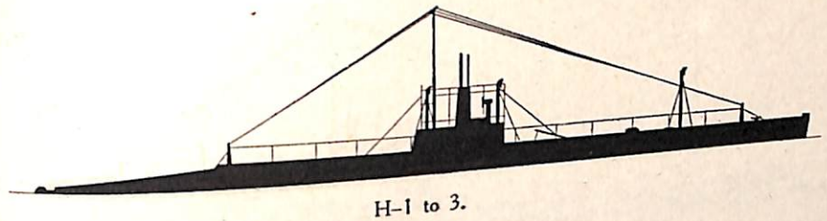
G—3.



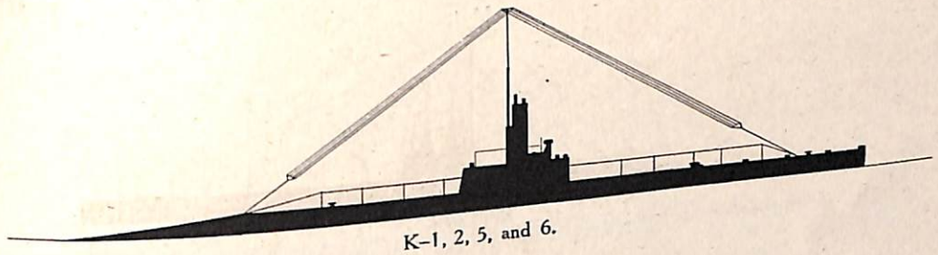
G—4.

NOTE.

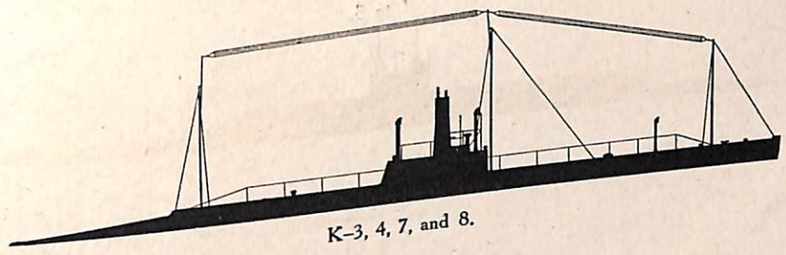
On all submarines, ventilators may be either housed or extended; anchor cranes, stanchions, and life lines may be stowed, and radio masts may be housed.



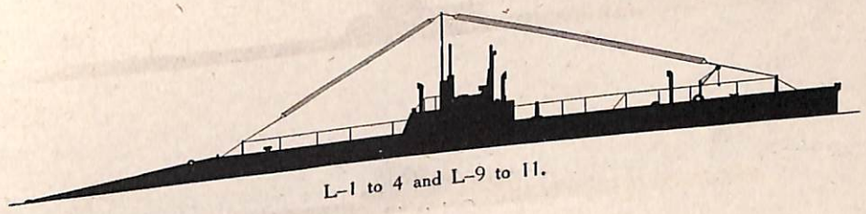
H–1 to 3.



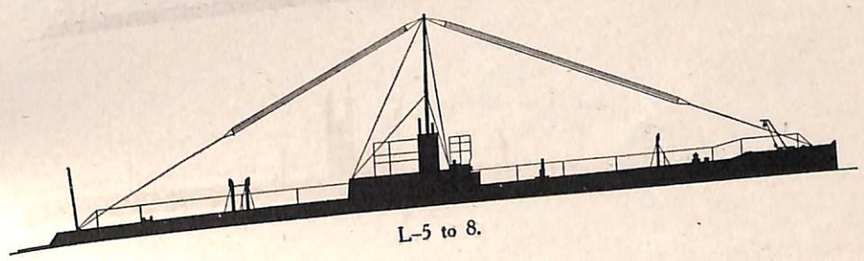
K–1, 2, 5, and 6.



K–3, 4, 7, and 8.



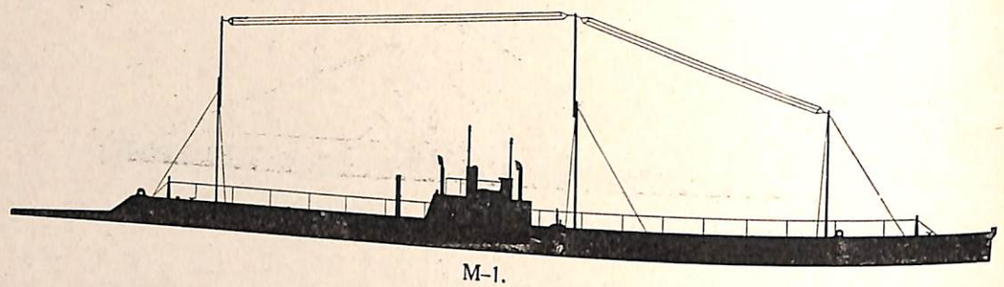
L–1 to 4 and L–9 to 11.



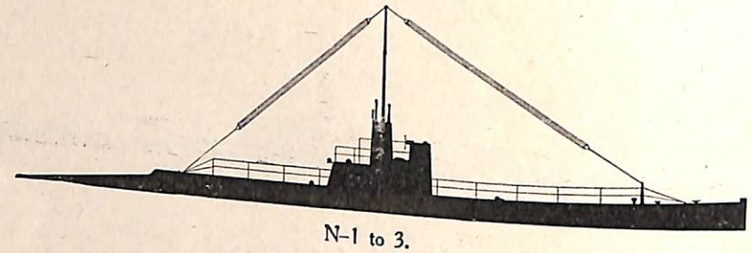
L–5 to 8.

NOTE.

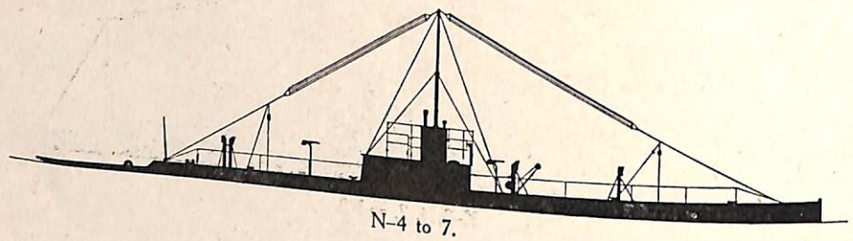
On all submarines, ventilators may be either housed or extended; anchor cranes, stanchions, and life lines may be stowed, and radio masts may be housed.



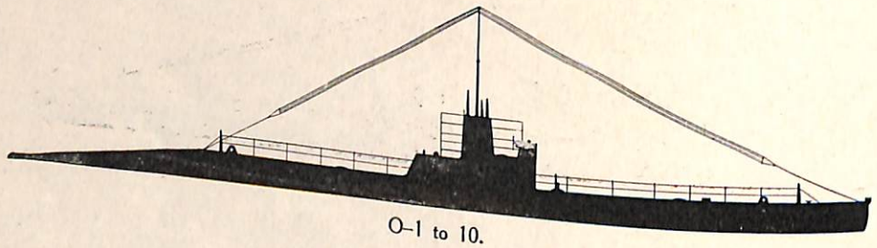
M–1.



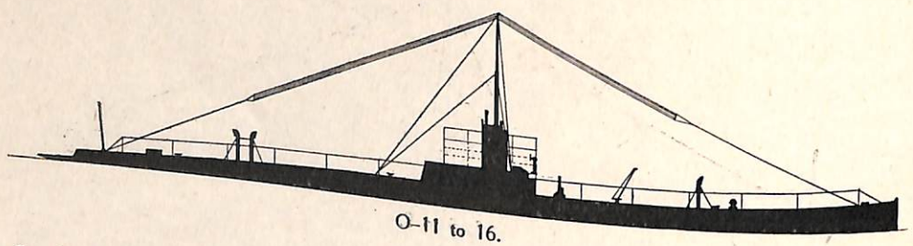
N–1 to 3.



N–4 to 7.



O–1 to 10.



O–11 to 16.

NOTE.

On all submarines, ventilators may be either housed or extended; anchor cranes, stanchions, and life lines may be stowed, and radio masts may be housed.

MINES.

(89)

MINES.

The accompanying illustrations show high-explosive mines such as are being used by the Germans and other belligerent powers.

These mines, when first put in place, are so anchored that they are held at a certain distance below the surface of the water. It is intended that they shall remain invisible and be exploded when struck by any vessel that may come in contact with them. They are called submerged contact mines.

Such mines may be removed by various methods of dragging or sweeping, such as by sinking a long cable each end of which is attached to a tug, and thus dragging a suspected locality. This should only be done by persons who have had experience in work of this nature.

If, due to stormy weather or for any other reason, a mine becomes detached from its anchor, as is often the case, it comes to the surface, and for an indefinite time may be carried about by various currents, and continues to be a danger to navigation, because of being as destructive afloat as submerged. Likewise, floating mines are often cast upon the beach and should be carefully avoided.

Under any conditions whatever a mine floating, stranded, or anchored should be approached only with the greatest caution. If possible, the mine should be destroyed by rifle or gunfire.

It is very desirable that the kind of mine be determined by those who may discover it before they destroy it or leave the vicinity—that is, whether it is of English, French, or German make. It is for this purpose, as well as to caution all seafaring people, that this pamphlet is being distributed.

If, under very favorable conditions of weather, it is possible to approach a floating mine in an effort to identify it, the greatest care must be exercised not to do so when any other floating object is likely to touch it, and not to permit any part of your own vessel to come in contact with it. A floating mine is generally harmless unless it touches some other object.

If an attempt is to be made to destroy a mine by gunfire, those who have not had actual experience in such work should not open fire at a shorter range than 200 yards.

Whether or not an attempt be made to destroy a mine, the fact of its discovery and a report of all circumstances in the matter should be made to the Hydrographic Office, the collector of any port, any officer of the Navy or the Army, or to any other Government officer at the earliest possible moment.

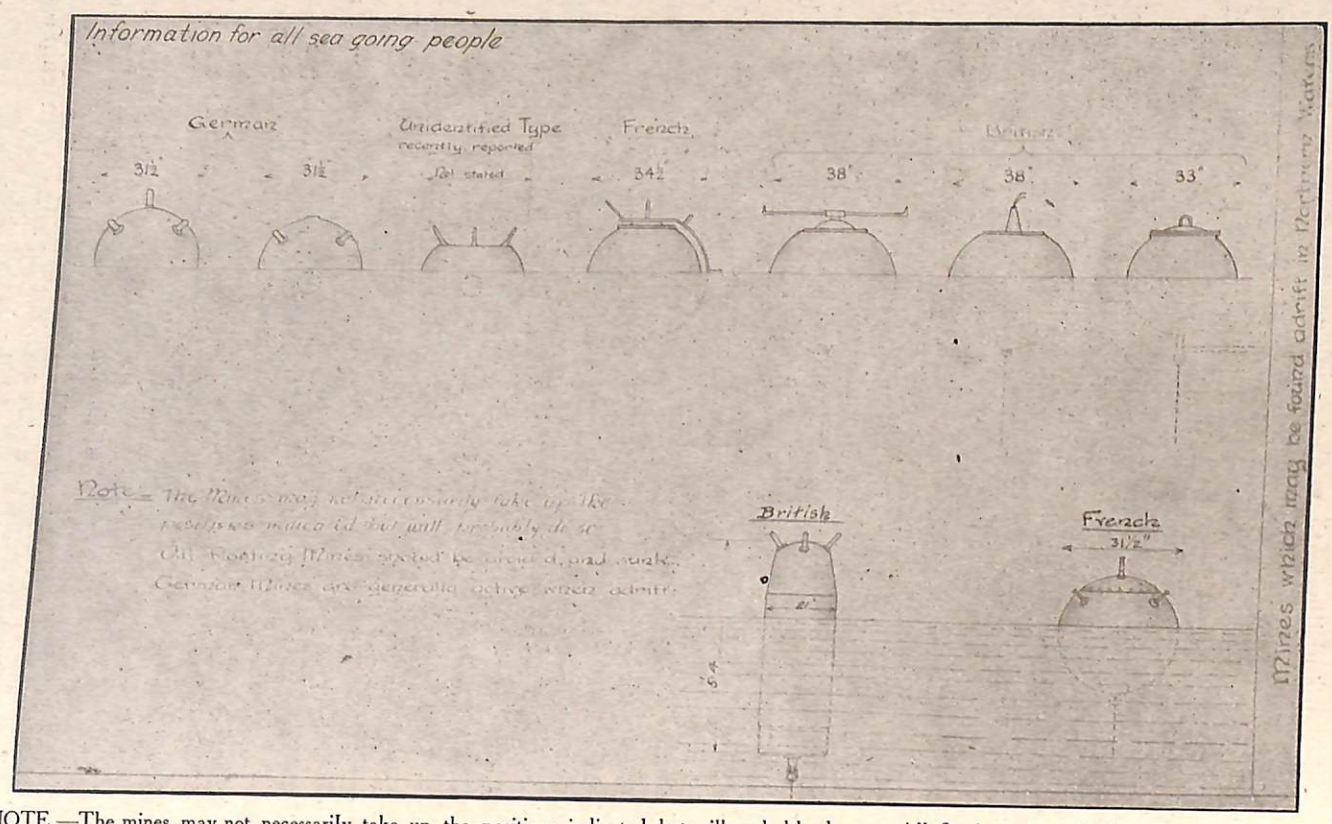
Report the presence of any floating object that may resemble a metal ball or cylinder in order that proper investigation may be made.

If all people along the coast or at sea keep always on the lookout and bear in mind these instructions, a great loss of life and property may be avoided and service of the greatest importance to the Government will be rendered.

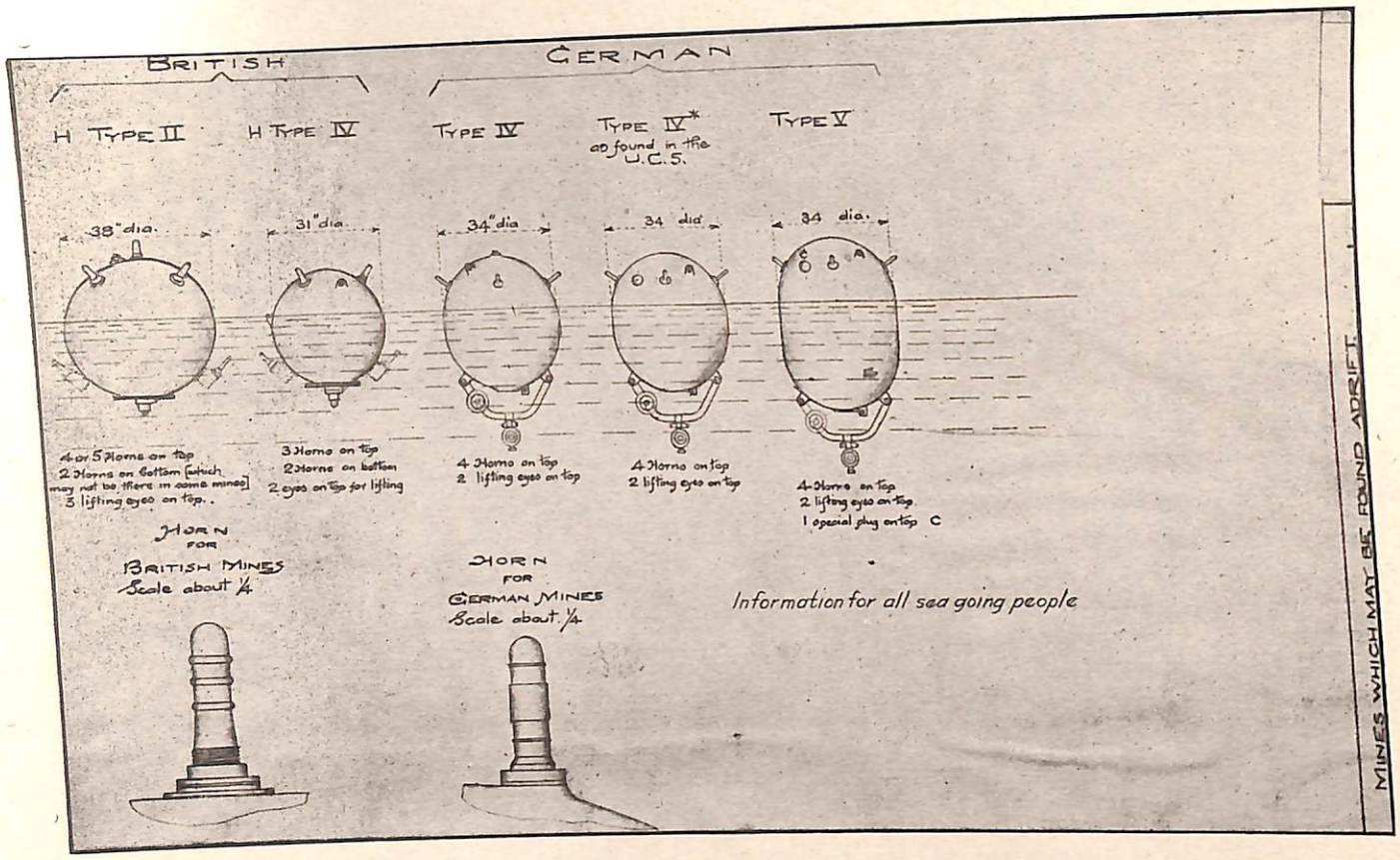
Every effort should be made to destroy a floating mine by machine-gun, rifle, or gunfire. This to conserve the safety of following vessels.

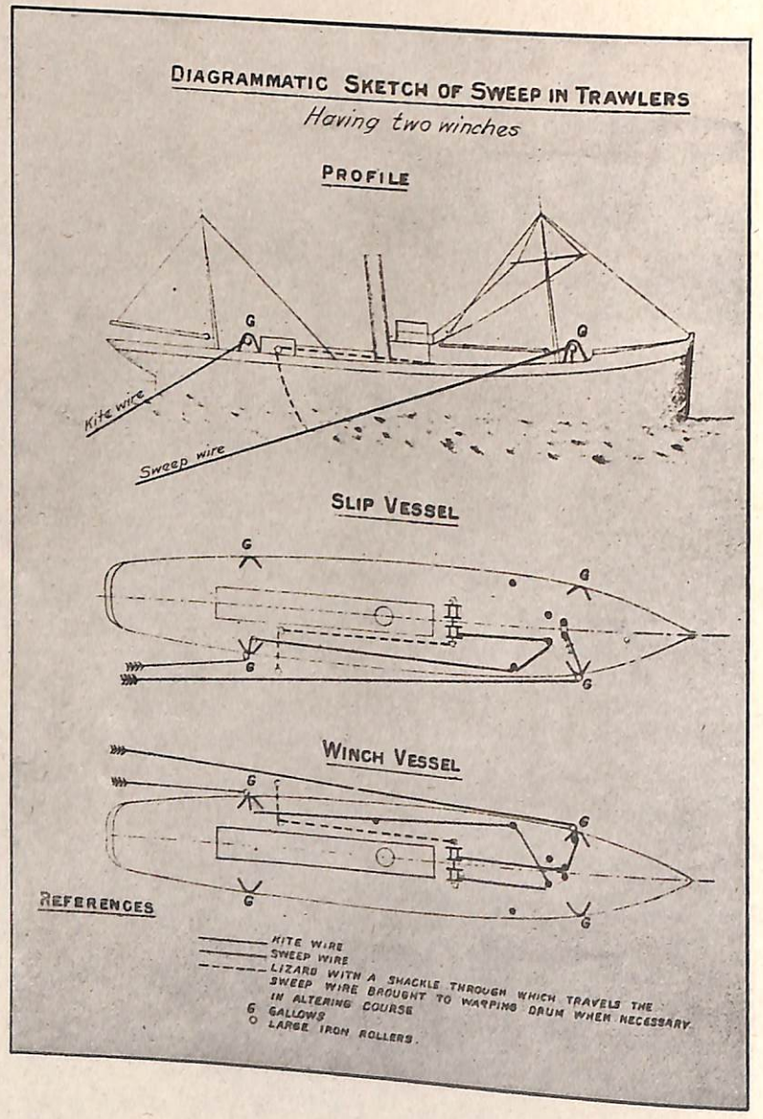
The fact that a reported mine field has been recently swept is not prima facie evidence that all is clear. Adhere to navigational and patrol directions.

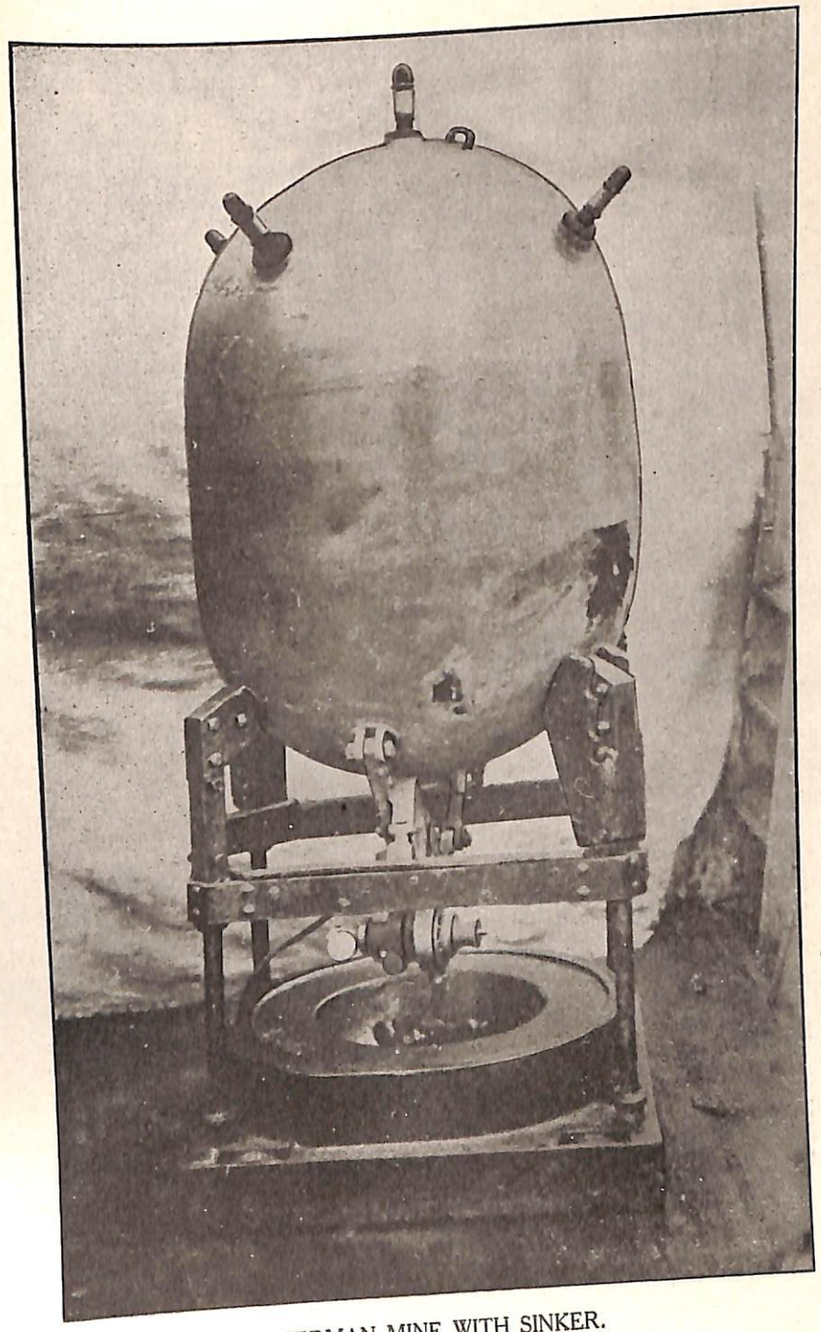
MINES WHICH MAY BE FOUND ADRIFT.



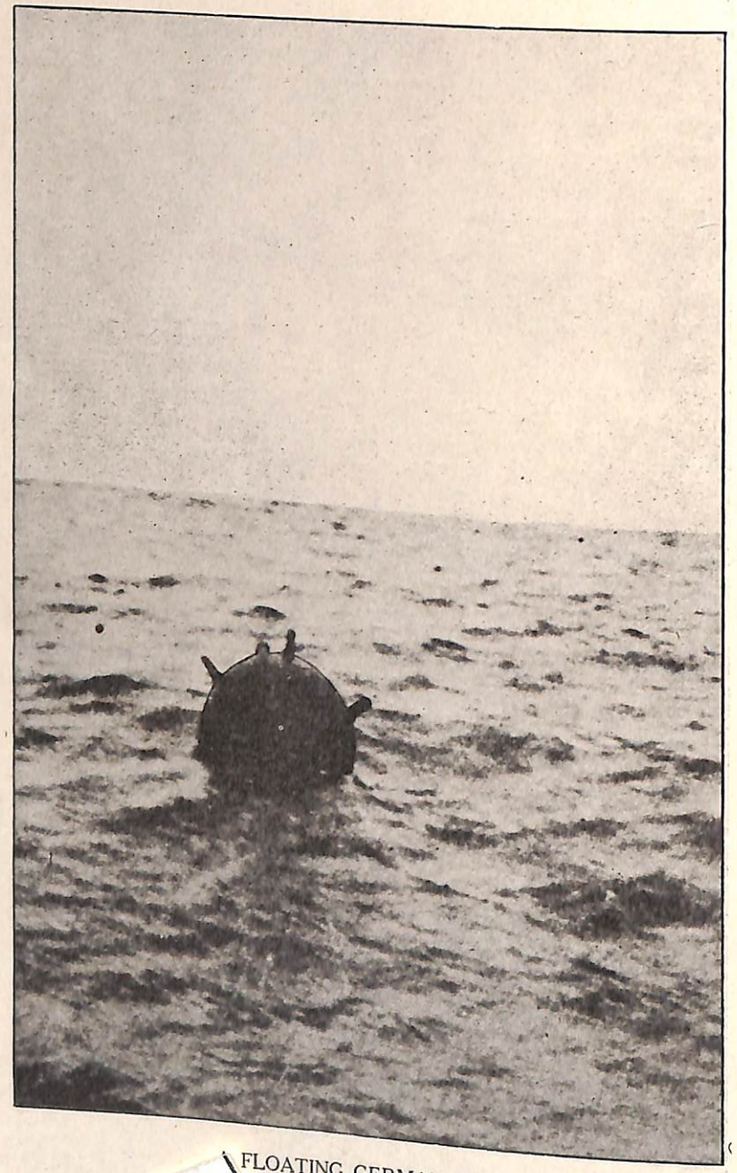
NOTE.—The mines may not necessarily take up the positions indicated, but will probably do so. All floating mines should be avoided and sunk. German mines are generally active when adrift.



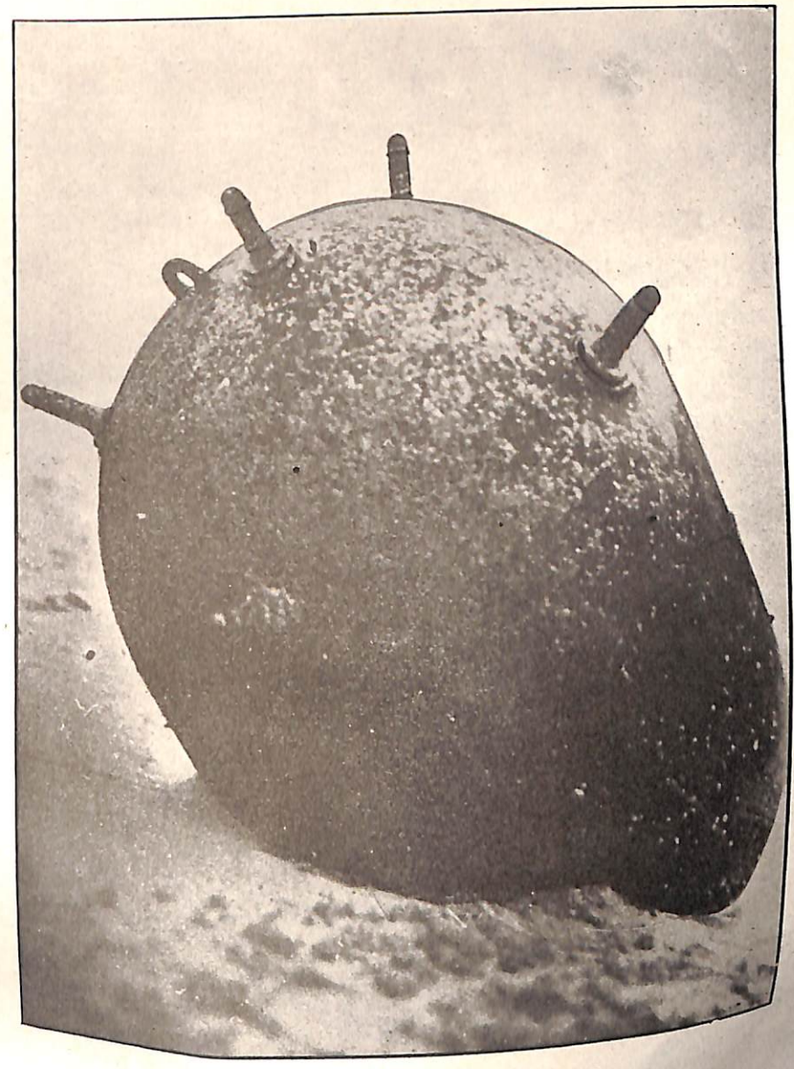




GERMAN MINE WITH SINKER.



FLOATING GERMAN MINE.



A GERMAN MINE WASHED ASHORE.

20652—17—7

○