The Enemy Submarine

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Information of construction, methods of attack, the torpedo and its actions and methods proposed for defensive and offensive protection.

COMPILED BY THE

U.S. NAVAL CONSULTING BOARD

AND

WAR COMMITTEE OF TECHNICAL SOCIETIES

FROM

Information Already Published and Other Recently Released.

Examined and publication authorized.

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Secretary of the Navy.

NAVAL CONSULTING BOARD

OF THE UNITED STATES

OFFICE OF THE SECRETARY

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FOREWORD.

This Bulletin is prepared to supersede Bulletin No. 1, "The Submarine and Kindred Problems," issued on July 14th, 1917, by the Naval Consulting Board; to indicate more fully the requirements for war inventions; to state the limitations outside of which creative effort may not be expected to produce results of value and to assist the student in avoiding the duplication of previous accomplishment. It is also intended to give wide publicity to certain general information already well known to the enemy, in order that the difficulties in overcoming the German submarine may be understood.

References from which detailed information in relation to submarine problems may be obtained, and a list of references with extracts in relation to submarine strategy and tactics, are included.

The Naval Consulting Board is acting officially as a national board of inventions and is conducting its work with the active coöperation of the War Committee of Technical Societies.

By means of the condensed information contained in Bulletins, it is hoped that inventors and others who wish to present matters for examination will be enabled first to analyze their own inventions. By this help, the examiners can devote a large part of their time to the development of inventions, plans, or devices which give promise of assisting the Government in prosecuting the war.

EXPERIMENTS AND DEVELOPMENT.

The Army and Navy and the various civilian organizations coöperating with them are continually experimenting with and developing new ways and means to increase the effectiveness of the machinery of War. The Navy is giving special attention to the submarine and kindred problems, but for obvious reasons many of the details of this work cannot be disclosed.

The amount of time and labor necessary to determine the value of a device, as compared with what is already in use, is infinitely greater than can be appreciated by the layman or even the average engineer. Few realize the stress, hurry and lack of facilities in a battle. Any delay or difficulty in the operation of new devices in action is fatal. For these reasons many schemes and devices appearing practicable and effective in laboratory tests have to be abandoned when tried out in service. There is, therefore, a very wise reluctance on the part of the Government to undertake experiments with, or development of proposals that appear, on preliminary examination, to be of such a delicate or complex nature that they would probably, though perfected, lack the essentials of strength, ease of operation and reliability.

No proposal which involves premises not based on the laws of nature, as understood and accepted by authorities, is entitled to be recommended for experiment and development, unless the inventor shows that he is thoroughly familiar with such laws and can demonstrate that there is a possibility of the accepted understanding being erroneous.

Experiments and development are unnecessary in the case of devices which, though apparently operable, do not promise greater efficiency than those already in use.

It may be stated that the inabilty of the Government to make use of most of the proposals submitted is due to the fact that the devices suggested are either already in use, less efficient than those now employed, or, for good reasons, are thought to be impracticable and open to one or more of the objections mentioned in the list below:

1. It has already been suggested and passed upon.
2. A similar device is already in use.
3. A desideratum, rather than an invention, is offered.
4. It is not considered practicable.
5. According to the authorities, such a device is not required.
6. Prevailing conditions render its use impossible.
7. The desired purpose is now more efficiently accomplished.
8. There is no known method of applying the suggestion.
9. Not practicable according to natural laws as known.
10. The facilities for construction are not available.
11. It would violate laws of war as interpreted by this country and its Allies.
12. It would be too dangerous to use.
13. A similar suggestion has been tried and abandoned.
14. The proposal is not fully understood.
15. Its use would interfere with handling a ship.
16. Not practicable under marine conditions.
17. Ineffective against submarines as now built.
18. Development in the art has progressed beyond that which is indicated by the proposal.

No proposal that is open to any of the foregoing objections will be recommended by the examiners.

Many proposals which depend for their operation upon effects which are contrary to natural laws as known have been submitted. Below is given an outline of some of the most popular misconceptions.

Electro-Magnets

Although the laws governing the use of electro-magnets are generally known and applied in a practical manner in a multitude of devices in common use, even the man of wide experience will be astonished at the limited range of their effect. For instance, the magnets used in our manufacturing plants, for lifting heavy masses of iron or steel are designed to exercise maximum magnetic effect, and for operation require a very considerable amount of electrical energy; yet a magnet which can lift twenty tons when placed in contact with an iron plate of that weight, will not lift two pounds of iron or steel if separated from it a distance of two feet. Therefore proposed devices which depend on the attractive power of magnets for their operation in deflecting or arresting torpedoes, mines or submarines, must be governed by the simple laws of magnetism. A torpedo weighing approximately 2,500 pounds and traveling at a speed of from 25 to 45 miles an hour, will not be deflected to any considerable degree by any known application of magnetism; and it is not believed that an enemy torpedo, mine or submarine will ever be found in a position to be interfered with effectively by any electro-magnetic means, however powerful.

Detection by Magnetic Needle

Tests made on an actual submarine have shown that the magnetic effects, due to this mass of iron, are quite limited in range. For instance, at 150 feet distance the magnetic effect due to a submarine is only about 1% as much as the earth's magnetic effect.

Influence on Compass

The submarine is equipped with a gyroscopic compass that cannot be affected by any magnetic influence from the outside.

Mine Attached by Magnets

A magnet deriving its power from any battery that could be contained within a bomb would not be powerful enough to hold the bomb in contact with a boat running through the water; therefore the scheme is impracticable. The main point would be to locate the submarine. When the submarine is once located, very simple methods of disposing of it are at hand.

Electrical Effects

There is a general misconception regarding the electrification of water and the atmosphere. There is no known method of charging the sea with electricity; of shooting a bomb of electricity, or of charging the atmosphere with electrocuting currents. Suggestions along these lines should show that the writer has made research in the laws governing the application of electrical energy, and should contain sufficient proof of their feasibility, to insure serious consideration.

On the other hand, applications of the transmission of electrical energy by means of alternating or pulsating currents—as used in wireless systems, for example—belong to a different class of electrical development. Inventive genius is rapidly improving apparatus of this type for the sending and receiving of signals and messages, and the possibility of valuable results in this field is unlimited.

THE SUBMARINE AND ITS OPERATION.

History

The first recorded experiment in submarine operation was made by a Hollander, Dr. Cornelius Van Drebbel, who in 1624 constructed a one-man submarine operated by feathering oars, which made a successful underwater trip from Westminster to Greenwich on the Thames.

Dr. David Bushnell, an American inventor and graduate of Yale in the class of 1775, nearly sank the "Eagle" in New York Harbor during the Revolutionary War by the use of his little one-man-powered submarine, the "American Turtle."

In England, the American inventor, Robert Fulton, in the presence of William Pitt, then Chancellor, and a large number of spectators, blew up a brig by exploding a mine which he had placed under her bottom by the use of his submarine boat. Both of these inventors were discouraged and were refused the necessary assistance to enable them to develop further their ideas regarding submarines, although they had undoubtedly shown that there were great possibilities in the underwater type of vessel.

Various unsuccessful attempts were made to utilize submarines during the Civil War, but at that time their only means of offense was a torpedo on the end of a long spar, and the solitary recorded hit was disastrous to both the warship and the submarine. Just as the breach-loading rifle, a very ancient device, failed to come into its own until the invention of the metallic cartridge, the submarine had to await the invention of the automotive torpedo before it became a really efficient means of offense.

Types.

Modern Types

Modern submarines are divided into two general classes: the Coast Defense type of from 300 to 700 tons surface displacement, and the Cruising type of from 800 to 2,500 tons displacement, having a radius of action of from 3,000 to 8,000 miles and capable of operating along the Atlantic Coast of the United States from European bases.

Germany appears to be devoting her energy at present to the construction of a small group of a still larger type, reported to have a displacement of 2,800 tons, which also possesses superior gun equipment for surface operations, greater speed when cruising on the surface, very much more habitable quarters for the crew, and storage capacity for a larger number of torpedoes and other supplies.

"One-Man" Type

Many hundreds of proposals have been received advocating one-man submarines and submarines of small size, to be manufactured in great numbers for the purpose of attacking and destroying the larger types of enemy submarines. This subject has been given exhaustive consideration and it has been conclusively proved that no small submarine can be provided with the necessary power, speed, equipment and living quarters for the crew to enable it to operate successfully in the submarine zone. Even the smallest of modern submarines requires a number of devices for its successful operation; an internal combustion engine, an electric motor—which also can be used as a generator to charge the storage batteries—water ballast and trimming tanks, pumps, air compressors, air storage tanks, torpedo tubes, storage space for torpedoes, quarters for crew, and other machinery and auxiliaries.

Submarines Carried by Mother-Ships

Proposals to have small submarines carried by mother battleships or merchantmen and put overboard have not received favorable consideration, because of the practical difficulties involved in launching and maintaining them. Although a special type of small submarine has been designed with the intention of having it carried upon the deck of a battleship and launched for operations in the immediate vicinity of the ship, no records of successful tests are available. The smallest type of modern coast defense submarines, which can hold the necessary apparatus to have a useful range of action, weighs about 300 tons; the handling of such weights from the deck of a vessel at sea cannot be accomplished with any degree of safety.

Submarines for this purpose have been proposed many times and in some cases carefully designed. No really successful design, however, has been evolved.

Construction.

Hull Construction

Generally, the German U-boat—which is the designation for the enemy ocean-going submarines—is made with a double hull. The bottom space between the inner and outer hulls is used for water ballast; the top space is used for carrying fuel oil. Water ballast displaces the fuel oil as it is consumed by the internal combustion engine.

The frequent statements that oil has been seen on the sea, after a U-boat had been attacked, may have merely indicated that the submarine's outer hull had been punctured. However, there is some oil slick on the surface when the exhaust mufflers are flooded.

According to recent statements, the conning tower, in the latest type of German submarine, is protected by a thin belt of armor plate, and the vital parts of the hull, which are exposed when operating on the surface, are also made heavier than the rest of the hull, to protect them at least from the smaller caliber guns.

Even if the periscope and conning tower are shot away, the submarine may still be able to keep afloat and operate.

Source of Power

The internal combustion oil engine of the Diesel or Semi-Diesel type is almost universally employed for surface operation in modern submarines, although much experimenting has been done with steam-driven craft, and many engineers believe that, for extremely high power, steam may yet be used effectively if some of the inherent disadvantages—excessive heat, etc.—can be overcome. The limit of practical size has almost been reached in the internal combustion engines used in the latest type of submarine, and if more power is needed the engines themselves will have to be improved, or, perhaps steam plants will be resorted to.

Owing to the fact that internal combustion engines require a great deal of air for their operation, which is not available when a boat is submerged, submarines must be equipped with an electric motor run by storage batteries for underwater propulsion. It is, therefore, necessary, after the storage batteries are discharged by use, for the boat to come to the surface while its electric generating apparatus, driven by the internal combustion engine, recharges the batteries.

Speed

The speed of a submarine, like that of other vessels, depends upon the power of its engines or motors in overcoming the resistance of the hull to being driven through the water. For submerged operations, the electric motor operates the propeller, the engine being uncoupled and the current for the motor supplied by storage batteries. This electrical equipment, if it be of high power, occupies much space and is extremely heavy, especially if an extended submerged range of action at high speed is desired. Therefore, the space for such equipment on the underwater craft has to be provided by increasing the size of the craft. If high surface speed is also required, larger and heavier engines must be installed, which necessitate an additional increase in the size and displacement of the vessel. Maximum surface and submerged speeds cannot both be had in one type of submarine, and therefore a compromise which gives the most efficient general results has to be effected. The main engines in a modern submarine constitute approximately 8% and the storage batteries 16% of the total weight of the boat. If greater surface speed is required, the percentage of weight allotted to the engines is increased, or, if greater submerged speed, the weight of the batteries is increased and smaller engines installed. In general, submarines, to be capable of the highest possible speed, both for surface and submerged operations, must necessarily be of the largest type, and many predictions of giant submarines are made.

German cruising submarines have a maximum speed of about 17 knots on the surface and 10 knots submerged.

Details of submarine construction are of less immediate importance than ways and means to protect surface vessels from submarine attack, but details of construction and of the many life-saving devices, such as detachable chambers, or conning towers and other mechanisms which have been proposed, experimented with and discarded, may be found in the references mentioned on a subsequent page.

Equipment.

Listening Devices

The submarine when submerged so that its periscope does not project above the water is blind, but not deaf, for it is provided with sound detectors or microphones that will indicate the approach and direction of a ship, if its own machinery is at rest or moving slowly, with noise so slight as not to interfere with the listening.

The propagation of sound through water is more rapid and efficient than through air, because water does not have so great a cushioning effect upon sound waves. While we speak of sound waves, and can measure their amplitude in some cases, there is no bodily displacement of the medium through which they travel. In general the harder, denser and more incompressible the medium, the more efficient the transmission of the sound waves.

The underwater listening devices which are so frequently availed of in submarines, and patrol boats and destroyers used to attack them, consist primarily of a large diaphragm or its equivalent in some other physical form. The diaphragm is submerged and the pressure of the water upon it tends to cause it to deflect inwardly to a slight extent. When the sound wave strikes the diaphragm, the deflection is increased and, when the wave has expended itself, it is followed by a reduction of pressure which allows the diaphragm to recover until the succeeding wave strikes it.

The human ear can detect sounds having periods of vibration as low as 16 per second and as high as 30,000 or 40,000 in extreme cases, so that there is a very wide range of pitch over which listening devices might be used.

The vibrations emitted from a submarine are usually of low frequency, and therefore the listening devices which are particularly designed for submarine detection have to be specially adapted to low frequency, at the expense in many cases of their capacity for receiving the high frequency vibrations; whereas with submarine signaling devices, designed to communicate from one vessel to another, a frequency of several hundred vibrations per second is found to give better results.

In one typical form of listening device the diaphragm is provided with a telephone transmitter. The vibrations of the diaphragm vary the electrical resistance in the transmitter, which are either listened to by a telephone receiver directly, or amplified by means of relays, such, for instance, as the audion and other similar apparatus, which enable sounds to be heard which otherwise would be inaudible.

Ways and means to tune out extraneous noises, such as the falling of rain on the surface of the water, the noise of the pumps and other machinery on the boat carrying the listening device, and arrangements to determine the direction of the source of sound have been given a great deal of study and been developed to a considerable degree of effectiveness. Sound waves tend to emanate from the source radially, which is availed of in the direction-indicating devices. However, the details of these devices are more or less confidential, and only the general principles can be made available to the public.

Periscopes

The superior gunfire to be expected from a merchantman which has been properly equipped makes it prudent for the hostile submarine commander to obtain his observations, for accurate aiming of the torpedo, through a periscope.

A submarine is usually equipped with two or three periscopes, extending about twelve feet above the conning tower, the more recent periscopes being of the "housing" type, which permits them to be quickly raised and then drawn down after the observation; thus allowing the undersea boat to operate unseen much nearer the surface, and not lose time in changing its depth of submergence.

It is rumored that the latest German U-boat has a short periscope, of from 4 to 6 inches in diameter, extending about 8 feet above the periscope "fair-water," which encloses the stuffing-box through which the periscope slides up and down. The periscope fair-water usually extends 4 or 5 feet above the top of the conning tower. The short periscope is used when the boat is moving at considerable speed through the water. An additional periscope, which can be extended to a height of from 14 to 16 feet above the periscope fair-water, is also provided. It is used only when the boat is stationary or nearly so. This taller periscope is used to reduce the chances of exposing the conning tower and hull of the submarine while patrolling in a rough sea, with the hull submerged. It is very small in diameter at the top, and is commonly called the "finger" periscope. Owing to the vibration prevailing at any speed above four knots, it cannot be used when a submarine is moving rapidly. A third periscope, smaller in diameter, is usually provided as a spare, in case of accident to the two periscopes described above.

A periscope is usually designed to have about a 45° angle of horizontal field of vision, and the vertical field may be less. It is rotated by the observer, in order to scan the whole horizon.

When a submarine is cruising on the surface, the top of the periscope may extend to a height of 23 or 24 feet above the water, thus giving a range of vision of about six miles to the horizon, if the day is bright; while an observer standing upon the conning tower can see the horizon at a range of only about four and one-half miles; however, the observer can usually see much more distinctly by his direct vision than through the periscope. The upper parts of ships can, of course, often be seen beyond the horizon.

Greatly increased optical efficiency in the periscope is not a theoretical possibility, although various sizes and designs of periscopes have been experimented with. Any increase of submerged diameter, or length of periscope, impedes the submerged speed of the submarine. The older type gave a great deal of trouble from defective mechanical construction; but the more modern devices are hermetically sealed by the manufacturer, and are reasonably free from condensation of moisture on the lenses and from vibration.

Experiments have been performed on the subject of decreasing the visibility of periscopes. It is very difficult to see a periscope, and the artistic use of paint, simulating foam and green water, is one of the best means of making a periscope invisible. A periscope so painted, projecting a few feet above the water from a motionless submarine, can be seen at a very short range only, and if it is thrust up in a quick observation and then withdrawn, the presence of the submarine is usually not disclosed.

The use of mirrors has been suggested and experimented with, but the conclusion has been reached that their use is not practicable. Any rolling of the submarine will change the angle of incidence and reflection, and serve to reveal the position of the submarine.

Periscopes having their upper portions made of glass tubing, to reduce visibility, have also been proposed.

It is, however, the wake of the periscope on a moving submarine, rather than the periscope itself, that attracts the attention of an observer.

Torpedoes

A submarine may be equipped with from one to four, or even more, torpedo tubes. These tubes are usually located in the bow, but some of the larger vessels also have tubes in the stern, and there are some with broadside tubes. These, however, are not German. The tubes in the submarine usually being built into the hull, it is necessary, in order to aim a torpedo, to maneuver the vessel so that the tube points at the target. Swiveled torpedo tubes are considered undesirable for submarine work.

A submarine carries as many torpedoes as possible, the number varying with the size and style of the boat. (See Torpedoes, page 31.)

Mines

In addition to being equipped with torpedoes, some German submarines carry as many as twenty or more mines. (See Mines, page 33.)

Guns

For surface operations, a submarine is usually provided, fore and aft, with guns of from 3 to 6-inch caliber. Sometimes these guns are secured rigidly to the deck, and sometimes housed within the hull and thrust up when they are to be used. A portable machine gun is also usually provided.

Wireless

Telescopic or collapsible masts are provided, and wireless apparatus operated upon them, particularly at night, when the masts cannot be seen by an enemy even if he is close at hand.

Net-Cutting Devices, etc.

Numerous devices and attachments have been provided to enable submarines to cut nets, put out divers, and to send a marking buoy to the surface in case of accident, and have proved more or less ineffective.

Methods of Offense.

Bases

Where a surface fleet of naval vessels has control of the seas, it is customary to have mother ships carry supplies and spare parts and to accompany a fleet of submarines; but unless the seas are so controlled it is necessary to supply the submarines from a shore base.

A base for submarines, to be of any value, must be easily and safely accessible, and equipped to provide a safe storage point for large supplies of liquid fuel, spare torpedoes, food and other requisites for their proper maintenance. Its location, if in enemy territory, must, of course, be kept secret, as the discovery of a submarine base leads to the destruction or capture of the submarines dependent upon it. It is reported that one or more German secret bases, along coasts under control of the Allies, have been discovered and destroyed.

Maneuvering

In areas that are under intensive anti-submarine reconnoissance, both enemy and friendly submarines have to remain submerged a large portion of the time. If they remain on the surface during daylight, they are in constant danger from patrol vessels and aeroplanes. When operating in the open sea, submarines may remain on the surface most of the time, especially at night.

In maneuvering it requires at least 60 feet—preferably 100 feet—depth of water to remain concealed and safe from gunfire, ramming, or collision with surface craft. Submarines are frequently tested for safe operation at depths of as much as 200 feet, at which depth few effective obstructions, trawls, or nets can be used against them.

A modern submarine may, if it is in good order and the hull is not punctured, remain resting safely on the bottom for a day or more without inconvenience to the crew. Under favorable conditions, where the waters are less than 200 feet in depth, a submarine might lie at rest on the bottom and detect the approach of a vessel several miles away. In case the water is more than 200 feet in depth, a submarine must usually be kept in motion, to obtain steerage-way, in order to hold its proper depth of submergence. This speed need not exceed one knot.

Method of Attack

Submarines, to operate most effectively, must approach within close range of the vessel which is intended to be torpedoed; but the installation of offensive weapons on the merchant marine has increased the necessity for the utmost care being exercised by the submarine commander to remain unseen. It is reported that, many times, a submarine has followed a slow-moving merchant vessel, at a safe distance, during the daylight and has remained undetected, but, as dusk approached and the visibility of the submarine decreased, the merchantman has been overhauled, when the submarine moved into a position to discharge one or more torpedoes at short range, with deadly effect. Reports from abroad indicate that in many cases submarines have remained along lanes of travel for periods extending into weeks, with the expectation of torpedoing certain vessels.

In its method of attack, the submarine has many advantages over its adversary. The ship to be attacked presents a definite target, of comparatively large size, and is easily seen by the submarine commander at a range where the submarine's periscope is usually quite invisible to those on the surface vessel. Even though the submarine be cruising on the surface it is not easily seen, because it has a very low freeboard.

As the submarine approaches an enemy's surface vessel it submerges, the periscope being the only evidence of its presence. Periscopic sighting of the target is necessary, as it has been found impossible to see through an underwater window far enough for practical observation. In the event of accident to the periscope, a submarine must come to the surface for observation or else maneuver blindly. If the sea be rough, or the weather misty or foggy, the periscope may not be seen until its prey is destroyed by a torpedo, and in some cases not even then. The submarine commander thus has every opportunity to verify his adversary's identity, speed and course, also to decide upon the most vulnerable point of attack, and to place his boat in the best position to discharge an effective shot.

Torpedoes may be discharged with equal effectiveness whether the submarine is on the surface or is submerged, but, at the most effective range, say one-half mile or less, the superior gunfire and greater accuracy of the guns of armed merchantmen and war vessels (because of their higher and steadier gun platforms) make the defeat of the submarine, operating on the surface, probable—in fact almost certain—if the torpedo attack is unsuccessful. A single effective shell might disable or sink the submarine, because of its relatively small positive buoyancy, while the surface vessel might have many shells strike it and still remain in a seaworthy condition.

PROTECTION OF VOYAGING SHIPS FROM THE SUBMARINE.

This subject, which is occupying the public mind as is no other, divides itself into a number of problems, the most important being the following:

Detecting the presence of submarines.
Nets, screens, guards, etc.
Decreasing the visibility of vessels.
Speed of vessels.
Special ship construction.
Convoying.

Detecting the Presence of Submarines.

Microphones

Many merchantmen and transports are equipped with microphones so that they may detect the presence of submarines, take the necessary and available precautions to defend themselves, or make escape. These instruments are of the same general type as those used by the submarines and have already been described under "Listening Devices."

Nets, Screens, Guards, Etc.

Nets or Screens to Be Attached to Vessels

Many designs of such devices are suggested, and most of them are intended to be attached to the hull of the vessel to be protected. Many other suggestions along these lines, differing only in some of their minor characteristics from the foregoing, have been received. Up to the present time not one of these proposals involving screens of any kind has received the approval of the Navy Department or of the Merchant Marine. The principal objections to these devices are that they are heavy, difficult to hold in position, unmanageable in a heavy sea, and that they interfere with the speed and with the ability of the vessel to maneuver. Many of the suggested devices would prevent the launching of life-boats or rafts from the vessel. It is barely possible, however, that there may be developed some form of this general plan which will be found practicable. In no other field have so many suggestions or so many duplicate inventions been presented to the Board.

Pontoons and Guard-Boats

Pontoons and boats, from which plates or screens are sometimes designed to be suspended, to intercept a torpedo, either self-propelled or towed on both sides of the vessel or convoy to be protected, have been proposed, but require so much power to propel that they are considered wholly impracticable.

Devices Projected to Intercept Torpedoes

Many forms of furled nets to be opened in front of an approaching torpedo have been proposed; nets contained in shells to be discharged from guns and to be released on striking the water; nets to be dropped over the side of a vessel when the torpedo's approach is noticed, etc. The operation of these devices, even if practicable as mechanisms, would require an appreciable time interval, and even if the torpedo's approach were detected, the few seconds intervening between its being observed and its striking the ship would probably be insufficient to permit of their use. Quick maneuvering of the ship, however, has frequently been effective in dodging a torpedo.

Torpedo Deflectors

No effective means has been found to destroy a torpedo in flight or to divert one from its course. Heavy charges have been exploded, experimentally, directly in front of and at the side of torpedoes, for the purpose of determining the possibilities of deflecting them from their course, but the regulating gyroscope of a torpedo immediately brings it back to its normal course, so that such methods may be considered as ineffective. Moreover, it should be understood that there is usually no knowledge that a torpedo is coming, until it actually hits the vessel.

The deflection of a torpedo by water or air jets operated at the sides of the vessel has been repeatedly suggested, but the power required to operate the pumps necessary to furnish the streams of water, and to give adequate protection against a rapidly approaching torpedo, would be much greater than that required to propel the ship. If the power were available, it might better be used to drive the vessel at increased speed, by means of the propeller.

Numerous experiments, with devices employing magnets for arresting or deflecting torpedoes, have been tried, with discouraging results. It has been found that magnetic influences are not felt at a practical distance. (See "Magnets, etc.," page 8.)

Mine Sweepers

Mine-sweeping boats and devices to precede a vessel entering or leaving port are sometimes used for the purpose of cutting the cables of submerged, anchored mines, sweeping them away or otherwise rendering them harmless.

Decreasing the Visibility of Vessels.

Smokeless Combustion

The point of lookout on a submarine being close to the water, the position of a vessel at a distance can be determined only by observing its smoke, which floats high in the air. Improved smokeless combustion is therefore desirable.

The visible particles in smoke can be scrubbed out with several well-known types of apparatus. The whole subject has been considered at length, and the conclusion reached that to handle the quantity of gases emitted from a vessel's stack, would require such an amount of machinery and equipment as to make these systems inadvisable. The small submarine chasers are equipped with internal combustion engines and emit no smoke. Torpedo boats and destroyers use oil-fuel, and can suppress or emit smoke at will. Anthracite coal and other smokeless fuels have been tried on coal-burning vessels, with good results.

A number of systems for the smokeless combustion of soft coal have been developed, for operation in power plants and factories. Most of these systems involve the use of special types of grates and stokers which are not often found in the vessels at present in service; however, there seems to be no theoretically insurmountable obstacle in adapting the devices to marine work.

Smoke Screens

Under favorable conditions of wind and position, many vessels have saved themselves from torpedo attack by the production of a smoke screen. This may be formed either by incomplete combustion of the oil used for fuel by most naval vessels, or it may be created by burning chemicals, such as phosphorus and coal tar, or mixtures in which both of these and other materials are used.

After hiding itself from the submarine in a cloud of dense smoke, the vessel, if possessed of sufficient speed, may be able, by a quick maneuver, to change her position and escape before the submarine is able to discharge an effective torpedo.

Blinding Enemy Periscopes

In some cases, a quantity of heavy, black petroleum, or similar substance, which will float on the surface of the water, has been used to cloud the optical glass in the periscope's exposed end. However, in view of the ease with which most of these substances may be washed off, and the vast area to be covered, the use has been abandoned.

"Camouflage" Painting

Relative invisibility may also be afforded by methods of painting. The art of so-called "camouflage" is applied to the painting of ships, as well as to land warfare. Ships are sometimes painted to resemble the sea, and various devices have been proposed to conceal their character, size and identity.

The visibility of ships may be greatly reduced by designing them with a low freeboard, and eliminating masts, smoke stacks, superstructure, etc., and this matter has been given a great deal of study.

Suggestions as to any other method of reducing visibility will be of interest.

Speed of Vessel.

The undeniable evidence of submarine activity, which has been accumulated during the past few months, has demonstrated that the immunity of a vessel to submarine attack is dependent very largely on its speed and also its maneuvering ability. The percentage of vessels having speeds of 15 knots or more, and which have suffered from submarine attack, is very small; while the loss of slow vessels, having speeds less than that of a submerged submarine, is practically one hundred per cent of those attacked.

The merchantman or other craft of high speed quickly passes beyond the range at which a high percentage of torpedo hits can be scored, but slower boats give the submarine ample opportunity to take careful aim and to score a hit with almost every shot.

A ship steaming at twenty knots will cover a distance of one-half mile in one and one-half minutes, but a ship at ten knots takes three minutes; showing the greater chance to escape the high speed ships have when the submarine has finally maneuvered into a position for the proper aiming of a torpedo; but, as a submarine seldom has time to get into position to aim torpedoes accurately at a fast ship, such a ship is almost immune to submarine attack, unless the U-boat happens to be lying submerged in its path.

Merchant vessels, in order to be fast and at the same time economical cargo carriers, must of necessity be of large size.

Special Ship Construction.

The explosion of a nearby submarine mine or torpedo frequently tears great rents in the ship's plating, in some cases opening a jagged hole ten feet or more across. The destructive effect at any given distance, at the point of explosion, depends, to a large extent, upon the framing and plating, and may be greatly diminished by special hull construction.

Many suggestions are made for ships of unusual form to provide for safety in case of such explosions; most of these plans being an elaboration of the usual watertight bulkhead construction, now required in structural design for all modern ships.

Watertight Compartments and Air Cells

The multiplicity of watertight compartments in any hull design tends to add to the vessel's safety. The modern tank steamer, used to carry fluid cargo, such as petroleum products or molasses, is a good example of this design, which has been in general use for many years.

The honeycombing of hulls with air cells has been proposed in an infinite number of variations, and air tanks, such as are now used on liferafts, have also been suggested in various proposed arrangements for installation within the hulls of vessels.

The ordinary self-baling lifeboat, such as is used by the Coast Guard Service, probably represents the most highly developed form of non-sinkable ship that can be constructed. Its hull is filled with numerous watertight cans or boxes, so that injury will merely admit water to the space occupied by the boxes, and only a little reduction of the buoyancy of the boat will occur, as each box is an individual float. It is very unusual for a lifeboat of this type to sink, even though the hull is badly wrecked.

The object of a passenger vessel is to carry passengers, of a freighter to carry freight, and of a war vessel to carry offensive armament. Air cells and watertight compartments in their various forms decrease the convenience and carrying capacity of the different types of vessels, and the problem which has to be solved for each type is one of overall efficiency. In other words, how much capacity is the designer justified in sacrificing in order to increase the safety from torpedo attack?

Cargo-Carrying Submarines

Cargo-carrying submarines of many designs, either self-propelled or towed, have been suggested. They are expensive to build and operate, and are inefficient.

Life Saving Devices

Floating superstructure and many other special life-saving devices have been proposed, but an increase in the number of lifeboats, rafts and regulation life preservers has usually been considered preferable, as most of the special devices are inconvenient and cumbersome.

Convoying.

It has long been the custom to provide convoys for merchant shipping and transports carrying soldiers. The advantage of the convoy is very great, where a number of unarmed ships can be protected against submarine attack by one or two destroyers, and convoys are being used wherever the need is most important. In many cases, however, the commanders of fast vessels prefer to trust to their speed rather than to allow themselves to be hampered by the necessarily slow speed of a convoyed fleet.

OFFENSIVE AGAINST SUBMARINES.

Confining to Bases.

The question as to why submarines are not destroyed before they reach the open sea is a most natural one. The best answer which it is possible to give, according to the officers of our Navy and those of the foreign commissions who have visited this country, is as follows:

The submarine bases are very strongly protected by land batteries, aeroplane observers and large areas of thickly mined waters, extending to such distances that the largest naval gun cannot get within range of the bases. Nets, when laid, are promptly removed by the enemy, whose trawlers are in turn attacked by our destroyers. In spite of these protections, there is now going on a continuous attempt on the part of the Allied navies to entrap or otherwise defeat the submarines as they emerge from the protected areas.

Means of Discovery.

Nets There are three general types of anti-submarine nets: the indicator net, the bomb net and the entangling net. The indicator net is solely for the purpose of detecting the presence of the submarine. These nets are generally made of light $\frac{1}{4}$-inch stranded wire and have about a 10-foot mesh, or they may be made of fiber rope. The bomb nets are also of light material, only sufficiently strong to carry the bombs. The entangling nets are made of much heavier material, but German submarines are now equipped with various devices for clearing themselves.

Anti-submarine nets are so placed that the upper edge is between 15 and 20 feet below the surface of the water. The waters in which nets are used are under such close surveillance that no submarine would operate on the surface there in the day time. By keeping the top of the net under the surface, its location is not disclosed to the enemy.

Nets and Bombs

The value of nets with attached bombs is problematical, owing to the great danger from the very rough handling which these nets invariably receive, especially when attempts are made to lay them in rough water. The bombs and the apparatus which is usually designed to explode them are heavy, bulky and require occasional inspection for proper maintenance.

An almost imperceptible tidal current causes an anchored net to lop over to one side so much as to sink the top of the net to a surprising extent. The behavior of nets, either towed or anchored in a current, is very difficult to comprehend, until seen.

Trawling

The dragging of trawls, or nets, by trawlers and destroyers, not only with the view of locating submerged submarines but also to sweep up mines, is frequently suggested. Under certain conditions this operation is practicable and effective, and has been constantly employed abroad since the beginning of the war.

Aircraft

Aeroplanes, dirigible balloons, kites and aircraft of all sorts are used for detecting the presence of submarines. They may be operated either from shore or from the larger ships, and are sometimes very effective; as, under favorable conditions, a submarine is discernible from aircraft flying at a proper height, even though the submarine be submerged to a considerable depth.

While aeroplanes have been thus used successfully in the English Channel, they are unable to operate far out at sea, where the submarines are now most active. The construction of mother ships for carrying and launching aeroplanes is necessarily a slow process under present conditions, when all shipyards are overloaded with other important work.

Optical Detection

Many devices which depend upon optical means of detection, such as special forms of telescopes and field-glasses, to be mounted on ships or on scouting vessels, are suggested. Experienced and alert lookouts, however, have proved to be the most essential factor. Without such men, no optical device appears to be of value, and at night, or in bad weather, such devices are apt to be unreliable.

Wake of Submarine or Torpedo

The fact that a moving torpedo leaves in its wake a stream of air-bubbles caused by the exhaust-air from its propelling engines, offers under favorable conditions, one means for discovering its approach. This evidence is, however, difficult to detect in a rough sea or at night, and, furthermore, the bubbles do not reach the surface of the water until after the torpedo has travelled onward a distance of from 50 to 200 feet towards its target. Only a very small percentage of torpedoes are seen.

Seeing Under Water

Many proposals for boats with glass windows in the bottom, and other means for observing submerged objects have been made. The waters in which submarine activity is most pronounced are so lacking in transparency that experiments have proved it impossible to see objects such as submarines at an average distance of more than 10 or 15 feet. Even in the clearest sea water, objects under the surface cannot be seen if distant more than 100 or 150 feet.

Many special forms of searchlights and projectors, to enable an observer to see a greater distance through water have been suggested and experimented with, but so far none of these devices has proved successful.

It will be seen that each of the above methods, however useful, has its limitations; therefore, scientists and inventors should apply themselves not only to the task of improving these, but also of finding supplementary methods and devices.

Patrol for Submarines.

In open waters, where storms and heavy seas are encountered, the patrol for submarines is generally carried on by large, fast boats of the destroyer type. In the more protected waters the patrol for submarines devolves upon light, fast surface craft, aircraft and submarines.

Submarines Used Against Submarines.

Submarines have very low visibility. They were primarily designed to operate against the large surface vessels, and it has been the general impression that submarines are not effective against submarines. This belief was also held by the general naval staffs of the various combatants at the beginning of the war; however, Allied submarines have been successfully used in destroying enemy submarines.

In operating against hostile submarines, the hunting submarine may employ one of two methods; it may remain totally submerged and take observations by thrusting up the periscope every few minutes, or it may remain on the surface and only dive when the enemy submarine is sighted. In both cases the hunting submarine maneuvers very slowly, in order to avoid attracting the attention of the enemy, and to prevent detection by means of listening devices. The method of total submergence is used in restricted waters, such as channels and lanes through which the enemy submarine must pass. Torpedoes are used when submarines fight each other, and, if possible, the extremely effective ram. All submarines can ram without specially designed devices for so doing.

Destruction of Submarines.

A submarine is most vulnerable to attack from gunfire when it is on the surface, recharging the storage batteries; for the gases rising during this operation are stifling and must be vented into the air, and several minutes are required to close the hatches and submerge.

Quick firing guns of sufficient caliber and depth charges are used by surface vessels, such as destroyers and chasers, when they are unable to discharge an effective torpedo.

Gunfire

A rapid-fire gun is effective when the submarine is within close range of the gun; but when only the conning tower is exposed the target is so small that it is difficult to hit.

A submerged submarine can be reached with ordinary service shells only by high angle fire, because at low angles they ricochet on the surface of the water.

The Navy has one or more types of shell that penetrate the water satisfactorily, and any improvement would be along the line of straighter underwater trajectory and reduced underwater resistance. The screw-nosed shell has been suggested many times, but it would seem that inventors are laboring under a misapprehension: viz., that the shell will screw its way into the water, whereas a shell rotates only once in about 25 or 30 calibers, and the fraction of a revolution which it makes while entering the water is negligible.

Depth Charges

The powerful effect of any submarine explosion on all neighboring bodies provides a simple means of destroying or crippling an undersea boat. Once it has been even approximately located, the setting-off of a heavy charge of high explosive, well submerged within about 50 feet of the submarine, will bring about this result.

Howitzers and mortars to throw depth charges at a submarine have been proposed, but the deck of a merchant vessel would have to be reinforced to support the recoil, if heavy charges were to be handled. Catapults have been proposed as a substitute for howitzers, but are believed to be theoretically and practically less efficient for this work.

Bombing Hydro-Aeroplanes

The rapid development and improvement of the depth bomb, and the increased carrying capacity of the modern high-powered hydro-aeroplane, have made possible a new type of "bombing hydro-aeroplane," designed to carry a considerable number of bombs, each containing a heavy charge of high explosive.

A great many nest arrangements of torpedoes have been suggested and considered, also torpedoes combined with nets, but the authorities do not believe that any of these combinations are as practicable as other means now at hand. **Nests of Torpedoes**

The idea of having chasers towing mines has often been suggested and used to some extent. This is a good method when the whereabouts of the submarine are known. **Towing Mines**

Torpedoes to be controlled by sound have been frequently proposed, the torpedo to be tuned to automatically steer itself and strike the vessel destined to be destroyed. This design has been very carefully considered by torpedo experts and associated scientists. **Torpedo Influenced By Sound**

To develop such a weapon would require years of experimentation and while a successful design might be attained, the relative increase in value would hardly compensate for the time and study necessary.

There are many methods for dealing with the submarine when its whereabouts are determined. The problem lies rather in locating the submarine.

TORPEDOES.

The modern submarine torpedo varies in size according to the service for which it is intended, and ranges from 14 inches in diameter and 15 feet in length to 21 inches in diameter and 21 feet in length, weighing from 1,000 to 2,600 pounds, the smaller type being used by the Germans to sink unprotected freight and passenger ships at short range. **Size**

It is capable of a speed of more than 30 miles per hour, and when traveling at normal speed, possesses great momentum, about 65,000 foot second pounds. **Speed**

A torpedo is projected by means of a special form of tube or gun. The tube is usually built into the hull of the submarine, in which case it is aimed by maneuvering the boat. In the case of destroyers and battleships, the torpedo may be projected from submerged tubes or from deck tubes. **Method of Discharge**

Generally speaking, torpedoes are projected from submerged tubes by compressed air and from deck tubes by a small charge of gun powder. Submerged tubes on battleships, however, may be designed to use either powder or compressed air. When the torpedo is fired from a submerged tube, the compressed air or the gas from the powder follows the torpedo out of the tube with a rush, and causes an eruption on the surface of the sea, which is visible for a considerable distance. As a result of the warning given by this eruption, vessels have sometimes been able to escape the torpedoes by a quick maneuver.

Propulsion The modern torpedo is self-propelled, being driven through the water by its own compressed air motor, the air being supplied from a strongly built reservoir within the body of the torpedo itself. Torpedoes directly operated by internal combustion engines as motive power have been experimented with and discarded.

Range The range of a torpedo is approximately a mile, those designed for use on battleships and destroyers being longer ranged than those for use on submarines. The great difficulty in getting proper direction and sufficient motive power to give the required speed for a long duration of time renders the long range torpedo impracticable. It is stated that the latest German torpedo has a range of about 2,000 yards, as the compressed air storage reservoir has been reduced in size in order to increase the charge of high explosive in the warhead. The charge is said to be from 300 to 400 pounds.

Method of Steering The torpedo keeps a fairly accurate course by means of a gyroscopic steering mechanism, which is immune to outside magnetic disturbance.

Course The depth at which a torpedo travels may be regulated to hit the most vital part of the vessel, and that is usually about 10 feet below the surface. In case of torpedo attack against an armored ship, the torpedo, to be dangerous, should strike beneath the armor belt, which usually extends about 10 feet below the water line.

Torpedoes are usually provided with means to cut, more or less effectively, through nets placed in their paths. Net-Cutting Devices

The detonation of the torpedo is accomplished through a mechanism placed within its warhead; and if the torpedo is checked in its forward motion, the firing mechanism instantly ignites the heavy charge of explosive contained within the warhead. It is not necessary to strike a firing pin on the end of a torpedo to detonate the charge. Detonation

Many suggestions have been submitted to the Board for a torpedo to be electrically propelled from a ship by means of a flexible cable connecting it with the ship. This was the first type of torpedo built, but was discarded for the present dirigible type, as the weight of cable, difficulties in insulation, etc., render it of no practical value. Controlled By Cable From Ship

MINES.

Generally speaking, there are two types of mines: fixed and floating. The fixed or stationary submarine mine is fired by contact, electricity, timing device or fuse. Such mines, which are extensively used by all navies, are rugged in design and may contain large charges of explosives. They are placed in position by submarines and other especially equipped mine-laying vessels. Such a mine is provided with an anchoring device and is deposited, if possible, in harbors and channels of the enemy or in the paths of ocean travel. Stationary Mines

Floating mines differ from fixed mines in that they are unanchored, and unless guard boats are at hand to warn friendly vessels of their proximity, may be as dangerous to friend as to foe. Such mines must be, according to laws of war, designed to become inoperative within a few hours after being set adrift. Floating Mines

The German floating mines are often cast adrift in pairs, connected by a line about 100 feet long. If a ship runs between the two mines they are drawn alongside the ship, and exploded.

Many proposals have been received suggesting the use of a contact depth mine, which will rise to the surface if Contact Depth Mines failing to contact. This type, however, is considered unnecessary and inadvisable. The essence of the depth charge is that it explodes in the vicinity of the submarine, in case it fails to strike the boat itself. The use of the contact depth mine presupposes the necessary accuracy to strike the target. The recovery feature is of no particular value, and would necessitate numerous safety precautions to insure absolute safety in picking up.

REFERENCES ON THE SUBMARINE AND KINDRED PROBLEMS.

The student is advised to consult the following publications, which may be found in any public library:

The General Electric Review, Schenectady, N. Y., August, 1917, containing "Bibliography of the Literature of Submarines, Mines and Torpedoes," by David B. Rushmore, which gives a list of books and papers in relation to the subject.

The Journal of the Franklin Institute, Philadelphia, Pa., August, 1917, in which appears an article entitled "The Submarine in Periodical Literature, from 1911 to 1917," which gives a digest of a number of articles on the subject, and is helpful for anyone who wishes to get a general idea of the problem.

Scientific American issues of 1917 and 1918, "Submarine Problem."

List of References on

SUBMARINE STRATEGY AND TACTICS

Prepared by Library Service Bureau, United Engineering Society, 29 West 39th St., New York City, September 14, 1917, for the Naval Consulting Board.

1912—Nimitz, Lieut. C. W.

Military value and tactics of modern submarines.
Proc. U. S. Naval Inst., 1912, Dec., vol. XXXVIII, pp. 1193-1211.
Discusses the factors of communication, mobility, invulnerability and offensive strength, the relative advantages and disadvantages of submarines and submersibles.—Coast defence submarines.—Tactics of an offensive sea-keeping group of submarines.

1914—Biles, J. H.

The protection of battleships against submarine attack.
Engr., 1914, July 10, vol. 118, pp. 33-35.
The defensive aspect of submarine tactics is referred to, with particular reference to the advisability of providing battleships with bottom armour. The points for discussion were as follows: (1) Is 4-inch armor sufficient protection against torpedoes to justify its adoption in battleships of the class of the later Dreadnoughts? (2) Is the submarine menace of sufficient importance to justify the adoption of 4-in. armor protection on the bottom? (3) Is the submarine menace of sufficient importance to justify the building of smaller, slower battleships of, say, 16000 tons displacement of 18 knots? (4) Is the method of applying armor to the bottom of sufficient value in itself to justify the adoption of a form of ship which offers greater resistance than the ordinary form?

1915—Robinson, R. H. M.

The modern submarine in naval warfare.
J. Franklin Inst., 1915, vol. 179, pp. 283-311.
Extremely valuable paper. The two general roles of submarines, viz. the defensive and offensive roles, are dis-

cussed at length. The question of the tactical use of the submarine in groups is also commented upon. For the purpose of tactics, submarines are considered in this article, according to their capabilities, under three heads, viz., harbor defense, coast defense and sea-keeping offensive submarines.

1915—Horsnail, W. O.

Submarines versus surface craft for future navies.

Fortnightly Rev., 1915, Oct.

The question is being asked whether the functions of a modern navy can be carried out by submarine craft.

These functions are:

"(1) To fight enemy ships.

(2) To blockade an enemy's coasts.

(3) To capture enemy merchant vessels in all parts of the world.

(4) To chase and destroy enemy commerce-raiders.

(5) To destroy forts on shore.

(6) To assist land forces by shelling an enemy's position within range of the sea.

(7) To obtain information regarding an enemy's naval movements.

(8) To protect the transport of troops and supplies."

These functions might be modified if, for instance, commerce might be carried by submarine vessels or by aircraft. But a consideration of this question shows that this will be impossible or impracticable. Merchant types will remain the same. The other functions may be considered as conducted against submarine naval types.

(The author concludes that it is possible to develop submarine naval types corresponding to the present elements of naval construction—battleships, battle cruisers, destroyers, etc. High surface speed for submarine or submersible type is contingent upon the development of an "oil turbine." Other types, carrying armor and heavy guns, are practicable from the standpoint of design, and they could perform their functions.)

Resisting submarine attack.

United Service Gazette.

Canadian Military Gazette, 1915, June 22.

The submarine has had more success amongst large battleships in the present war than most experts anticipated. Some, indeed, believe with Vice-Admiral Sir Percy Scott, that the submarine was destined to drive the battleship from the sea, but the majority held the other view. Up to the present no Dreadnought has been sent to the bottom by this agency, so far as officially known. In this connection the distinction between the Dreadnought and the pre-Dreadnought is important. In the Dreadnought type the bottom has been more effectively divided than in the previous construction, and this double bottom and division system has been extended with each successive ship; and though a full test has probably not been made, the protection is undoubtedly very complete. Notwithstanding this, the case of the "Lusitania" was disquieting, for the underwater construction of the ship was to an extent that of the latest Dreadnoughts. In both the "Lusitania" and the "Titanic" the watertight doors were closed; and since apparently none of the present Dreadnoughts have encountered the latest type of torpedo from a submarine, and none have been subjected to the experience of the "Titanic" with an iceberg, the effect of any of these conditions on the latest ship construction of the navy is still a matter of speculation.

There are two ways of affording complete protection to the bottoms of the vessels from submarine attacks—either to build boats that will destroy the submarine, or cover the bottom of the ship with armor protection sufficient to resist the torpedo. The latter method has long been under discussion. It is estimated that covering the bottom with a sufficient thickness of armor would reduce the speed of the ship by at least two knots under forced draft. Of course, the adoption of such protection by all navies would reduce the speed all around, with no resulting comparative loss.

In order to fit the armor, the design of bottoms would have to be different from the present form, and experts claim that the change of construction would result in a design for a ship smaller and shorter than at present. This would return the size of battleships to more moderate dimensions. These changes would necessitate lighter armor on other parts of the hull, a certain sacrifice of gun-power, and other compromises.

1916—Degouy, Admiral.

The protection of commercial steamers.

Revue des Deux Mondes, 1916, Dec. 15.

Submersibles and submarines have tremendously increased in size, speed, radius of action, and armament. There is talk of a submersible cruiser of 5,000 tons, and it seems that some submarines are carrying 150 mm. guns in addition to their torpedoes. The large new types make 18 or 20 knots on the surface and 12 to 14 submerged. They have petroleum engines, or motors, whose fuel they can replace from any victim's store or cargo. They have most elaborate wireless equipment. German submarines have bases in many quite well-known localities, threatening all trade routes. Despite the vigilance of the United States authorities, they are probably in wireless communication with agents in that country, and receive information as to sailings, cargoes, descriptions, etc., of outgoing vessels. They doubtless do not too closely conform to the rules concerning territorial waters in watching for their prey.

How can ships be protected? Can they protect themselves? Can convoys be provided? What are the best methods to protect them?

The problem presents itself under two aspects. Protection is needed throughout the voyage in the smaller bodies of water. In the Atlantic, protection is particularly needed in getting out into the high sea, and in making land. The submersible high-seas cruiser has happily not yet appeared; but who can say that it may not be in process of construction? As to self-protection, the guns so far in general use are smaller than those that seem to be borne by the new type of submersibles, which are apparently budding into bombarding war vessels. For the liners, many guns, gunners, and skilled observers would be needed, as well as captains bold enough to fire upon the pirates, although superiors recently condemned to death one who did fire.

For the shorter and more dangerous lines of travel, for example in the Mediterranean and the North Sea, it might help to follow unusual and varying courses, but the vessels should be convoyed out and in. For this duty, fast-sailing, small craft are best; we can not have too many.

Furthermore, the voyages should be shortened as much as possible. Why not make more use of mixed transportation? Many voyages could be shortened by utilizing shore transportation. In many places by utilizing railroads and motor vehicles, the danger could be reduced 50 per cent.

In the Atlantic, vessels should be well covered in getting away from land, and in making land. To do this effectively, careful and thorough organization would be necessary. Trying to ferret out submarines, especially when our cruisers must respect territorial waters while the submarines can disregard their limits and escape detection, is an almost hopeless task.

Here, too, convoys for the entire voyage would be best; but we always come into contact with "established principles." We can not get enough small craft, and we hear such objections as that of the retardation of fast-sailing liners by slower convoys. Better more time and greater safety. Besides, every sailor knows that the liner could tow her convoy, and she would not need to throw out a steel cable to do it. The smaller vessel could follow in her wake.

There are many minor means of lessening the danger to vessels. Are the least visible colors used for painting? Can the art of "making-up" be utilized? What can be done by means of false water lines, false lengths for the ship, false heights for masts, smoke-stacks, etc? All these details would have to be put into practice outside the port of departure. They could be done after sailing; one could put into certain convenient places for the purpose when the seas ran too high. The use of paint and other artifices like those mentioned would assist in misleading the enemy in his calculations of distance, etc.

Munitions should not be carried on personnel transports. There are enough explosives aboard for the guns carried as an armament in these cases. These, too, should not be considerable, and they should not be placed in the hold, where a mine or a torpedo may explode them. Better an explosion on deck than in the hold. Protective or palliative measures could be provided on deck, though the probable inconveniences are recognized as serious.

Wireless telegraphy, collective and individual life-saving equipment, numerous carefully constructed ship's boats, perfected methods for promptly lowering the boats, notwithstanding any possible inclination a torpedoed ship might take—all these should receive our most careful attention. Means should be worked out for eliminating the smoke, which reveals at great distances the presence of a vessel.

In default of the means of providing convoys for the entire voyage, there should be organized a route of relay protection, over which a ship could pass from one protected zone, or from one safety lane to another. It will be noted that there is a striking resemblance between the methods that it would be well to adopt in the maritime theaters of operations and those already established on land in a warfare of movement. There are not two ways of waging war; there is only one, the proper way.

There is no intention here to open a discussion which will doubtless be brought up later. But it may be repeated that we shall not succeed in wresting from the Germans the undeniable mastery which they exercise, not on but under the sea, except by attacking methodically and successively, with all the appropriate means of action, the naval bases of their submarines, for the purpose of destroying them or hermetically sealing them up.

1917—Defense against submarines by smoke screens.

Army & Navy Jour., 1917, March 10.

The device used on British merchant steamers to envelop themselves in smoke includes two drums that are attached to the after deck, one on each side of the ship. Each drum is filled with phosphorus. When the lookout sights an undersea boat, an order is given to fire the phosphorus in the drums, from which almost immediately heavy clouds of black smoke pour, entirely enveloping the ship, and leaving such a long trail that the submarine cannot locate the fleeing merchantman.

McGrath, Senator P. T.

The strategic value of Newfoundland in a submarine war. Forum, 1917, Apr., vol. 57, no. 4, pp. 431-36.

It is claimed that the possession of this island is indispensable to the future security of the United States in the event of war. The chief value of Newfoundland lies in the fact that the power which possesses it has in it the means of providing a base for its naval forces rarely equaled elsewhere in the world, and of exercising thereby an influence on Canada's development which cannot be otherwise approached. It must be perfectly obvious, therefore, as an outcome of the lessons of naval warfare in the present struggle, that on the one hand the power owning Newfoundland and controlling operations within its waters, would be able, by use of nets and other appliances employed to impede submarines at present, to render Belle Isle Strait inaccessible for these, while the type of big guns now in use would enable land forts to prevent hostile cruisers forcing through that channel; whereas, on the other hand, submarine operating by the power owning all the adjacent seaboard, would render it impossible for an enemy to approach this seaway at all.

1917—Degouy, Admiral.

The submarine war of 1917.

Revue des Deux Mondes, 1917, Jan. 15.

From the beginning the necessity has been recognized of breaking up the enemy's organizations of small bases for submarine supplies, fixed as well as mobile. There is at present much trouble, in this respect, connected with the coasts of Spain, where various activities are being carried on.

But I repeat that the difficulty of operating against the large submersibles, with their vastly increased radius of action, the increase in the time during which they can remain immerged, their increased speed, etc., is becoming much greater. The small craft, useful against small submarines, will not be sufficient to cope with the large seagoing submersibles. What succeeded in 1915 will not succeed in 1917.

We are facing the problem of dealing with a different class of submersibles, the veritable submersible cruisers.

We must do something new, and not content ourselves with developing old systems. This war is undergoing transformations every day. What can one do against an enemy that invents, or uses in a masterly fashion the inventions of others, if one does not also invent, and invent more and better than he? To catch up with Germany it is not sufficient to take one step in the same time that she is taking one.

Such are the grave problems confronting us today. When all is said and done, if the appeal to invention proves fruitless, it should be remembered that the masters of the seas still have at their disposal a radical means of finishing this submarine warfare.

Stirling, Commander Yates (U. S. N.)

The submarine.—Strategy; tactics.

Proc. U. S. Naval Inst., 1917, July, vol. 43, no. 7, pp. 1386-89.

The following situation is discussed by the author: Two belligerent naval powers, each with formidable surface fleets, holding them in port, fearing in the case of the stronger, the enemy's undersea power and in the case of the weaker, the enemy's surface power. A nation weak in capital ships and therefore unable to maintain a threatening naval force upon the flank of an advancing enemy should be able to rely upon an effective submarine offensive. With mobile types a dangerous sea area can be made for an enemy, when he enters this area he will be navigating in the vicinity of numerous unchartered rocks—the submarines. If the weaker nation owns high-speed battleships, capable of tracking an enemy fleet without being brought under superior gun power, these submarines can all be concentrated upon the enemy. Tactics both for offensive and defensive are outlined.

1917—Woodhouse, H.

Submarine hunting by air craft.

Flying, 1917, May, vol. 6, no. 4, pp. 267-273.

Some months before the beginning of the great war, the British submarine A-7 was lost near Plymouth, and an airplane was employed, among other means, to find it. The airplane proved to be the most efficient means for finding the submarine. The great war was only a few months old when the revolutionary value of both submarines and aircraft became evident. As the number of both submarines and aircraft increased, their operations extended more and more, and as the submarine menace grew, the nations had to meet it, and found that the aircraft was the best weapon for hunting submarines. Sir Edward Carson reported that since the commencement of the war the British navy had examined 25,874 ships. From the beginning of the war up to Oct. 30, 1916, the British navy transported across the seas 8,000,000 troops; 9,420,000 tons of explosives and material; 47,504,000 gallons of gasoline; over a million of sick and wounded and over a million mules and horses. When it became necessary to build up a system of protection against submarines, the warring nations pressed into service thousands of small vessels, destroyers, trawlers and submarine chasers; and as fast as they could obtain them, they put into service seaplanes and dirigibles, to coöperate with the ships in locating and capturing and destroying hostile submarines; and in convoying ships, protecting them from submarine attacks.

The first report of an attack on submarines by an aircraft was issued by the German Admiralty on May 4, 1915. It stated that on May 3, a German naval dirigible fought several British submarines in the North Sea and dropped bombs on them, sinking one. The submarines, the report stated, fired on the dirigible without success. Numerous other reports of attacks on submarines and sinking of submarines were made public in 1916, mostly successes of the Allied aviators. The policy has been to capture the submarines whenever possible. The report of one of the latest cases is where two submarines were enmeshed as the result of the coöperation between aircraft and trawlers. The U-boats were detected beneath the surface by a patrol seaplane. The aviator signaled for trawlers and circled about, directing the placing of nets. Soon these were drawn completely about the unsuspecting submersibles, which were brought to the surface. Hundreds of these aircraft are employed to coöperate with destroyers, trawlers and submarine chasers in capturing or destroying hostile submarines and searching coasts for submarine bases. The usual evidence of the submarine's presence is the wake of the periscope. This wake cannot easily be seen from ships, but can always be clearly seen from airplanes. For one thing, the aviator is not troubled by the reflection of the rays of light, which interferes with the vision of the person on a ship. The aviator, flying at a height of from 1000 to 5000 feet, has a range of vision of many miles, and the whitish wake of the periscope is clearly visible against the dark surface of the waters, even in cases where the sea is fairly rough and white caps are showing. In clear weather an aviator from a height of between 1000 and 3000 feet can also see a submarine under water. In clear weather and clear water, he can see the submarine even when it is at a depth of 100 feet. The U-53 is 213 feet 3 inches long, and later ones are even larger. Such submarines present a very large track, and whereas their speed submerged is between 10 and 15 knots at most, the seaplanes, which go at a speed of up to 90 miles an hour, and even the seaplanes, which have a speed of only about 35 miles an hour, have an advantage over the submarines. If a submarine is seen under water, the aircraft, whether seaplane or dirigible, being equipped with wireless, and bombs, first send a wireless summoning destroyers, trawlers and submarine chasers. Whenever possible an opportunity is given to the trawlers or the ships which operate the nets to come up to the submarine and enmesh it in the huge net. That saves the submarine, and the crew is made prisoner. If a submarine finds itself in danger and submerges, it leaves an oily patch, which is clearly visible from the air, although far less visible from a ship. Whereas the submarine cannot launch a torpedo without getting its bearings, i. e., without showing its periscope above the water, it should be an easy matter for a seaplane to follow the course of a submerged submarine and attack it with bombs at the very moment the periscope pops out of the water. Considering that when a periscope shows the pilot has to decide how to act, and that unless the aircraft is flying low, it is hard to distinguish the features of the submarine from a height, one can well understand why even naval men in different countries have found it hard to tell whether a given submarine was one of their own or the enemy's. The only way to prevent mistakes and not let hostile submarines get away is for the commanders to give the aerial submarine hunters information regarding the movements of friendly submarines operating in the locality. Hundreds of kite balloons have been used as lookouts for submarines in the great war. When they see a submarine or a doubtful ship, they summon the seaplanes, destroyers and submarine chasers by wireless. The employment of kite balloons as lookouts releases dirigibles and ships from continuous patrol of different localities which are equally well protected through the work of the observers in the kite balloons.

NAVAL CONSULTING BOARD

OF THE UNITED STATES

OFFICE OF THE SECRETARY

ENGINEERING COUNCIL'S

WAR COMMITTEE OF TECHNICAL SOCIETIES

15 PARK ROW, NEW YORK

July 20, 1918.

TO MEMBERS OF THE TECHNICAL SOCIETIES:

The men who, at the call of patriotism and duty, have joined the colors, are not only risking their lives, but are cheerfully sacrificing their careers and in many instances their financial interests to protect the honor of the nation. It, therefore, becomes the duty of those of us who, for various reasons, are unable to enlist, to do something more than our share in keeping the machinery of industry moving.

therefore, ... are unable to enlist, ... reasons, ... in keeping the machinery of industry moving.

... fought only on land and sea, but in this conflict the combatant areas have been greatly extended by the advent of submarines, flying machines and even subterranean warfare. In previous wars the armies and navies of belligerents were practically the only forces engaged; in this war the full economic strength of nations is drawn into the contest and every branch of scientific and industrial effort is taxed to the utmost.

Intensifying production and conserving the supply of food and clothing constitute service within the reach of all, but the engineers, electricians and chemists of this country can go a step further and utilize their technical training to develop such new devices and improvements, equipment and methods as will give our Army and Navy that superiority which will assure victory.

Inventive talent in this country is by no means confined to the membership of our Societies; members who have employees or acquaintances of an originative turn of mind should make an effort to stimulate that most useful talent by passing on to such persons the bulletins as they are received, and also by calling attention to the numerous ably written articles on the mechanical phases of the war, published in technical and popular magazines.

In the world-conflict which is going on today the three dominating factors, the submarine, the automatic machine gun, and the flying machine, are all American inventions. This nation is still in its youth and can therefore be expected to do in future still greater things than it has done in the past. War is a new occupation to us, but under the stimulus and pressure of its necessity, we should advance as far in the arts of war during the next two years as we normally would in twenty.

Some of the civilian engineers of this country are now rendering great service to the Government through the agencies of the COUNCIL OF NATIONAL DEFENSE, the NAVAL CONSULTING BOARD, the NATIONAL RESEARCH COUNCIL and their numerous auxiliary committees, but unfortunately only a small proportion of the technical men of this country are so situated that they can go to Washington and engage in this service; therefore, some means of utilizing the patriotism and originative thought of our members had to be devised.

For this purpose the War Committee of Technical Societies has been organized, and it hopes to give the members of the Technical Societies who are obliged to stay at home, an opportunity to use their inventive talent and technical training in the study of the varied problems which arise in the preparation for and prosecution of the war - thus making valuable contributions to the national cause.

and prosecution of the war ... the national cause.

The ... to discover and utilize ... of value that may inhere in suggestions and inventions submitted. Not only will they receive studious examination, but when necessary, trials and experiments will be conducted. All inventions which have successfully passed the necessary examinations and tests are turned over to the particular department of the Army and Navy Service where they may be most profitably utilized.

D. W. Brunton

Chairman.

Inventions and suggestions received by the Naval Consulting Board are examined in a preliminary way by the Secretary, who is aided by the following committee of examiners:

Charles Messick—Lieutenant (j. g.), U. S. N. R. F., detailed to Secretary's office Naval Consulting Board; Member Am. Inst. Elec. Engrs.; Patent Attorney; developed and patented electrical hoisting and conveying machinery; developed and patented new methods in continuous casting of soft metal; developed and patented the combined clutch and adjustments device used on modern motorcycles, etc., etc.

G. Herbert Condict—Consulting Engineer; Member Am. Inst. Elect. Engrs.; Franklin Inst.; Member Executive Committee, American Peat Society; Past Pres. N. Y. Electrical Society. Among other activities, 1896-7, Genl. Mgr. and Chief Engr. Englewood-Chicago Electric Ry.; 1897-1902, Chief and Consulting Engineer, Electric Vehicle Co., New York and Hartford; 1903-06, Vice-Pres. and Genl. Mgr. Electro-Dynamic Co. in New York; 1906-09, Genl. Mgr. Box Electric Drill Co.

Carl K. Mac Fadden—Technical advisor of companies interested in petroleum; Member Society Naval Architects and Marine Engineers; Associate Member American Soc. Naval Engineers; Fuel Oil Expert and Consulting Engineer.

Charles E. Parsons—Consulting Engineer; B. E., Union College, 1898; 2nd Lieut. Second New York Volunteer Infantry, Spanish-American War; Chief Engineer Hudson River Water Power Co. and Atlanta Power Co., 1898 to 1913; President Ambursen Construction Co. to 1915; Vice-President Deppe Motors Corporation; Member American Society Civil Engineers; Associate Member American Institute Electrical Engineers.

Samuel E. Darby—Patent Lawyer and Expert; attended United States Naval Academy, 1882-86; Assistant Examiner and Chief Clerk U. S. Patent Office, 1886-94; Commander, 1901-03, and Captain commanding Illinois Naval Reserve, 1903-05.

Donald M. Bliss—Consulting Engineer; Chief Engineer, Holtzer-Cabot Electric Co., Designer of electric motors and special devices for battleships, navy yard and coast defense apparatus, direct and alternating current motors, 1896-1907; President, Engineering Specialty Co., 1908-09; Chief Engineer, Laboratories Thomas A. Edison, 1910-13; designed and equipped Munition Plant of Canadian Car & Foundry Co., 1914-15; Proprietor, D. M. Bliss Co., New York.

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