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Novelettes

THE BARRIER **Anthony Boucher** **9**
 If time travel is, or ever is to be possible—why haven't time-travelers appeared now? A famous detective-story author has ferreted out a solution that makes a sound and intriguing suggestion—

NERVES **Lester del Rey** **54**
 Nerves and a wild, uncontrollable atomic furnace don't blend well—unless they're steel-wire, ice-cold nerves that can stand the tension of wondering whether it's six hours or ten till the map blows up—

WITH FLAMING SWORDS **Cleve Cartmill** **109**
 They were self-designated Saints—Saints by reason of a freak a strange weapon brought about. But no Saints in their way of governing the world—

Short Stories

THE TWONKY **Lewis Padgett** **34**
 Things aren't always what they seem—particularly when the radio is actually a Twonky, and starts washing dishes and censoring reading habits—

PRIDE **Malcolm Jameson** **92**
 Old Tom was a robot—and couldn't hope for immaterial immortality, or even that he'd wear forever. But he had his pride of existence, and an answer to the problem—

STARVATION **Fredric Brown** **100**
 He was the mightiest fighter that ever lived, the giant, irresistible Tyrant-lizard King. All feared him, all ran from him—on swift, elusive little mammalian feet.

Article

DEATH UNDER THE SEA **Willy Ley** **44**
 Companion to "Bombing Is a Fine Art," this article describes the weapons that lurk beneath the sea, or run silent, invisible, to seek their prey—

Readers' Departments

THE EDITOR'S PAGE **6**

THE ANALYTICAL LABORATORY **90**
 An Analysis of Readers' Opinions.

IN TIMES TO COME **102**
 Department of Prophecy and Future Issues.

BRASS TACKS **104**
 Concerning Purely Personal Preferences.

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DEATH UNDER THE SEA

By Willy Ley

● The art of death from the air was described in a recent issue—the more efficient, though even blinder art of unseen death under the sea, takes the history of mine, torpedo and submarine back further than most realize.

Illustrated by Willy Ley

It is a tempting idea to speculate how naval warfare of today would look if Robert Fulton had not lived. For Robert Fulton may be held responsible for more than half of all modern naval weapons. This statement may sound a bit surprising to all those to whom Fulton's name is just the name of the inventor of the steamship, but it is nevertheless true.

Of course there can be no doubt that Robert Fulton's fame in our time is based mainly on the *Clermont*, the first American steamship which began to ply the Hudson between New York and Albany in 1807. Incidentally, the *Clermont* was not, as one can read occasionally, the very first steamboat ever built. Fulton himself had demonstrated an earlier version to the Parisians in 1803. While the demonstration had been successful in itself, it had failed to convince anybody of the value of engine power aboard ship—even the *Clermont* needed quite some time to break down the inertia of thousands of years of sailing tradition.

When residing in France Fulton had also invented and built a successful small submarine, the *Nautilus*, which swam and dived in the River Seine without any mishap. The propelling power for that boat was muscular power, of course. Fulton had been quick to realize the military value of submarines and had offered vessels of the type of his *Nautilus* to the first consul of the French Republic, a gentleman by the name of Napoleon Buonaparte. But the first consul—who hated the Italian "u" in his last name—had rejected the offer. It was not because he doubted that larger and seaworthy submarines could be built. Napoleon rarely doubted the possibility of any invention as long as the inventor could tell in reasonably clear terms what he wanted to do and how he wanted to do it. Napoleon was one of the least conservative men of his time, a man who offered and paid large sums of money to early chemists who made sugar from sugar beets instead of sugar cane that would not grow in France, he

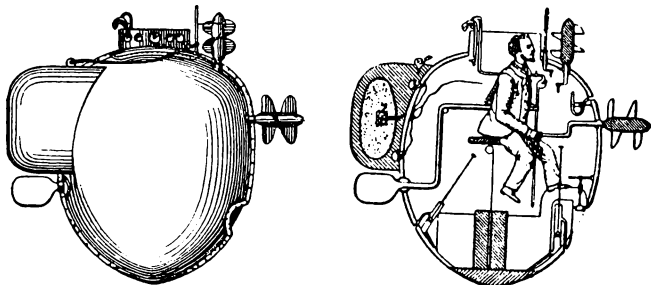
was one of the first men who wanted to build a tunnel *sous la Manche*, under the English Channel from Calais to Dover when his political relations with England were still good—Napoleon, as I said, did not doubt that submarines could be built. But he was a soldier educated in the tradition of open battle, he wanted to face an open enemy openly, with the bigger cannon on his side. He simply did not like submarines.

Having been rejected, Fulton went to England, only to experience a British version of the same rebuttal. He then hinted at French invasion plans and devised a barrage of submerged contact mines. It was "no" again. Back in his native America he advocated a variety of torpedo and got so far as to have a test arranged. But, as Fulton pointed out, the commander of the vessel to be torpedoed knew what Fulton was going to do—and when he was going to do it—while he himself was left in ignorance about the defenses of the vessel. The obvious result was that the test did not come off so very well.

Judging from all this one might be tempted to say that without Fulton there would be no steam-propelled surface navy, no submarines and consequently no depth charges, no mines and, therefore, no mine layers and mine sweepers, no torpedoes and, of course, no torpedo-carrying vessels.

As a matter of fact the difference would hardly amount to anything. Somebody else would have thought of putting a steam engine aboard a vessel. Somebody else would have conceived the naval mine—in fact most of the later designers of naval mines never knew that Robert Fulton had toyed with that idea—and submarines had been invented before Fulton and were again invented after him.

Still, the person of Robert Fulton is something like a focal point. Earlier half-forgotten ideas were taken up by him and advanced, new ideas formed constantly in his imaginative brain and even though many of the later inventors of naval



BUSHNELL'S SUBMARINE.

Fig. 1. The first war-time submarine—a real, one-man job, where the man did all the work of propelling, pumping and controlling.

weapons knew Fulton only as the inventor of the steamship and as the inventor of some peaceful machinery for spinning and weaving, the history of their ideas converges on Fulton's name in retrospect.

As for the submarine, only two successful attempts had been made before Fulton constructed his *Nautilus*. Disregarding some obviously fantastic claims, the honor of having invented the first successful submarine goes to a Dutchman by the name of Cornelis van Drebbel, often called Cornelius Drebbel. It was a weighed rowboat, covered with leather and propelled by oars projecting from leather cones. One of his boats, built in 1622, is said to have carried several passengers, among them King James I, from London to Greenwich at an average depth of ten to fifteen feet, traveling "fast," since it was propelled by twelve experienced rowers.

The other successful attempt was David Bushnell's *Turtle*, so called because it looked as if it had been put together from the carapaces of two enormous turtles. It seated one man who could make it sink by admitting water to the bottom compartment and who lorded over an impressive array of handles and hand wheels. One of them operated a pump which was to eject ballast water, the other moved a rudder, one turned a horizontal and another a vertical propeller and one finally operated a screw by means of which a cannon powder demolition charge was to be attached to the wooden hull of an enemy warship below the water line. The *Turtle* had been designed to help win the Revolutionary War and it was consequently employed to attack the British fleet which block-

aded New York Harbor. The attack took place in 1777. The *Turtle*, manned by Sergeant Ezra Lee, was towed by a rowboat beyond Governor's Island under the cover of darkness, submerged and attacked one of the British men-of-war. It seems that Ezra Lee picked a spot where solid iron bracings held the rudder of the vessel in place—he could not see when submerged—at any event his screw failed to bite, the incoming tide tried to sweep the *Turtle* away and after some twenty minutes the air got so bad that Lee had to come to the surface. It was light enough to see clearly by then; he had to flee and abandon the mine which exploded harmlessly in the middle of the harbor. But Lee and the *Turtle* got away, David Bushnell's first and only submarine was later sunk ingloriously while aboard a ship which was to transport it elsewhere for another attempt at warlike action.

I do not know how the charge carried by the *Turtle* was called, nor whether Bushnell, Lee or anybody else went to the trouble of inventing a special name for it. The man who coined a name for underwater charges was Robert Fulton. His term was "torpedo" which then did not mean a weapon of naval warfare but simply the electric eel of South American rivers. It seems, however, that this name took hold in America only for quite a number of decades to come. Farragut, in the battle of Mobile Bay, ordered his captains to "damn the torpedoes!"—moored mines, in our terminology—but British writers were more likely to speak of "infernal machines" when referring to mines. The term "mine" seems to have originated with German writers who compared the submerged explosive charge to the buried explo-

sive charge of land warfare. And since the buried explosive charge could be placed under the position of the enemy only by a kind of mining operation it had been referred to as a mine since about 1500.

It is hard to say who really invented the naval mine—historians of warfare have agreed to confer this honor upon an Italian, Federigo Gianibelli of Mantua. The year of the invention was the year 1585 and the place the city of Antwerp.

The Netherlands were under enemy occupation then, fighting for her life against Spain. The city of Antwerp was still holding out, getting supplies by means of ships sailing up the Schelde River right into the city and right under the noses of the Spaniards. Antwerp, it seems, could pay well for any kind of war risk. Finally the Duke of Parma decided to put a stop to this "smuggling" and had a sturdy bridge built across the wide river. It was a masterpiece of engineering for its time, twenty-four hundred feet long, with a fort at each end and protected by one hundred and seventy big guns, not counting the batteries on the war vessels stationed next to the bridge. Heavy floating rafts were anchored above and below the bridge for additional protection, "one bow-shot away," as the old descriptions say.

The Antwerpens knew that they had either to starve and surrender or to destroy the bridge, and plans for an enormous vessel, designed to carry one thousand soldiers for a mighty assault, were drawn up. Then Gianibelli came with a plan of his own. He was at first refused, but then given two small vessels, of sixty and seventy tons respectively, named *Fortune* and *Hope*.

Gianibelli proceeded quickly to have them converted into what later was called a Demon Ship. A solid floor of masonry was placed along the bottom of the ships. On that floor he built the "crater," a box of masonry forty feet long, three and one half feet high by three and one half feet wide. The walls were five feet thick. The "crater" was then packed with cannon powder and covered by a six-foot roof, consisting of tombstones placed on edge. The space between the masonry box and the hull of the ships was filled with cannon balls, old chains, stones, marble slabs and anything heavy that came to hand. Then the whole was floored over and some wood was heaped on the deck.

In March, 1585, everything was ready for the attack. A large number of small vessels, heaped with dry wood and set afire, was sent drifting down the river, the Spaniards were to believe that the Antwerpens wanted to set their bridge afire. They did believe it and were greatly amused by the idea; laughing and joking, they roved to the burning vessels, boarded them and pulled the fires apart. Then the *Fortune* drifted down, with

a small fire blazing on her top deck and a slow fuse burning inside to fire the "crater." She ran aground, the Spaniards boarded her and extinguished the fire. Nothing else happened, the fuse must have gone out earlier. Finally the *Hope* came drifting down, also with a small fire on her deck, but with a clockwork mechanism instead of a slow fuse.

She ran into the bridge near one shore and was boarded. Soldiers busily pulled the glowing embers apart and threw them overboard into the river when the clockwork struck the spark that was to ignite the "crater." It did—in one enormous flash the *Hope*, the soldiers who had boarded her, several vessels surrounding her, one of the two bridge garrisons and fully half of the bridge disappeared. The bottom of the river was dry for a moment, then the water rushed in and swept splinters and corpses away. The bridge was destroyed, a thousand enemies killed in one instant.

If the Dutch had attacked as planned, they would have won—but their admiral, Jacobzoon by name, was frightened himself and did not issue any orders. Some time later Antwerp fell, but Gianibelli had meanwhile disappeared. It was later learned that Queen Elizabeth had called him to London. What he actually did is not known, but the Spanish armada lived in constant fear of the Demon Ships and once a part of it was destroyed because it ran away from small burning but otherwise harmless vessels—having been deliberately fooled into believing that they were Demon Ships.

The *Hope* is now classified as what it was, a gigantic floating mine, a weapon that is by no means obsolete as the British proved when they ran the explosive-laden old United States destroyer, *Campbeltown*, into the lock gates at St. Nazaire.

The first stationary—moored—naval mines did not appear until about three hundred and fifty years after Gianibelli's exploit. They were sown in the waters of the Black Sea during the Crimean War and they harassed the movements of the British fleet blockading Kronstadt, the harbor of St. Petersburg—now Leningrad.

Little is known about the mines used in the Black Sea, except that they caused no important damage since they were treated with the utmost respect by both sides. The Kronstadt mines did not do any better as far as effectiveness is concerned but the more important details of their construction have been preserved by a British naval officer whose account was published in William F. Williams' "England's Battles by Sea and Land," which was published in 1856. Referring to them as "infernal machines," the officer wrote:

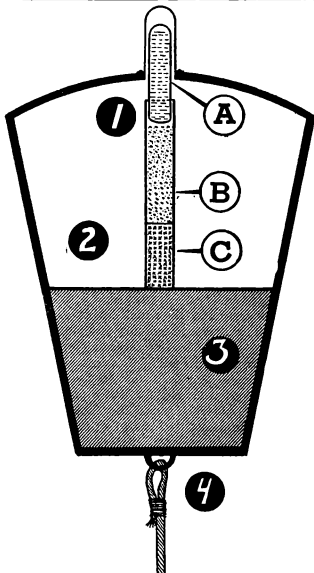
Each machine consists of a cone of galvanized iron, sixteen inches in diameter at the base, and twenty inches from base to apex, and is divided into three chambers;

the one near the base being largest and containing air, causes it to float with the base uppermost. In the center of this chamber is another which holds a tube with a fuse in it, and an apparatus for firing it. This consists of two little iron rods, which move in guides, and are kept projected over the side of the base by springs which press them outward. When anything pushes either of these rods inward, it strikes against a lever which moves like a pendulum, in the fuse tube, and the lower end of the lever bends or breaks a small leaden tube, containing a combustible compound, which is set on fire by coming in contact with some sulphuric acid held in the capillary tube, which is broken at the same time, and so fires the fuse which communicates with the powder—about nine or ten pounds—contained in the chamber at the apex of the cone. At the extreme apex is a brass ring, which is attached to a rope and some pieces of granite, which moors them about nine or ten feet below the surface—

These submerged mines were probably regarded mainly as a curiosity, something some Russians had dreamed up during long winter evenings but something that was not to be feared very much as a weapon of war, especially since the experiences of the campaign had shown that they did little damage.

This idea was to undergo a fairly sudden and quite complete revision some ten years later, when the American Civil War came. The Confederates soon noticed to their dismay that they were extremely vulnerable against naval attack. The Confederacy had not a single real warship of its own, but many of its important cities were either directly at the shore or situated not far from the shore on large and deep rivers. A Federal warship could have sailed up the James River right into the heart of Richmond. Something had to be done about it and it had to be done quickly. Submerged mines were suggested by literally scores of people and the suggestion was finally adopted. While the first Confederate mines resembled the Russian Kronstadt mines in outward appearance their design was new—in fact Confederate engineers hurriedly invented the prototypes of most modern naval mines in existence.

Their mines consisted of a truncated cone, made of one-half-inch boiler plate or any other heavy sheet metal that came to hand. The lower half of the inverted cone was filled with cannon powder, the upper half left empty to provide buoyancy. Through the center of the air space a thin-walled tube was inserted, its lower half filled with fine-grain rifle powder, its upper half with a mixture of powdered sugar and chlorate of potassium. On top of that mixture a glass tube containing concentrated sulphuric acid was mounted; it projected through a hole in the cover to the outside. For protection this glass tube was surrounded by a sheath of copper or lead. Some of the later designs had four or five such "horns," jutting out at various angles. When a ship's bottom hit the mine which was moored under water like the Russian mines, it bent the



Early naval mine, designed by the Confederates during the Civil War.

1. Delayed action fuse.
2. Air space for buoyancy.
3. Demolition charge of cannon powder.
4. Mooring cable.

Detail of fuse: A. Glass tube filled with concentrated sulphuric acid. B. Mixture of chlorate of potassium and powder sugar. C. Fine grain gunpowder.

leaden horn, breaking the glass tube. The sulphuric acid flowed out, dripped into the mixture of chlorate of potassium and powdered sugar and caused a chemical reaction generating enough heat to ignite the fine-grained powder. This, in turn, set off the cannon-powder charge.

But these automatic or contact mines had a big drawback. They would explode indiscriminately when rammed by a ship, not waiting to see whether it was an enemy or a friendly vessel. Consequently the Confederates set out to construct "observation" or controlled mines, mines which would be exploded from an observation post ashore. The

first attempt consisted of a moored mine with a friction primer.

To explode the mine somebody had to jerk a line from the shore. That arrangement worked fairly well during experimental tests, but poorly under normal conditions, i. e., with a line longer than about twenty yards. There was no other solution than electric ignition and an officer with some specialized knowledge, Lieutenant Hunter Davidson, was put in charge of the work. He soon found out that he was severely handicapped by lack of raw materials. After scraping all useful supplies in the Confederacy together he had a little less than four miles of insulated copper wire and four or five feet of thin platinum wire. And all the acids—for the batteries—that could be had were those in stock in local apothecaries' stores.

The electric fuse developed by Lieutenant Davidson consisted of a half-inch goose quill, filled with fulminate of mercury and plugged with beeswax at both ends after threading a fine platinum wire through the quill. The ends of the platinum wire were then connected to the end of insulated copper wire and the whole placed inside a red flannel cartridge cloth bag filled with rifle powder. The demolition charge of the mine consisted of cannon powder, incased in the usual cone of half-inch boiler plate.

The first three of the new electric mines had to be given up. They had been placed in the Rappahannock River, but a Negro had informed the Federals about their location. Two others, each containing a full one thousand pounds of cannon powder were placed in the James River and one of them almost destroyed a Federal gunboat. It failed to do so only because the watcher was nervous and exploded the mine when the gunboat was still ninety feet away. The water-spout was enormous, it smashed the guards of the gunboat and washed six men overboard. The captain turned his ship around, picked up his men and proceeded down river, passing over the second mine—but the watcher had unwittingly emulated Admiral Jacobson and had run away, overawed by the explosion.

Some time later, a Federal warship was actually sunk by an electric two-thousand-pound mine, the first warship ever to be destroyed by the new weapon. The sinking occurred at Deep Bottom in the James River, sixty of the crew of two hundred were killed by the explosion or drowned.

When the British fleet blockaded Kronstadt, wondering about the Russian mines and whether they would work or not, another danger seemed to be getting ready inside that harbor. Years before, a Bavarian by the name of Wilhelm Bauer, a low-ranking noncommissioned officer of a regiment of artillery, had built a small hand-powered

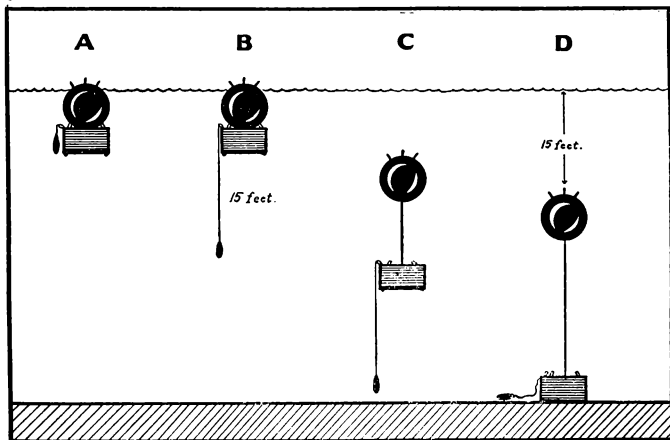
submarine. During its first test run it had sunk in the harbor of Kiel, but every expert knew that that had happened because a commission of "economy experts" had forced him to use boiler plate half as thick as he had planned and had greatly "simplified" the design. Now this man Bauer had been hired by the Russian Grand Duke Aleksandr to build him a much larger submarine. Money did not matter; he might be successful this time. He was; his second submarine made more than one hundred and fifty successful underwater runs, but it did not see any action. The British did not experience a submarine attack then, which would have been the second in the history of their navy.

But submarines did play a role in the Civil War. And the weapon they used was rather odd; it is now known as a spar torpedo. It consisted of a copper cylinder, holding some ninety pounds of cannon powder, and fastened to the end of a long spar or boom. Like the modern torpedo it was used by two types of craft, by true submarines and by small surface craft.

At first the Confederates had put some trust in a so-called line torpedo, a contact mine towed behind the submarine on a three-hundred-yard line. The theory was that the submarine would approach the enemy surfaced, then dive under the enemy vessel and surface again, so that the towed mine would strike the vessel on the side away from the submarine. It worked that way during tests on a smooth inland lake, but proved too dangerous to the submarine in the choppy water of the open sea. The spar torpedo was then substituted for the line torpedo.

Since the submarines of the Confederacy proved very dangerous to their own crews—the first of them had to be scuttled in the Bayou St. John, the second had foundered in Mobile Bay when a sudden squall blew up and the third, the *Hunley*, had drowned thirty-five men in five sinkings before seeing its first and final action—the spar torpedoes were used from small surface craft first. There were the so-called *Davids*, small steam-propelled craft with hardly any freeboard, carrying a spar torpedo in front. Ordinarily the spar torpedo was raised out of the water to prevent accidental explosion from striking driftwood, it was lowered into the water immediately before striking the target.

The first *David* attacked the Federal ironclad *New Ironsides* with a sixty-pound spar torpedo in the late evening of October 5, 1863. Lieutenant Glassell, the commander of the vessel, steamed far out to approach his victim from seaward. This method worked, when it was sighted by the lookouts on the *New Ironsides* it was already too close for the big guns of the ironclad. A few musket shots were fired in a hurry, then



The laying of a barrage mine progresses in four (automatic) steps. A. The mine, having just been dumped overboard by the mine-laying vessels, floats at the surface. B. The plummet begins to unreel until its line has attained the length for which it has been set, in this case fifteen feet. C. As soon as the plummet line has reached full length, the box anchor begins to sink, meanwhile unreeling the mooring cable. D. When the plummet touches the bottom, the winch of the mooring cable is arrested. Box anchor sinks to the bottom, dragging the mine below the surface. This way a certain depth for the mine is insured, its depth below the surface is the same as the length of the plummet line.

the torpedo touched. But the *New Ironsides* suffered only negligible damage, she was too powerful to be ruined by sixty pounds of weak gunpowder. The crew of the *David* was thrown overboard by the explosion, or jumped and generally gave their own vessel up as lost. One of the men clambered up on the *New Ironsides* and was taken prisoner. The commander was picked up by a Northern coal schooner and suffered the same fate. The machinist swam around in the dark for quite some time and found, finally, to his great surprise, the *David* still afloat, with the pilot, who could not swim, desperately clinging to the gunwale. Together the two men got the engine working and took the *David* back to Charleston. Eight more *David*s were built, but did not see action.

In February, 1864, the third Confederate submarine, the *Hunley*, was at last ready for action. It attacked the Union fleet on February 17th, picking the corvette *Housatonic* as its victim. Because of the bad record of the *Hunley* the crew was apparently scared to dive and attacked in an awash position, with hatches open. The *Housatonic* sank—first warship to be destroyed by a

submarine—but since the water was only twenty-eight feet deep at that spot most of the crew saved themselves by climbing into the rigging. The *Hunley* sank with all hands aboard. Divers later found the submarine one hundred feet from the wreck of the *Housatonic*, without apparent damage.

Not all attacks with spar torpedoes were as suicidal. In October, 1864, Lieutenant Cushing "torpedoed" the Confederate ironclad *Albatross* by means of a steam launch on the Roanoke River. The ironclad was surrounded with floating logs for just such an attack, but Lieutenant Cushing managed to break through. The *Albatross* and the steam launch sank, but Lieutenant Cushing saved himself by jumping overboard in time and swimming to the shore.

When the Civil War was over and war experts had examined all the data carefully and at leisure the results amounted to a confirmation of Fulton's early dreams. Submarines were feasible, and so were mine barrages. So was the spar torpedo, also advocated by Fulton—but it was too sui-

cidal. What had to be done was to improve on mines, build submarines that were safe to use and invent a torpedo that would have motive power of its own.

It was the last problem that was attacked first. Numerous types were invented, some of them containing electric motors, some being made heavier than water and suspended by ten-foot chains from a small surface float which housed the engine. All of them had to trail wires for power and for control; wires which fouled or became short-circuited with annoying regularity. Even when everything worked as anticipated the speeds obtained were too slow. The American navy spent much time and money on experiments with the so-called Howell torpedo, the motive power of which consisted of a heavy steel flywheel mounted inside. The flywheel was made to rotate rapidly by outside power; its axle was then connected with the drive shaft of the propeller immediately before launching. It was an ingenious solution of the power problem, but the flywheel could not store enough energy. And in the meantime the torpedo of today, the Whitehead torpedo, had been invented.

The Whitehead torpedo is a complete small submarine, carrying a large charge of high explosive in its head. One may say that it is a "Demon Ship," reduced in size and converted into a submarine. To conceive the Whitehead torpedo one had to imagine a model submarine, launched bodily at the enemy. The father of this idea, it is said, is the Austrian Captain Luppis. And it is all too likely that Luppis took his cue from Wilhelm Bauer.

Before Bauer was called by Grand Duke Alexander he had tried to sell his submarine to England, to France and to Austria, traveling around with a working model five or six feet long. He had demonstrated this model to the emperor of Austria in the Adriatic Sea, a demonstration which was highly successful but without consequences. It is probable that Captain Luppis witnessed the demonstration, or heard about it from a witness. Being anything but a mechanic himself, he approached the manager of an engineering firm in Fiume, a Scotsman by the name of Robert Whitehead.

Whitehead was interested and went to work on a model, having only his son and one workman helping him, to insure secrecy. For this reason it took over two years until the first Whitehead torpedo was finished (1865). It weighed about three hundred pounds, carried a charge of eighteen pounds and moved all of six m. p. h. But it worked and increasing size and speed was only a question of time.

At first two standard sizes were adopted by most navies, the fourteen-inch and the eighteen-inch torpedoes. The smaller type weighed a little more

than seven hundred pounds, carried a charge of one hundred fifteen pounds of guncotton and made thirty knots for the first six hundred yards of its run. The larger variety weighed one thousand one hundred fifty pounds, carried a charge of one hundred thirty-three pounds and ran twenty-nine knots over the first nine hundred yards.

There are still two sizes of torpedoes in use, the naval torpedo and the airplane torpedo, the latter being dropped by torpedo-carrying airplanes and fired by "pocket submarines" or very small surface craft. The naval type is about eighteen feet long and has a diameter of twenty-one inches, the high-explosive charge consists of five hundred pounds of TNT, the speed is officially given as thirty-six m. p. h., but seems to be above forty m. p. h. While the full range exceeds eight thousand yards, that accuracy is poor above two thousand yards. The dimensions of the smaller airplane torpedoes are secret, but a British aviation magazine published those of the German variety. They have a diameter of eighteen inches, weigh fifteen hundred pounds and carry a charge of four hundred ten pounds. The range was found to be only two thousand yards, the speed "high." The weight and size reduction has been accomplished, therefore, mainly at the expense of the machinery, only to a small extent at the expense of the demolition charge.

All modern torpedoes consist of two parts: the "model submarine" and the "head." The latter comes in three varieties. One is the war head, consisting of the high-explosive charge and a device called the "pistol" which fires that charge. This is the head for actual combat use. For practice firing there are two types of heads. If it is the machinery of the torpedo that is to be tested, a "blowing head" is attached to it. It is filled with enough water to make it weigh as much as a war head. When the torpedo has run out of power, a small flask of compressed air forces the water out of the head so that the torpedo floats to the surface and can be picked up. If the torpedo is fired for target practice, it is fitted with a "collision head," designed to absorb the shock of the impact.

The submarine part of the torpedo is completely taken up by fuel containers and machinery. The engine consumes a mixture of fuel oil vapor and compressed air, augmented by a thin jet of water which is converted into live steam and thus increases the bulk of the combustion gases. There are two screws rotating in opposite directions to eliminate torque, there are horizontal and vertical stabilizing vanes and rudders, there are gyro mechanisms for maintaining the course and the depth for which the torpedo has been set, the latter varying from about five to about thirty feet. But submarines can fire torpedoes when at a depth of

seventy-five feet below the surface and airplanes drop their torpedoes from fifty to one hundred feet above the surface—the torpedoes rise or sink automatically to the depth for which their mechanism has been adjusted.

By the time these torpedoes were fully developed the first modern submarines were ready to use them. The Davids had been re-created as torpedo boats and, somewhat incidentally, mines had been modernized. Then the Russo-Japanese War came with plenty of naval action. And after it was over and the heavy ship losses sustained by both sides had been tabulated as to causes, everybody was greatly surprised to see that no ship had been sunk by torpedo hits, but that many had succumbed to mines.*

Evidently mines were worth more than anybody had thought—and this realization had two widely divergent results. One consisted simply and plainly in increased activity of the proper sections in the various navy departments. The other consisted in thirteen articles drawn up at the Second Hague Conference in 1907 which all but outlawed naval mines. Mines were not to be laid in waters where they might harm neutral shipping, mines were not to be laid off the enemy's coast for the purpose of intercepting purely commercial shipping, et cetera, et cetera. That convention had precisely the same effect as any too severe law, nobody tried any too hard to obey it knowing that nobody else would. In fact, the first German ship loss during the first World War was the converted mine-layer *Königin Luise*, caught while mining British waters and not long after the Germans lost a vessel which ran into a British mine in German waters.

Generally speaking, however, the British admiralty was caught napping as far as mines were concerned. They had only small stores—some twenty thousand or so—and most of them had to be swept up again after they had been laid, being found unreliable and defective. American productive capacity saved the day, and American productive capacity resulted in the largest single job of mine laying ever done: the Great North Sea Barrage. But first another invention had to be made.

The improvements of mines made since the time Confederate engineers invented their "torpedoes" hurriedly, concerned mainly two things—manufacture and method of mooring. The spherical shell had been adopted generally, with a separate cylindrical charge fitted inside, thus providing buoyancy space. The mooring had been greatly improved, mines adjusted themselves auto-

matically to any depth of water within wide limits. This was accomplished by designing a box anchor with a separate small weight, called plummet, and an automatic winch inside the box. The plummet line was "set" for a certain depth, say fifteen feet, then the whole mine was thrown overboard. For a moment it floated at the surface while the plummet line ran out to the full length for which it had been set. Then the weight of the plummet released the catch of the winch, the mooring cable was payed out and the box anchor, with the plummet line dangling down from it, began to sink. As soon as the plummet touched bottom, the winch was arrested, the heavy box anchor, sinking to the bottom of necessity pulled the mine down, to precisely the same depth as the original length of the plummet line.

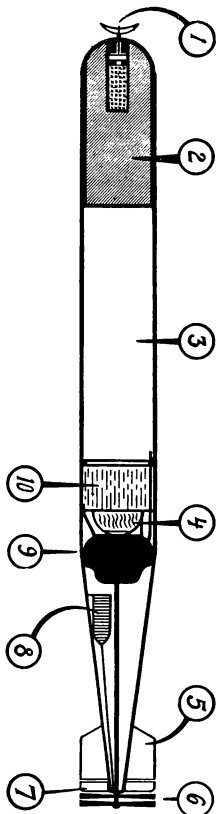
Little changes had been made in the fuse mechanism, however. There were still the two types used during the Civil War; the one ignited electrically by an observer and the other with horns, exploding when a vessel bent the horn. A safety mechanism had been added in the form of a hydrostatic switch, the mine could explode only when water pressure forced that switch inward.

What was lacking was a large radius of action. The explosion of three hundred pounds of TNT would push the hull of a vessel in, even when the vessel was fifteen or twenty feet away. But the mine did not respond to a vessel that did not touch it directly. This meant that mines had to be laid very densely to close a waterway effectively. The British had mined the Channel with fair success, but there existed a plan of closing the North Sea in the North, too, by means of a barrage stretching from Scotland to Norway. The Channel barrage was some twenty miles long, the Scotland-Norway barrage would be two hundred fifty miles long, requiring roughly a thousand mines per mile to be sufficiently dense for surface craft and U-boats alike.

It was then that Ralph Cowan Browne of Salem, Massachusetts, invented a new type of mine. He took an ordinary barrage mine with horns and added two things: an electric detonator and a thin copper cable, adjustable like the plummet line, but with a hollow copper float at its end, instead of a solid leaden plummet. Thus a copper wire extended upward from the mine—and when an iron hull touched the copper wire in the salt solution called sea water it was precisely the right electrochemical combination for the electric detonator to work on. The antenna, as it was called, increased the danger orbit of each mine from three to thirty feet; the mining of the North Sea could be begun.

Nine thousand five hundred mines, laid in twenty parallel rows, were used to block the Channel again; simultaneously the British began to mine the area east of the Orkney Islands and Scapa

*Even today the tabulations of the causes of ship sinkings show figures different from what might be expected. Of the first eight hundred ships sunk in the present war submarines accounted for two hundred twenty, mines for about one hundred eighty, airplanes—both bombs and torpedoes—for about one hundred, surface craft for the remainder.



21-inch Whitehead Torpedo With War Head.

Length: 18 feet.

- (1) "Pistol" consisting of a plunger which, on impact, fires a percussion cap. The percussion cap fires the priming charge, which in turn sets off (2) 500 pounds of TNT. (3) Container for compressed air. (4) Container for fuel oil. (5) Stabilizer vanes. (6) Twin propeller rotating in opposite directions. (7) Rudders. (8) Steering and depth-setting gear. (9) Combustion chamber, air and engine. (10) Container for water.

Flow, leaving only a carefully watched ten-mile channel near the islands, for the emergency use of the Grand Fleet. Pushing eastward from that area the United States navy laid fifty-six thousand six hundred eleven mines in a sector one hundred thirty miles in length, the final gap east of that sector was closed by the Royal and the United States navies in collaboration. The British total in that barrage was fifteen thousand ninety-three mines, but most of them were of American manufacture. The more difficult job, brilliantly executed throughout, was the removal of those mines after the war was over, not the laying.*

It is not very well known that mine sweeping is a Russian invention. When the waters of the Black Sea were infested with mines during the Crimean War the Russians dispatched small vessels to drag weighed lines through the water. The lines were to break the mines from their moorings so that they could be destroyed by means of rifle fire. This method was then regarded as a makeshift, especially because of the loss of some of the mine-sweeping vessels. But when the Federals had to clean up rivers in which Confederate mines were hidden they could not think of a better way and the method is still essentially the same. The only major change occurred when Lieutenant Commander Sir C. D. Burney, R. N., invented the paravane in 1916, enabling single vessels—instead of pairs—to sweep for mines.

Looking like a ten-foot model of a strange airplane with stubby wings, the paravane stays away from the ship and at a predetermined depth when being towed. The towing cable engages the mooring cable of the mine and guides it into a cutting blade. Released mines, which float to the surface, are then disposed of by rifle and machine-gun fire. Antenna mines are, incidentally, much easier to sweep, when the steel cable touches the copper antenna they simply blow up.

Since the Great North Sea Barrage was laid down and taken up again a few new types of mines have made their appearance. One of them is a free floating type, the "legitimate use" of which is to be thrown into its wake by a fleeing vessel so that the pursuers may run into it. Such mines are to be designed in such a way that they

* The western sector of the North Sea Barrage, beginning ten miles east of the Orkneys and extending fifty miles eastward from that line, consisted of nine lines of United States mines dangerous to surface craft and to submarines at periscope depth, three lines of United States mines at one hundred sixty feet and three lines of United States mines at two hundred forty feet, all with long antennae giving them a danger orbit of some severity feet. The center sector was one hundred thirty miles long and consisted of one line of British mines dangerous to surface craft, one line of British mines at ninety feet, eight lines of United States mines dangerous to surface craft and to submarines at periscope depth and four more lines of United States mines, two at one hundred sixty feet and two at two hundred forty feet with sixty-foot antennae. The eastern sector near the Norwegian coast was sixty miles long and consisted of eight lines of British mines, two each at fifteen, sixty-five, ninety-five and one hundred twenty-five feet, reinforced by four lines of antenna mines of United States make near the surface. To make sure that the center and the eastern sectors touch, six lines of antenna mines were laid over the junction where a mistake in ascertaining position might have caused a gap.

stay afloat for only one hour and then become harmless. The special variety I have in mind here was invented by the Swedish captain, Karl Iskar Leon. It consists of a steel cylinder with the TNT charge, fitted with a contact fuse, a hydrostatic switch, a small electric motor, an electric battery and a small propeller. It swims, or rather sinks, in a vertical position, with the propeller at its base. Upon reaching a certain depth the hydrostatic switch closes the circuit, the propeller begins to turn and pushes the mine to the surface. There the circuit is broken, the mine sinks again and the cycle starts anew, until the battery is exhausted.

Another new type of mine, which received much publicity, was the German magnetic mine, sown by means of parachutes from airplanes into the shallow waters of English rivers and estuaries. These mines were shaped like airplane bombs, made entirely of nonmagnetic metals—mainly aluminum—and weighed twelve hundred pounds, with a high-explosive charge of six hundred sixty pounds or three hundred kilograms. The diameter was about two feet, the length eight feet, dimensions obviously chosen to make the mines fit into the attachments of torpedo-carrying airplanes. Being heavier than water they sank to the bottom. The usual hydrostatic switch made them stay harmless as long as they were subjected to atmospheric pressure only. This is the reason why their construction is known: Commander J. G. D. Ouvry of *HMS Vernon* succeeded in taking one that had dropped on the bank of a river apart without being blown to pieces.*

Misled by the term "magnetic mine," some writers told fanciful tales how these mines rise from the bottom mud and follow iron ships, being attracted by their hulls and machinery. Actually nothing of the sort happens. The name refers only to the detonating mechanism which responds to the magnetic field created by a large mass of iron and explodes the charge when that field reaches a certain intensity. Once this was known it was easy to find remedies doing both,

*As a kind of "reprisal action" the German radio announced soon after that *HMS Vernon* had been sunk by a German submarine or a German mine. This was decidedly peculiar, inasmuch as *HMS Vernon* is not the name of a ship. It is the name of the Mine School, the division for mine warfare of the Royal Navy.

exploding the mines at will and protecting the ships. The first was accomplished by towing powerful electromagnets on floats behind wooden ships. The second was done with the so-called degaussing belt, a device creating an artificial counterfield to neutralize the natural magnetic field of the vessel.

The Germans, thereupon, discontinued the use of magnetic mines and substituted acoustic mines, with a detonating mechanism sensitive to the sound of a ship's engines. So far their construction has not been revealed but it has been reported that these mines are as easy to deal with as magnetic mines.

This article would be incomplete, however, if one naval weapon were not mentioned which is closely related to the naval mine: the depth charge. When Robert Fulton built his *Nautilus* and designed his "torpedoes" he failed to conceive a weapon which would be useful to combat enemy undersea craft. It is possible that he doubted there could be such a weapon—many naval experts wondered just what could be used against a submerged submarine.

The answer was simple: a mine. A barrage mine when a passage was to be blocked to submarines—the North Sea Barrage accounted for about a dozen known—and a free mine when a sub was caught on the high seas. Not a floating mine, of course, but a sinking mine, a mine without air space for buoyancy and with a hydrostatic switch that was coupled with the fuse mechanism to explode the mine at or near the suspected depth of the submarine. Since water is to all intents and purposes incompressible, any explosion under water assumes the character of a sudden and irresistible "squeeze." It works on the water, too, of course, but unlike the hull of a submarine, water cannot be squeezed effectively.

This goes for all explosions occurring under water and it is the reason why torpedoes and mines of all types are so potent and why a very close miss of an airplane bomb or an artillery shell might cause more severe damage than a direct hit. The direct hit may blow off a deck, damage superstructure and annoy the crew; the near miss, its pressure transmitted by the incompressible water, is apt to stave in the sides below the water line.

THE END.

