Incubation Period

Herodotus recounts the feats of a family of divers in the fifth century B. C. and of a statue of gold erected to Scyllias and his daughter, Cyana, at one of the Temples of Delphi. The legend was told that they could cover a distance of one mile underwater and were most celebrated for cutting the mooring cables of Xerxes' ships. As a result of these undersea tactics, the ships were swept ashore by a gale and smashed against the rocks.

Legend also has it that Alexander the Great, or Alexander of Macedon (356-323 BC), was lowered by chains in a large glass barrel to "see what was there and to defy the whale" (Figure 7). Alexander saw a fish so large that it took three days to swim past him -- although it was moving as swiftly as a flash of lightning. (In other words, this fish was about 48 billion miles long! More credible is the record that Alexander used divers at the siege of Tyre in 334 BC, as described by Aristotle in Problems. It is definitely known that Alexander's army contained a group of divers equipped with breathing apparatus. Also plausible is the statement that Alexander used naked divers to repair a break in the hull of one of his ships that ran aground by "pulling air from the surface through reeds" (like a Snorkel submarine).

During the siege of Syracuse, Thucydides says specialized divers cut stakes that were used in defense of the harbor mouth. This same technique was used some 2,000 years later by frogmen during World War II on the shores of Normandy.

In 305 BC, during the siege of Rhodes by Demetrius of Poliorcete, an iron navy ship called the SEA TURTLE was used for military purposes. It is reported to have been covered "with iron plates or strips to withstand the fire bombs."

Livy gives considerable information about Rhodian divers (approximately 180 BC) and says they were given half the booty brought back from a depth of 25 feet, 30 percent of that from 12 feet, and only 10 percent of that from depths of less than 3 feet.

Bohaddin, an Arabian historian of the twelfth century, briefly mentions that a diver with some type of breathing device called a "bellows" mounted on his back, was used to get an important message into Ptolemais when that city was besieged by the crusaders. This appears to have been an early version of the aqualung.

Figure 7. A thirteenth-century French manuscript shows Alexander the Great in a glass diving bell (Art by Ken Hodges).

In his novel, New Atlantis, Roger Bacon described a people with the art of constructing underwater ships and predicted the use of "instruments wherewith men may walk on the bottom of the sea." He also described a diving bell of around the year 1250, but one historian remarked: "It was a crude contraption and never amounted to much."

One of the first definite and seemingly authentic accounts of an underwater craft is dated 1505. In this account, Olaus Magnus, Bishop of Uppsala, Sweden, tells of seeing "in the Cathedral of Asloe [Oslo], two leathern boats used by pirates of Gruntland [Greenland] to attack merchant ships from the surface or from beneath it." (It appears now, however, that the "pirates" were nothing more than Eskimos in kayaks.)

In a 1536 writing, Veretius described a hermetically sealed leather cowl and horn goggles. The cowl was attached to a belt, and extended upwards to the surface where it was attached to a floating water skin filled with air.

The first completely closed, vs inverted submarine dates from the sixteenth century. About 1538-1540 (in Toledo, Spain), two Greeks held a demonstration for Charles V, in which they were lowered from a small boat in the waters of the Tagus. Sitting on a bench inside the inverted bronze tub and holding lighted candles, the divers remained submerged for 20 minutes and ascended perfectly dry. The event was called a miracle.

Leonardo da Vinci, probably one of the world's most brilliant inventors, designed underwater warships and diving gear, including swim fins. He also investigated the possibility of subsurface navigation and allegedly made a descent in a diving bell.

In 1552, two fishermen from Venice reportedly remained submerged for two hours inside a bell approximately 10 feet in diameter.

William Bourne, a chief naval gunner, suggested to Queen Elizabeth (at the time of the Spanish Armada's move on England) the employment of a submarine to destroy the enemy fleet. In his proposal to the Queen, Bourne wrote that the fleet could be eliminated by a "ship or boat that may go under the bottom, and so come up again at your pleasure." He made drawings of a submersible constructed of a strong wooden frame covered by a watertight leather skin (Figure 8). Screw jacks inside the hull were to alter the displacement (buoyancy), and thus aid the vehicle to descend or ascend. For life support, Bourne suggested a snorkel consisting of a hollow mast projecting above water.

The principle of the snorkel is at least 400 years old. References to the snorkel are frequent in historical records. One was designed by Robert Rabbards (Figure 9). Its early use was shown in a 1580 Elizabethan manuscript.

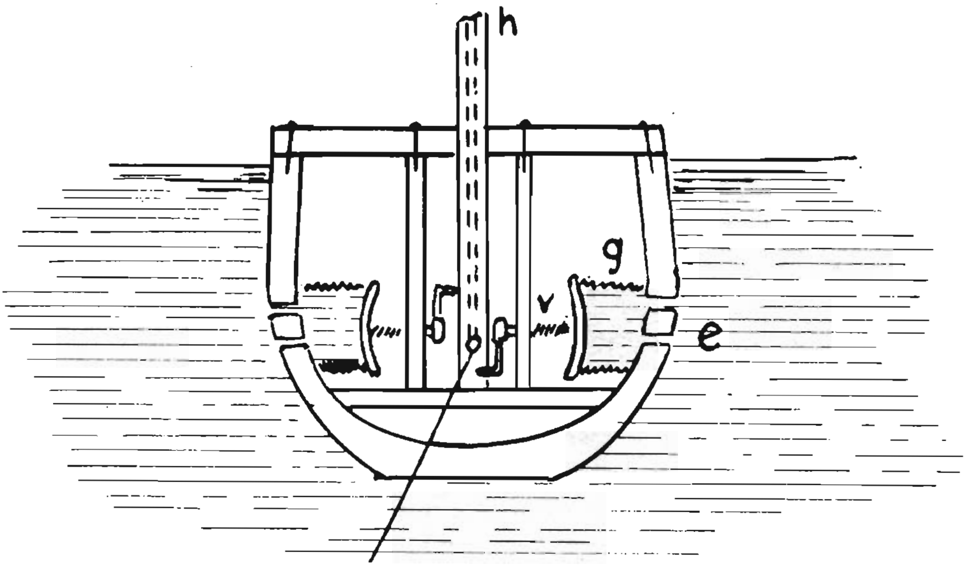

Figure 8. William Bourne's variable buoyancy using pistons. Water enters through orifice (e) into inner hull. The variable piston (v) moves the variable membrane (g). Air enters the vehicle through the tube (h).

In 1596, John Napier, the Scotch mathematician who invented logarithms, suggested "devices for sailing under the waters . . . and stratagems for the burning of enemies."

About the same time, a monk named Mersenus, proposed a complicated fish-shaped vehicle made of copper, and outfitted with guns with automatic plugs, phosphorescent bodies for lights, oars to propel the vessel, and ventilators for air rejuvenation. The purpose of this vessel was for "destroying the keel of enemy ships."

One of the earliest practical diving bells was invented by Sturmius at the beginning of the sixteenth century. The device consisted of a heavily weighted bell, which, when full of air, was allowed

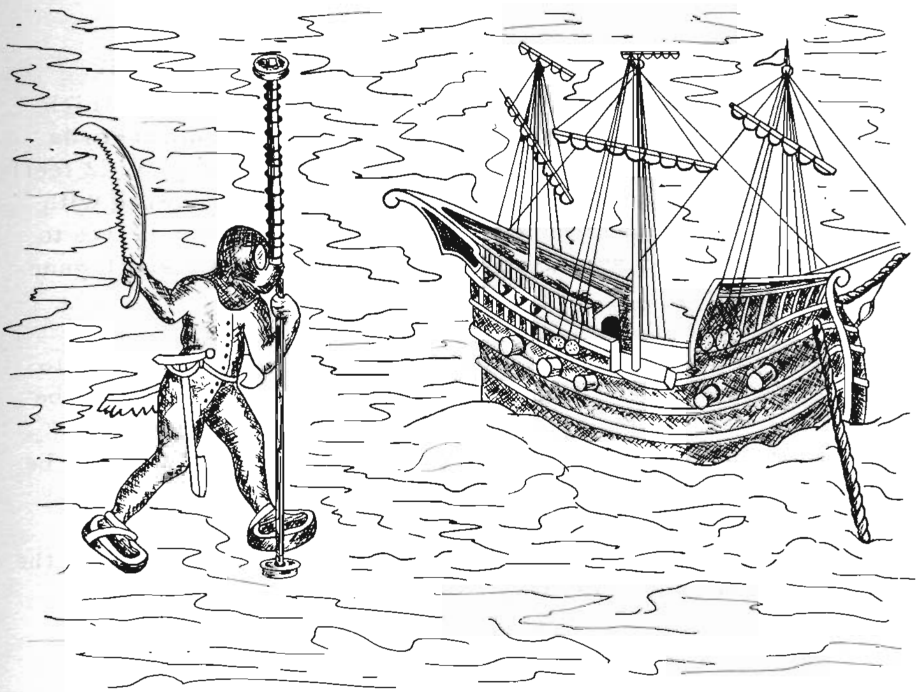

Figure 9. A 400-year old drawing shows a frogman walking toward an enemy galleon with his sword raised to cut holes in the ship and sink it. The snorkel is on his headpiece.

to sink vertically in the water until it touched the bottom. Because of air pressure, water penetrated the bell sufficiently to equalize the air pressure. At 10 meters, for example, one-half of the volume was water, and one-half air. Sturmius also appears to have been one of the earliest to consider the harmful effects of air compression. Panthot suggested that air should be taken into the bell in bottles which could be broken, freeing the air.

Mention is often made of ten men breathing underwater through a tube or reed. This is possible at a depth of only a few inches at most because the pressure of the water on the chest is simply too great to allow chest muscles to function.

Other designs reported during this period were apparently never constructed or tested, and no details of their apparatus are known. Among these designs were the vaguely described small submarine of Magnus Pegelius (1604), Lorini's bell with portholes (1609), and Father Schott's "acquatic corselte" (1620).

Cornelius van Drebble, a Dutch physician, scientist, and mechanic, constructed a submarine for the English in 1620 in which King Janes I is reported to have made a trip. The original records are missing, but it is alleged that the ship was large enough (272 feet) to hold a dozen people, made of wood, double-prowed, covered with leather, and propelled by oars, and could cover a distance of five to six miles. Van Drebble is supposed to have used a liquid which generated air.

Van Drebble said: "The inventor of this ship will undertake to destroy in a single day 100 vessels and such destruction could not be prevented by fire, storm, bad weather or the force of the waves, saving only that the Almighty should otherwise will. Vain would it be for ships lying in harbor to be regarded as safe."

Bishop Wilkin's Mathematical Magic, published in 1648, had the following to say about Van Drebble's submarine:

> "That such a contrivance is feasible and may be effected, is beyond all question, because it hath already been experimented here in England by Cornelius Dreble; but how to improve it into public use and advantage, so as to be serviceable for remote voyages, the carrying of any considerable number of men, with provisions and commodities, would be of such excellent use as to deserve some further inquiry."

After van Drebble's, another submarine was build in England by a mechanic named Day. On the first trial, this submarine and its crew remained submerged for 12 hours before surfacing. The submarine never returned from its second dive. The secret of this vehicle was well guarded, for we have no record of its construction other than that it had a double deck with ballast; it is presumed that, like van Drebble's submarine, the ballast was water, and could be admitted or rejected upon demand. Day's submarine (actually a sloop) had a watertight and airtight compartment that could carry 30 tons of stone ballast.* In June 1774, 30 tons of stone was added without submerging, hence Day ordered more stone ballast thrown into the hold of the sloop. It finally sank. Unfortunately for Mr. Day, he had no means for removing the ballast from inside the now submerged "submarine." Furthermore, there was no means to communicate with him. A friend of the inventor, Dr. N. D. Falck, reasoned that so long as Mr. Day was inside the submarine, in an air compartment, and could not be attacked by fish,

*See Falck, 1775.

Day had an excellent chance for survival. Therefore, Dr. Falck, leisurely went to the site of Mr. Day's submerged vessel the following month. Rescue operations continued into October, without results. Weather conditions turned bad and private business took Dr. Falck away from the rescue site. Mr. Day never was found.

In 1634, P. Mersenne considered the best configuration for a submarine to be a cigar-shape. He also suggested the use of a superstructure with valves for crew access.

In 1640, Jean Barrie de Pradine was commissioned by Ann of Austria to salvage the cargo of a ship sunk in the Dieppe. Nothing is known about the apparatus employed. In 1648, the mother of the King of France granted a privilege for submarine "fishing" to de Pradine for:

> "...having explained to us that, after long and continual effort and great labor and expense, he has discovered a device and mechanism, not yet put into practice, by means of which he can remain six hours in the depths of the sea in order to seek and draw up from the bottom of the water all the goods, cannon, ships, gear and other things that have been thrown therein and are submerged, as a result of the wrecking, breaking up, and running aground of vessels ... we grant (that he shall) enjoy, and he alone for 12 years, the profits from the mechanisms...with the exception of a right to one-tenth of the said things fished...and of the cannons...to hand over to the nearest port on payment of a third their value..."

About 1653, de Son, a Frenchman, built a small "military" submarine, 72 feet long, 12 feet high, and 8 feet wide. He was the first to use the paddle-wheel propulsion system on any vessel. This was installed in the center of the vessel. The submarine had large lengthwise beams, covered with steel, which were to be used to pierce enemy ships. After he proved (to himself, anyway) the success of his submarine, de Son offered to destroy a fleet of ships. He also claimed to be able to travel to the East Indies in his submarine in 10 weeks.

Pepys' Diary, dated 14 March 1662, says in part:

> "In the afternoon came the German Dr. Knaffler to discourse with us about his engine to blow up ships. We doubted not the fact, it being tried in Cromwells' time (a few years earlier), but the safety of carrying them in ships."

Abbé Blaise Pascal, in 1663, published a treatise on the equilibrium of fluids, relating to the science of hydrodynamics. He showed how water acting on submerged bodies presses on them from all sides, and how objects immersed in water are compressed inward, equally from all sides, toward the center. He stated:

> "No great degree of intelligence is required to grasp that a bag or tube attached to the mouth of a man under water will act in the same fashion. A man's lungs are a sort of bellows and in order to inflate them the man must raise the column of water which is pressing down on him from above. However, this column being very heavy and the strength of his muscles being very inadequate he finds he cannot raise the column of water and therefore he cannot breathe."

The discoveries of Pascal were directly applicable to diving, and it was only a short step from theory to a practical diving bell. Professor George Sinclair of Glasgow University took this step in 1665, when he built a practical diving bell and proved its usefulness by recovery of cannon from a famous Portuguese galleon sunk off the Island of Mall. Professor Sinclair described in considerable detail how the diving bell worked in equalizing the air pressure inside with outside water pressure. Thus, Sinclair can be considered the father of scientific diving. In 1669, Sinclair suggested that air in containers be sent down to a bell for the purpose of renewing the oxygen. In 1691, Denus Papen, making use of an idea of Barrie de Pradine made about 1640, further suggested that air be supplied inside bells by means of a force pump.

In his book, published in 1680, Father Borelli mentions several systems for diving, including one navy submarine (Figure 10). Large bags of air were located on the lower part of this submarine to allow it to rise when evacuated, and a lever was employed for actuating a pump (press) which removed the water. The submarine was propelled by oars shaped like the feet of geese. Borelli also designed a helmet which permitted the evacuation of expired air via a valve. In his operation of this helmet, Borelli apparently made the first known use of

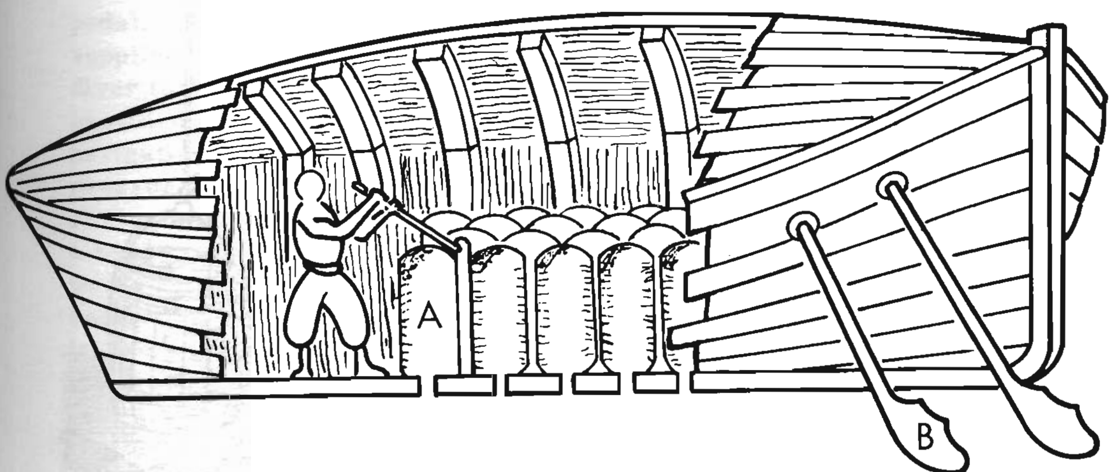

Figure 10. Father Borelli (1679). Air is stored in flasks (A); propulsion by oars (B).

compressed air which could be liberated on demand by means of a hand crank-driven rack and pinion. Claws were installed on the hands and feet of Borelli's suit (to better grasp rocks?). In a number of ways, the suit incorporated many features of the modern SCUBA diver (no hose to the surface, evacuation of expired air, compressed air on demand, flippers, and autonomy of movement).

Halley, the physician and astronomer primarily famous for "Halley's comet," had considerable knowledge of the tension or partial pressures of air. Aware of the importance of renewal of air which became foul by respiration, he built a bell (some time before 1716) which could be opened at will to allow jars of fresh air to be sent down into the bell, as well as to allow the warm foul air to escape through a valve at the bell's top (Figure 11). This was accomplished by means of a long leather pipe attached to the top of the vehicle and extending to

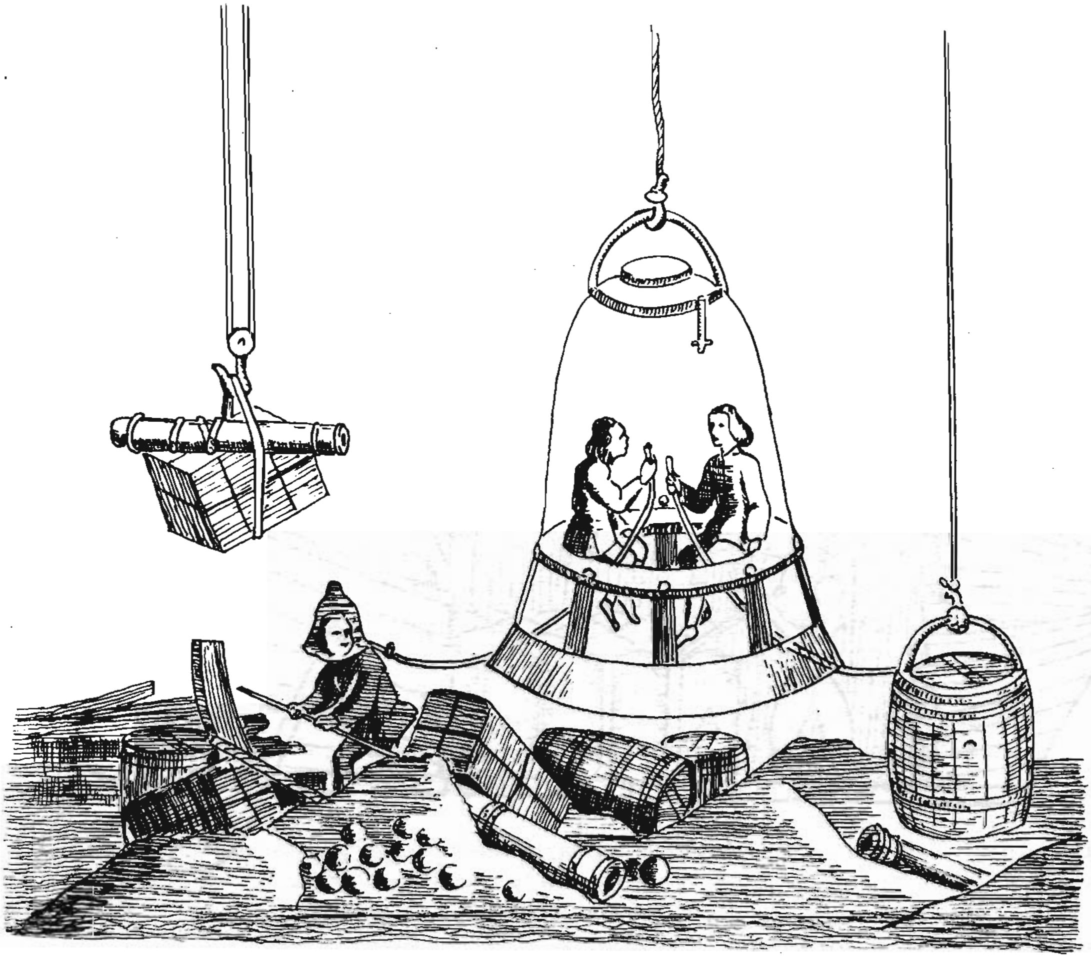

Figure 11. Halley's eighteenth-century bell brought fresh air from the surface, rejuvenating air in the bell, and allowed divers to work outside in the open sea.

the sea surface. Casks, containing about 160 liters of air, were weighted and lowered beside the hull, and air entering through the hole in the cask forced the old air from the bell. Air inside the bell could be refreshed almost indefinitely by this method. Halley also invented a tube and wooden helmet device which covered the diver's head, allowing him to leave the bell while maintaining his air supply from compressed air contained in the bell. At the age of 65, Halley successfully dove to a depth of 65 feet (with four volunteers) and remained at this depth for four hours.

In 1750, Spalding made certain mechanical improvements on Halley's apparatus by adding a removable section which, when jettisoned, allowed the vehicle to be brought to the surface. He dispensed with the cast-iron cannon balls serving as ballast, and substituted water ballast.

In 1773, David Bushnell, Yale graduate and Connecticut patriot, designed a one-man submarine whose main purpose was to sink British ships (Figure 12). * This was the prototype of the modern torpedo-firing submarine. The vessel's general appearance was that of two turtle shells joined together, and Bushnell appropriately named it THE AMERICAN TURTLE, or simply the TURTLE. Constructed of wood, 7-1/2 feet long, the TURTLE was hermetically sealed, and had a conning tower with glass windows all around which was used for both entry and observation. A valve located in the lower part was foot-actuated to admit water for diving purposes; a force pump, also operated by a foot pedal, discharged water; ballast kept the submarine vertical. Air was supplied from a small tank, which held sufficient air to support the diver for a half-hour submergence; on the surface, air circulation was provided by a ventilator. The operator was supplied with such modern navigational instruments as a phosphorus-covered compass and a glass pressure gage. The craft was provided with an oar in the front for rowing and with a rudder in the rear for steering, and was propelled by a hand crank which turned a screw-type propeller. Maximum speed was 3 knots. The "torpedo" (actually, a detachable waterproof powder keg with a gun hammer fuse) consisted of two hollowed-out timbers loaded with 150 pounds of powder. Mounted just outside the window of the vessel, the torpedo was fired by means of a small clock mechanism and was held forward with a string. A screw device was provided for fastening the torpedo to the lower hull of an enemy ship. Upon approaching an enemy ship, the TURTLE was to submerge, attach a wooden torpedo to the enemy ship, then run for cover pending the destruction of the ship.

The submarine described above was entirely Bushnell's idea and was in no way financed by the Continental Congress. He was determined to wage, if necessary, a one-man war against the British. For purposes of safety, the TURTLE was intended to operate under the cover of darkness, with only the conning tower visible above water.

Bushnell was an ingenious inventor but a rather nervous individual; for this reason, his brother was taught to operate the submarine. At the crucial time, however, the brother became ill, and Ezra Lee, a brave Army sergeant, volunteered at the last minute to sink Admiral Howe's flagship EAGLE. Lee navigated the TURTLE under the 64-gun EAGLE, but, when he attempted to screw the torpedo into the hull, found it was sheathed in copper. Not realizing that there was clean wood only a few feet away from the rudder post, Lee lost the opportunity to have the distinction of sinking the first ship by means of

*See F. Wagner, Submarine Fighter of the American Revolution; the Story of David Bushnell: Dodd.

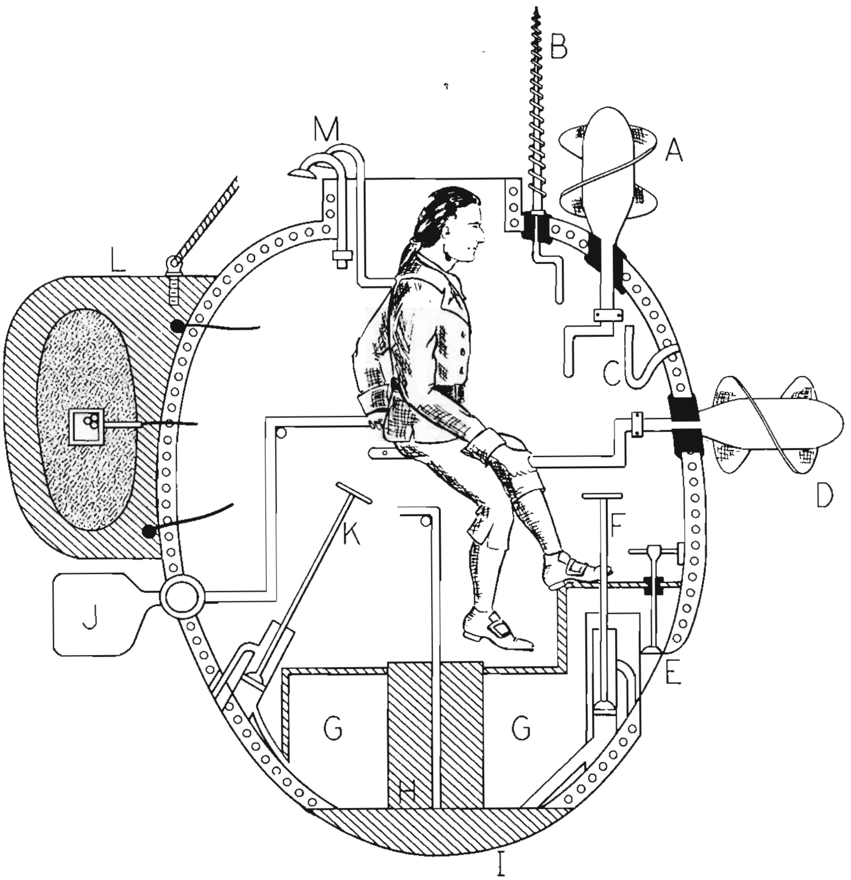

Figure 12. David Bushnell's TURTLE was the first submersible to make a concerted attack against a man-of-war. A - vertical propeller; B - torpedo screw; C - depth gage; D - propeller; E - flooding valve; F - pump; G - ballast tank; H - ballast; I - drop ballast and anchor; J - rudder; K - pump; L - torpedo; and M - ventilators.

a submarine. However, his exploit did have a psychological effect upon the British for they quickly moved their fleet for fear of another attack by the TURTLE.

Although Bushnell was urged to improve upon his submarine for salvage and other purposes, he quickly lost interest after this first discouraging venture.

Robert Fulton's greatest obsession as an inventor was his hand-operated submarine (he built his steamboat only after everyone had refused to consider his submarines). He first thought of the submarine while in Paris, and offered his great secret weapon to Napoleon . . . "for the destruction of navies and for the assurance of free trade for all nations." He built the NAUTILUS* and successfully operated it in the Seine in 1800 (Figure 13). Later, he actually attempted to attack the British fleet anchored at LeHavre, but the fleet was able to escape without damage. In 1806, Fulton designed an even larger submarine, which he attempted to sell to the British Admiralty through William Pitt. This submarine included a conning tower with a collapsible sail, and was propelled by men operating hand cranks attached to a screw propeller (Figures 14 and 15).

A large number of diving bells, in which air was compressed, have been built over the last few centuries, but none have been satisfactory because of the extraordinarily shallow submergence depth. In order to alleviate many of the disadvantages of these pressurized diving bells, research was simultaneously conducted on the diving suit.

The inventor of the diving suit has been lost in antiquity. Among the most successful suits were those developed by Borelli (used to work outside Halley's bell), Siebe of London, Cabirol and Rouquayrol, and Denayrouze. The Siebe suit is perhaps the most widely known and used throughout the world today. The world's record for this type of suit is about 600 feet, employing a gaseous mixture, including helium. From the time this suit was introduced until late into the twentieth century, however, it was seldom used to depths as great as 200 feet.

The SCUBA is largely a post-World War II invention. The record depth for this type of device, using special gaseous mixtures, is nearly 1,000 feet. Little work can be performed with hard-hat and SCUBA at great depths, and many divers actually suffer while using these types of gear, because they are constantly under hydrostatic pressures and often fail to decompress properly. However, saturation diving, as was used on the SEALAB experiments, perhaps will solve this problem.

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*Robert Fulton apparently was the first to use the name NAUTILUS for a submarine; other submarines named NAUTILUS were Jules Verne's submarine in "20,000 Leagues Under the Sea"; Campbell and Ash's submarine with electric motors (1886); Wilkins' renamed-U.S. submarine O-12 used under ice; and the nuclear-power submarine launched in 1954.

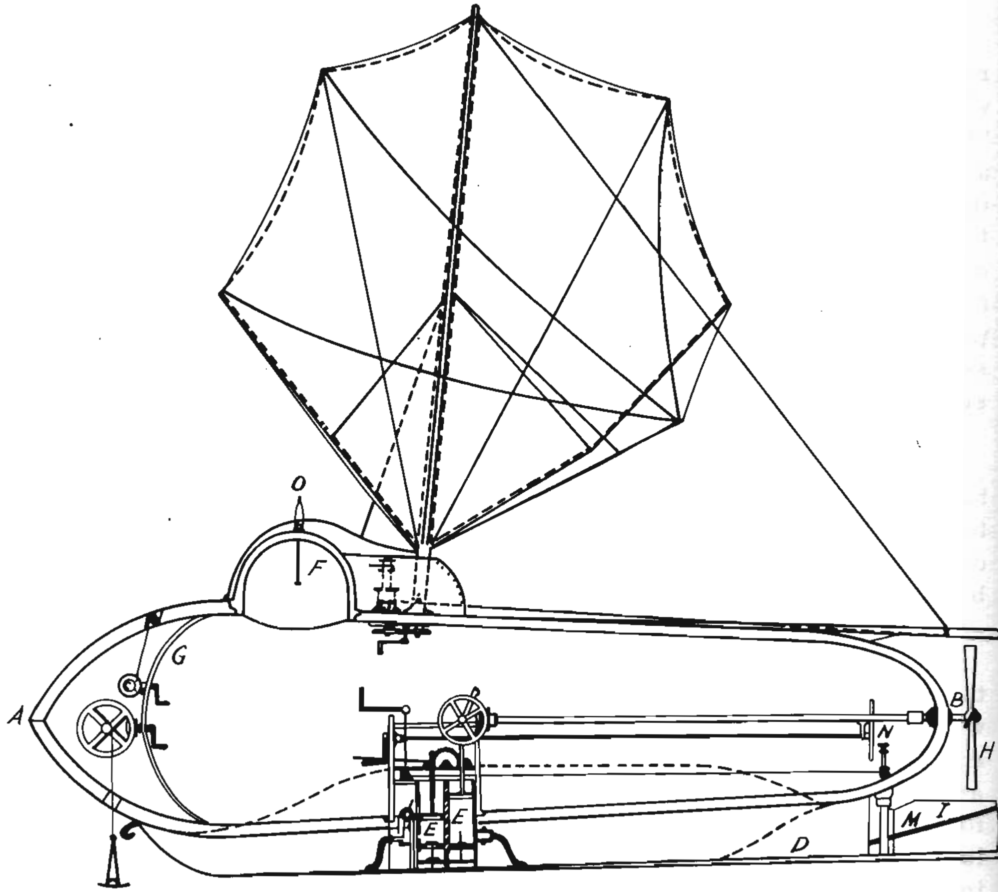


Figure 13. Robert Fulton's first NAUTILUS designed for France. AB - hull; CD - metal keel; EE - pumps; F - metal conning tower; G - cross bulkhead; H - propeller; I - vertical rudder; LO - horizontal rudder; M - fulcrum for L; and O - horn of the NAUTILUS.

After 1840, the U.S. Patent Office was deluged with new submarine innovations. Some of the patents are surprisingly well advanced; others are impractical (Figures 17 through 22).

Perhaps the most famous submarine of all time is Jules Verne's fictitious NAUTILUS, which allegedly traveled 20,000 leagues under the sea (Figure 23). It has been reported that Verne read over 500 books and articles as background material for his novels. Among the ingenious concepts described in his writing was the use of an electric motor to propel the NAUTILUS (1869).

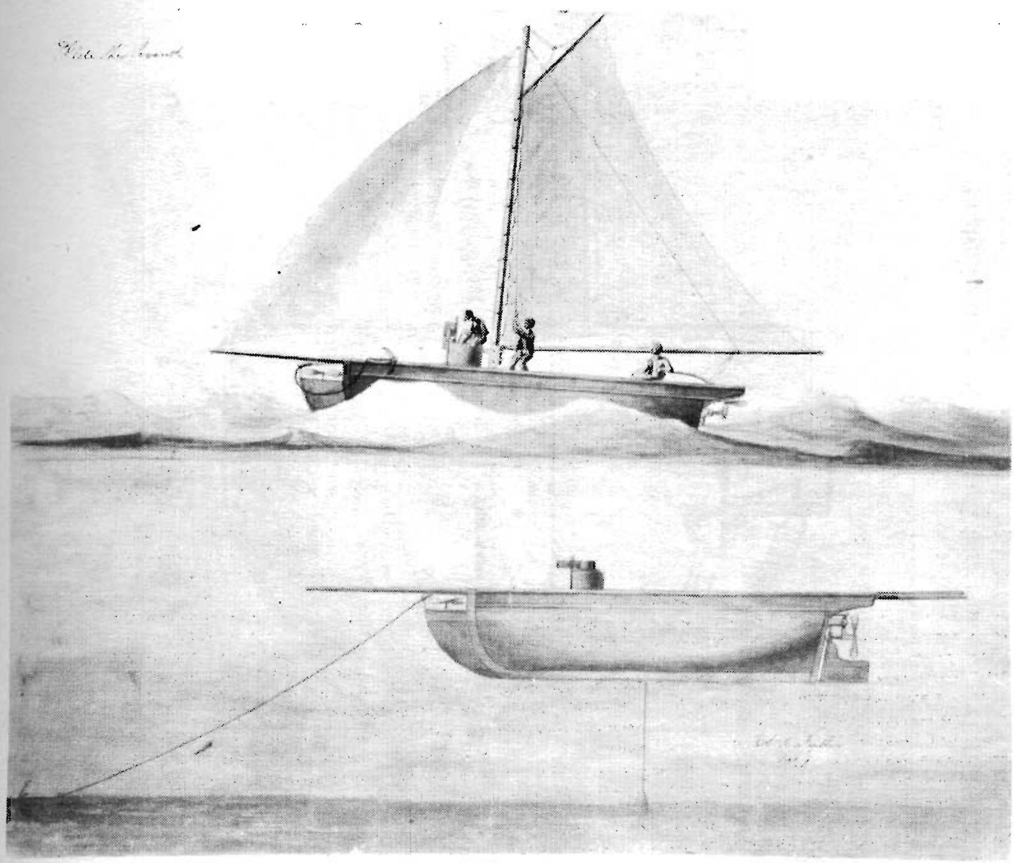


Figure 14. Pen and watercolor views made by Robert Fulton in 1804, showing his submarine on the surface with sails (upper half of illustration) and submerged at anchor (lower illustration)

In 1850, Wilhelm Bauer, an ex-corporal of the Bavarian Artillery, attempted to build a "submarine boat" to resemble a porpoise; when completed, however, the vessel looked much like a surface ship. Constructed of sheet iron and weighing 35 tons, it had four square windows and was driven by a single propeller turned by two men. Bauer submerged the boat by allowing water to enter ballast tanks, controlling the depth and attitude by means of a heavy weight which was hauled fore and aft along the bilges and caused the submarine to point its nose up or down.

Although opposed by contemporary German naval officers and scientists, Bauer achieved a moral victory in 1850. The Danish fleet

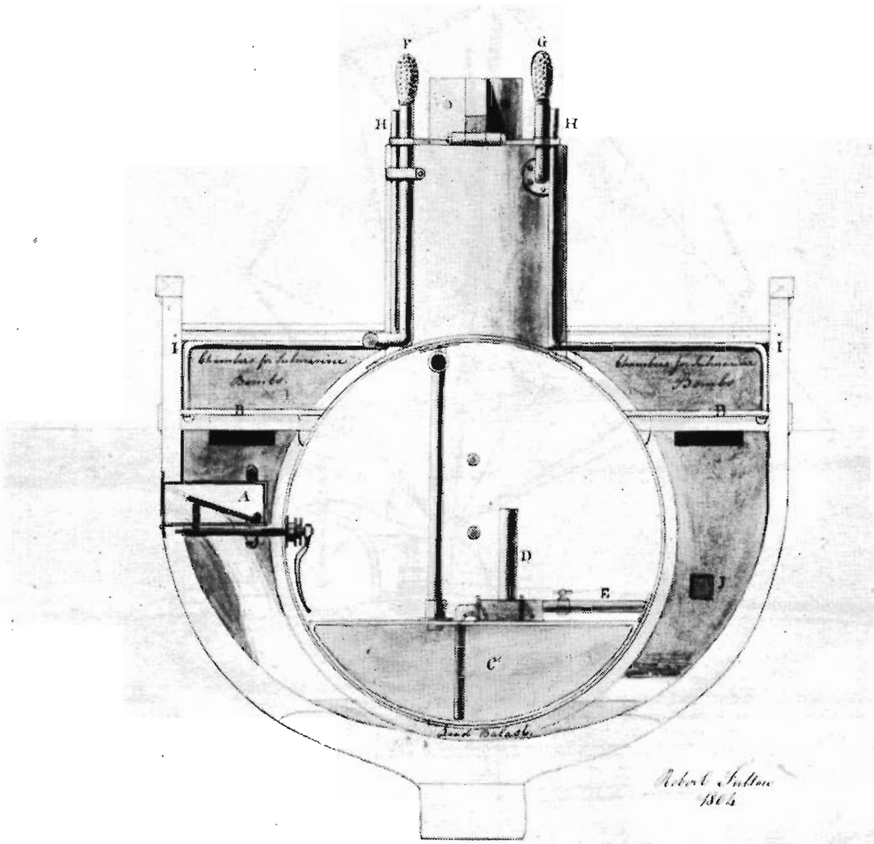


Figure 15. Cross section of Fulton's submarine (see Figure 14). Underwater propulsion was by means of a screw propeller actuated by men operating hand cranks. The vertical propeller in the bow regulated the depth. (Original paintings are in New York Public Library.)

had blockaded the German port of Kiel, and when Bauer showed up in his submarine, the Danes scattered their fleet and the blockade was lifted. The following year, in 1851, the Danes returned. This time, Bauer and his SEADIVER were completely ineffective, and the Danes succeeded in completely paralyzing Kiel and the German fleet. The SEADIVER went to the bottom in an uncontrolled dive; all three crewmen were able to escape from a depth of about 60 feet, by flooding the submarine to equalize air and sea pressure, then opening the hatch and floating safely to the surface. (Figure 16)

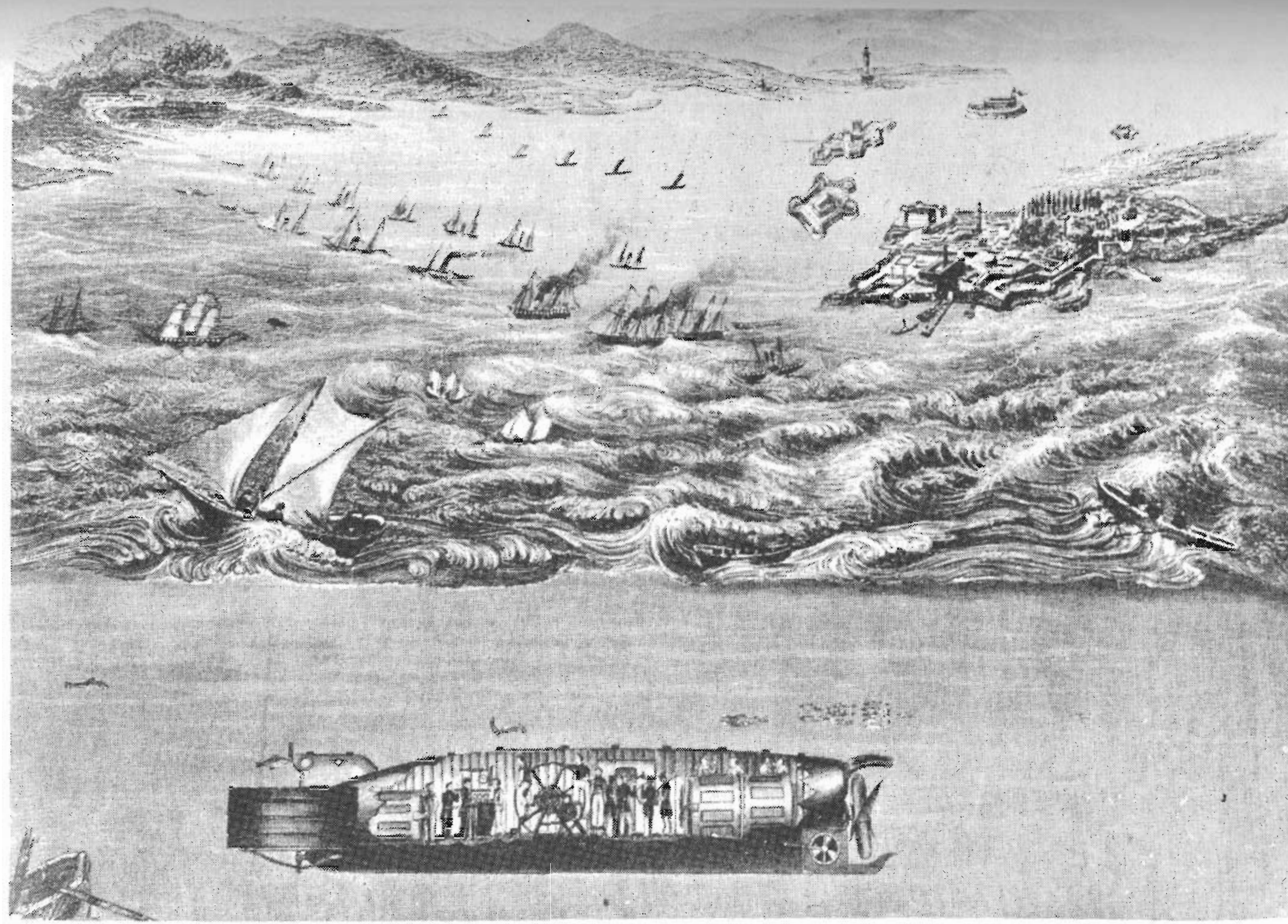


Figure 16. Wilhelm Bauer's BRANDTAUCHER frightened the Danish fleet blockading Kiel in 1850. Bauer also built DIABLE MARIN for Russia in 1855 (From "Dynamic America," General Dynamics Corp. and Doubleday Co., Inc.)

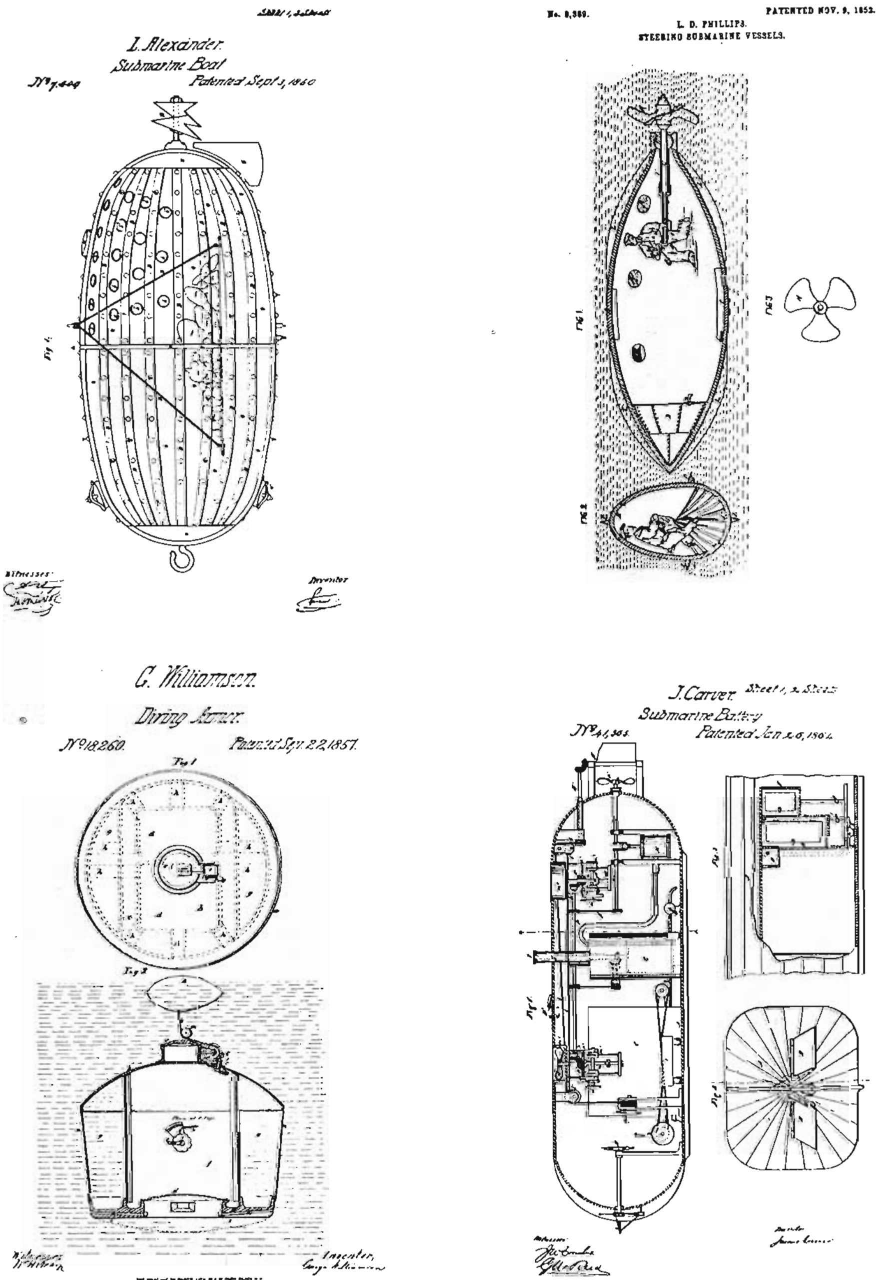


Figure 17. Earliest U.S. patents of submarines, 1850 -1864

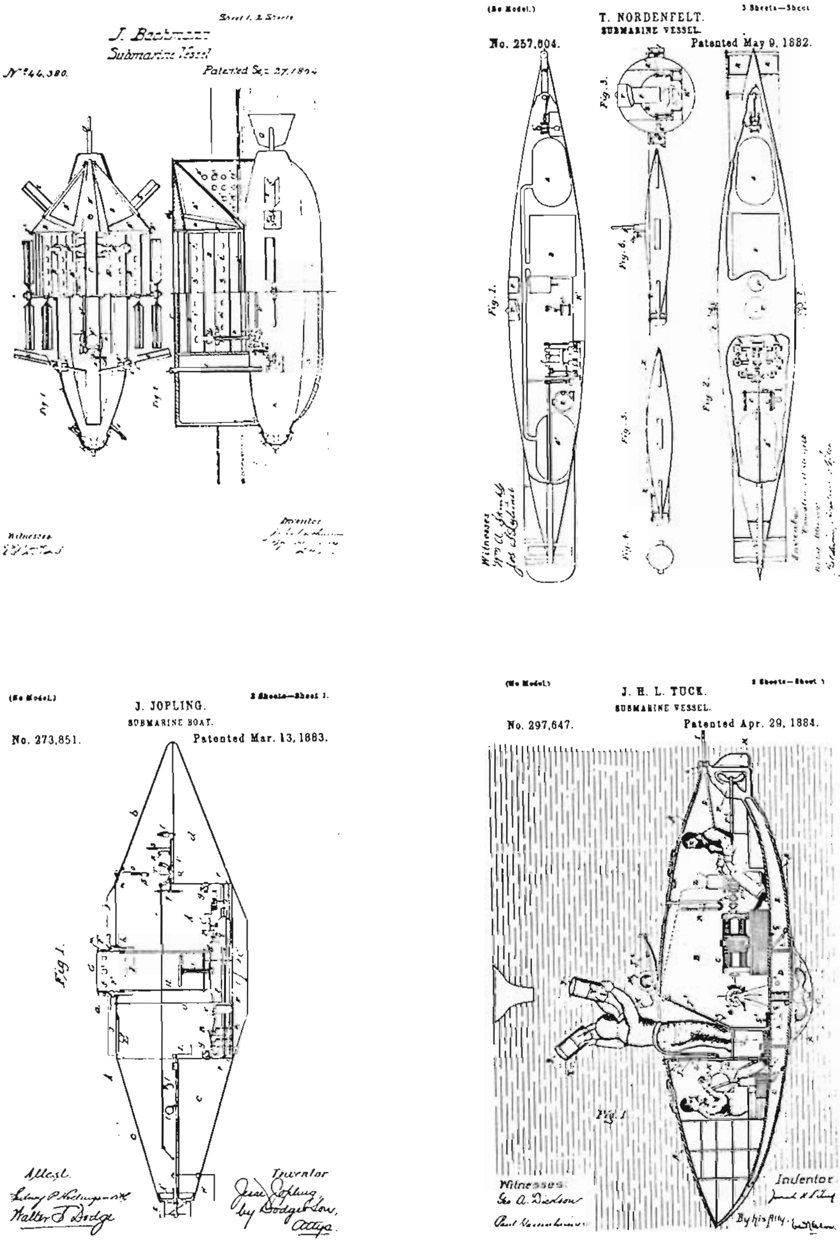


Figure 18. U.S. patents of submarines, 1864 - 1884

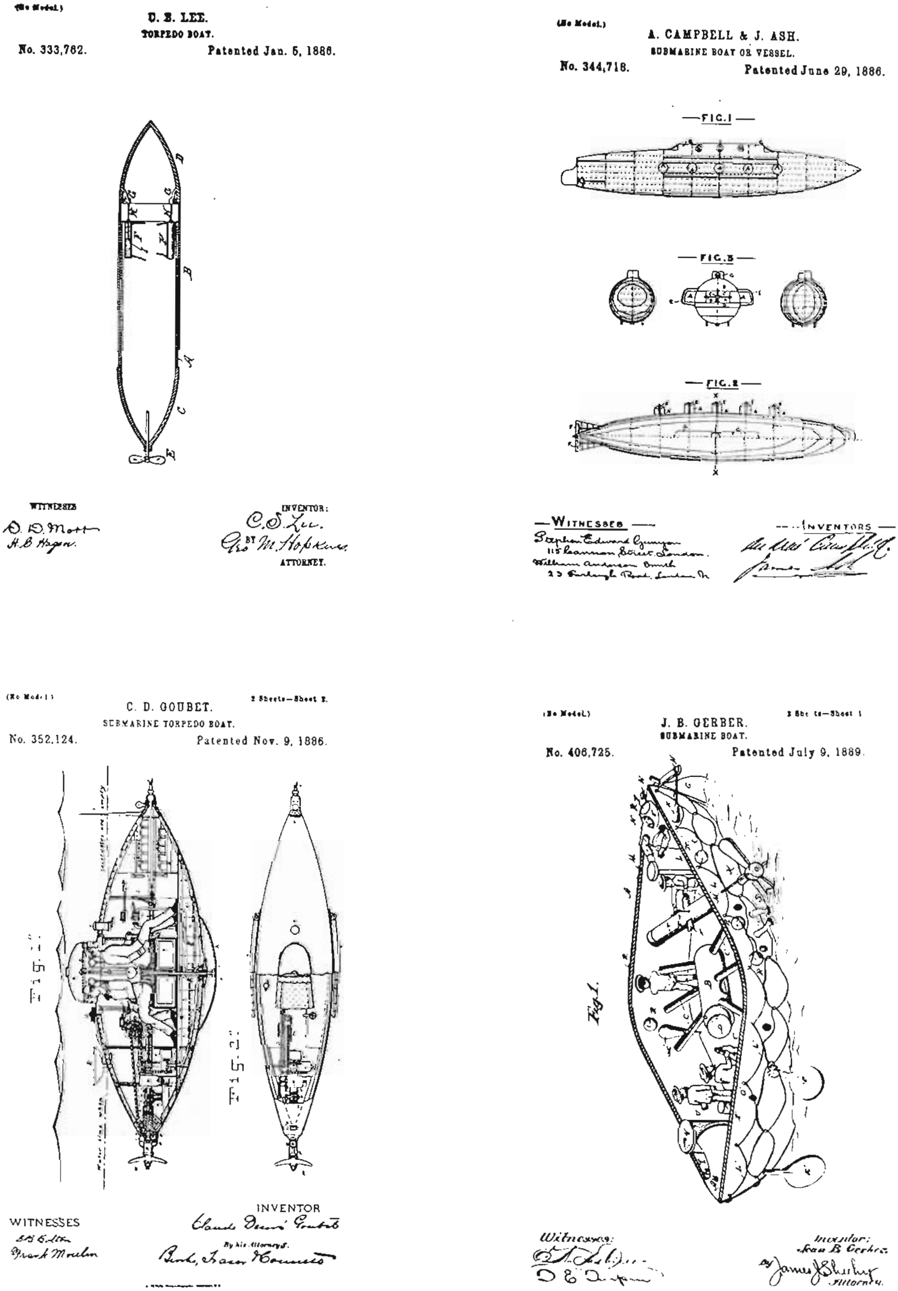
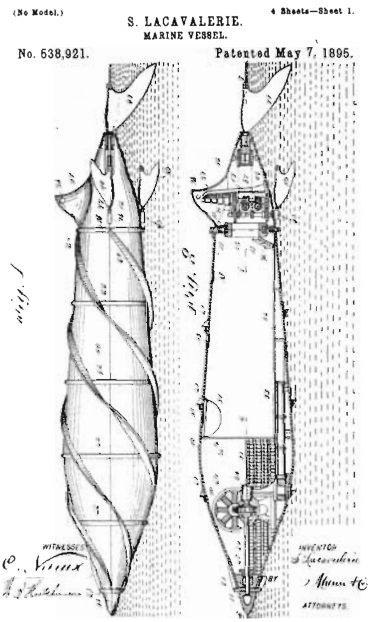
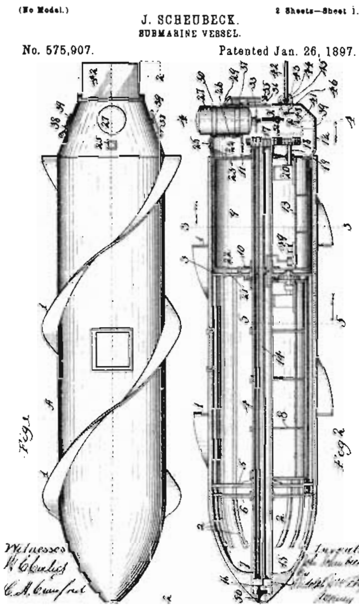
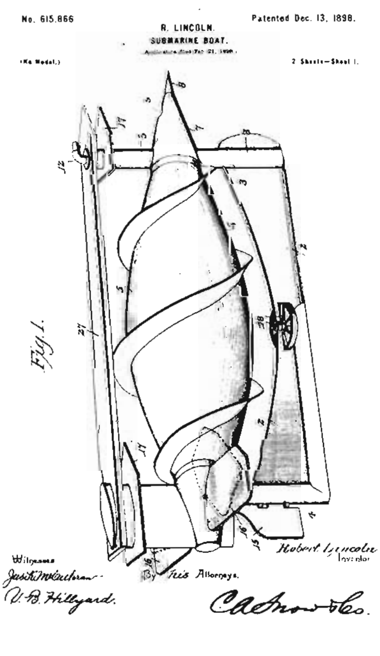


Figure 19. U.S. patents of submarines, 1886 - 188^







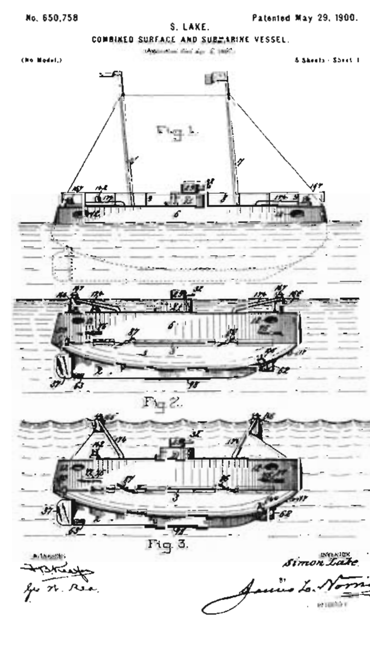


Figure 20. U.S. patents of submarines, 1895 - 1900

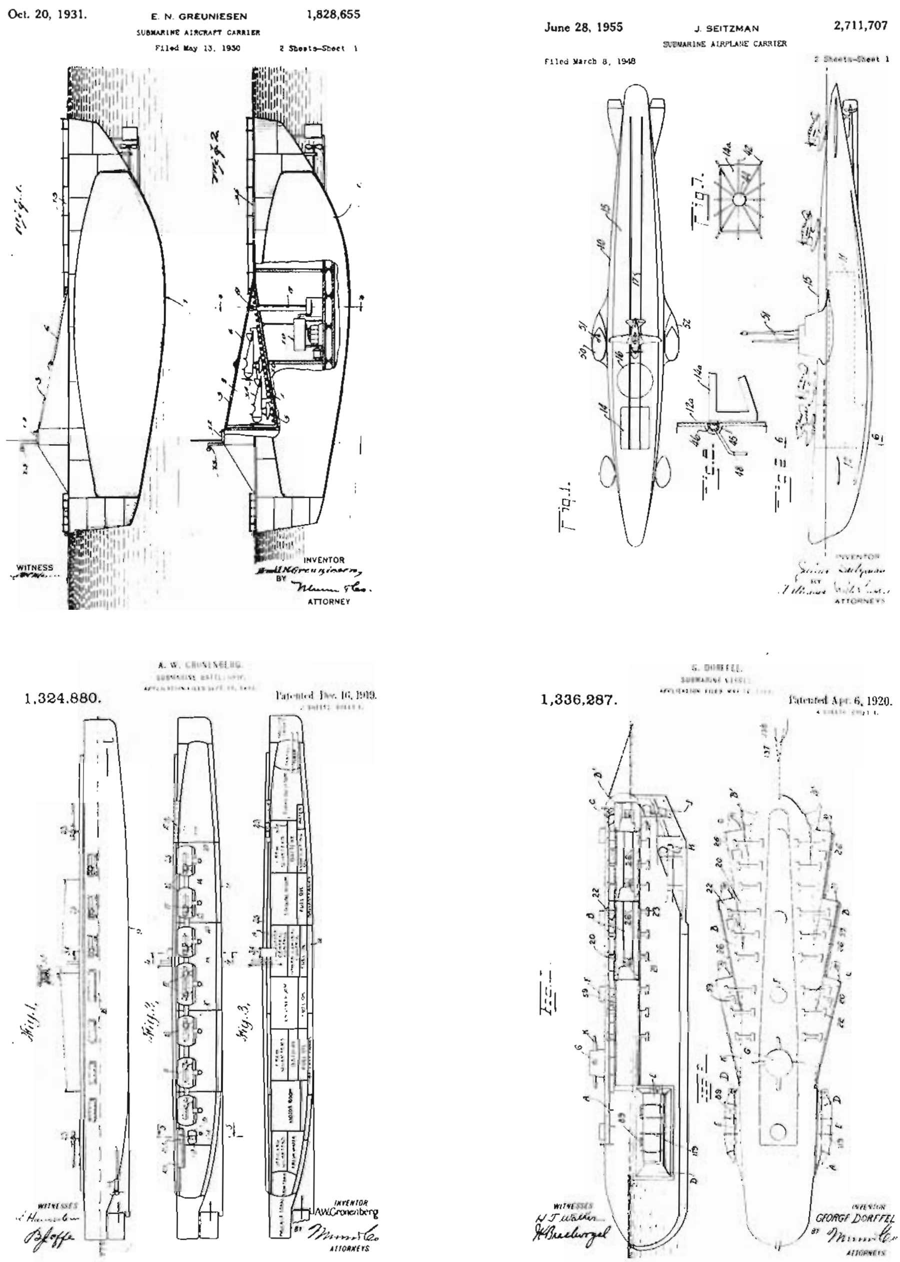


Figure 21. U.S. patents of submarine aircraft carriers and submarine battleships

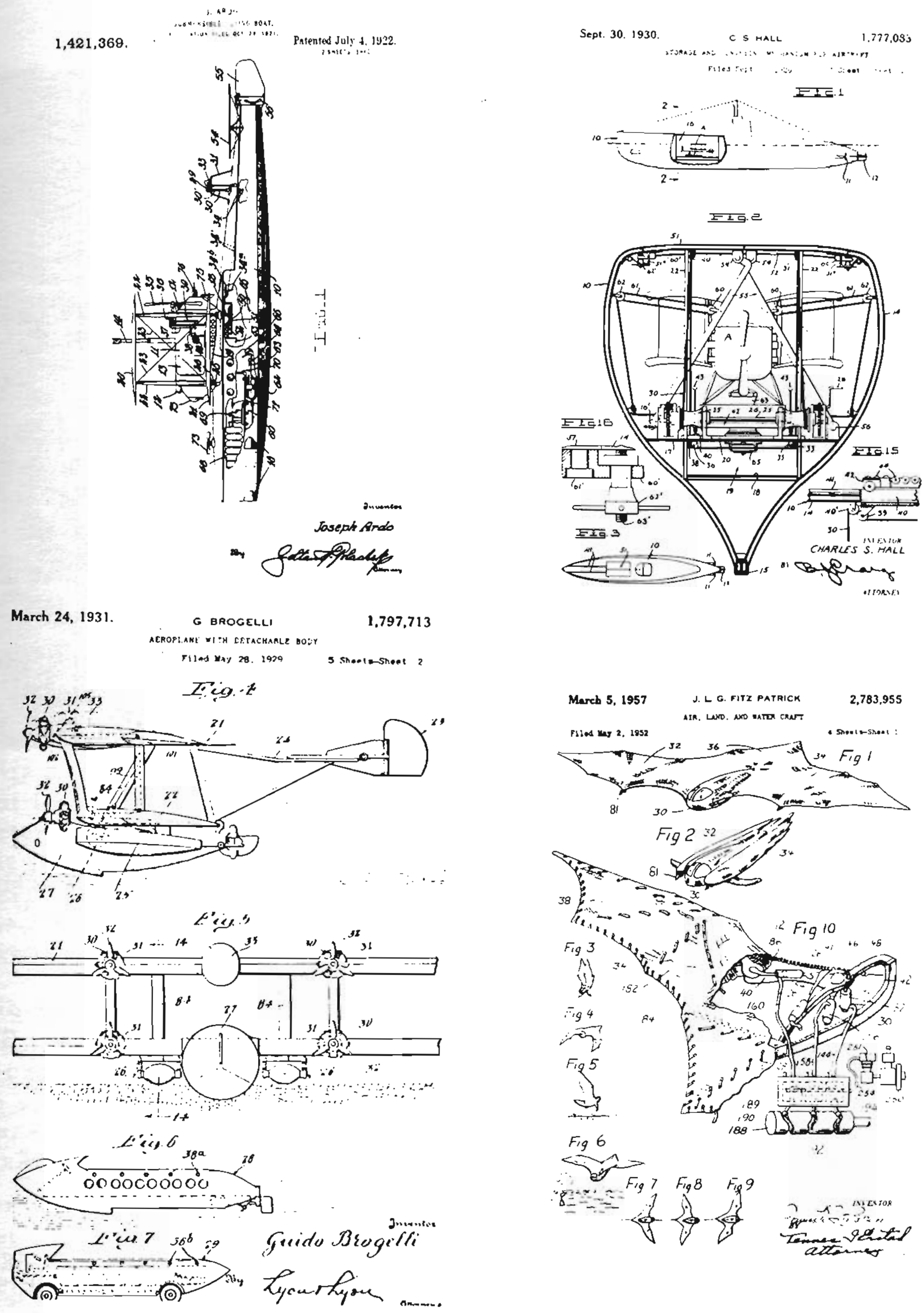


Figure 22. U.S. patents of submersible flying boats

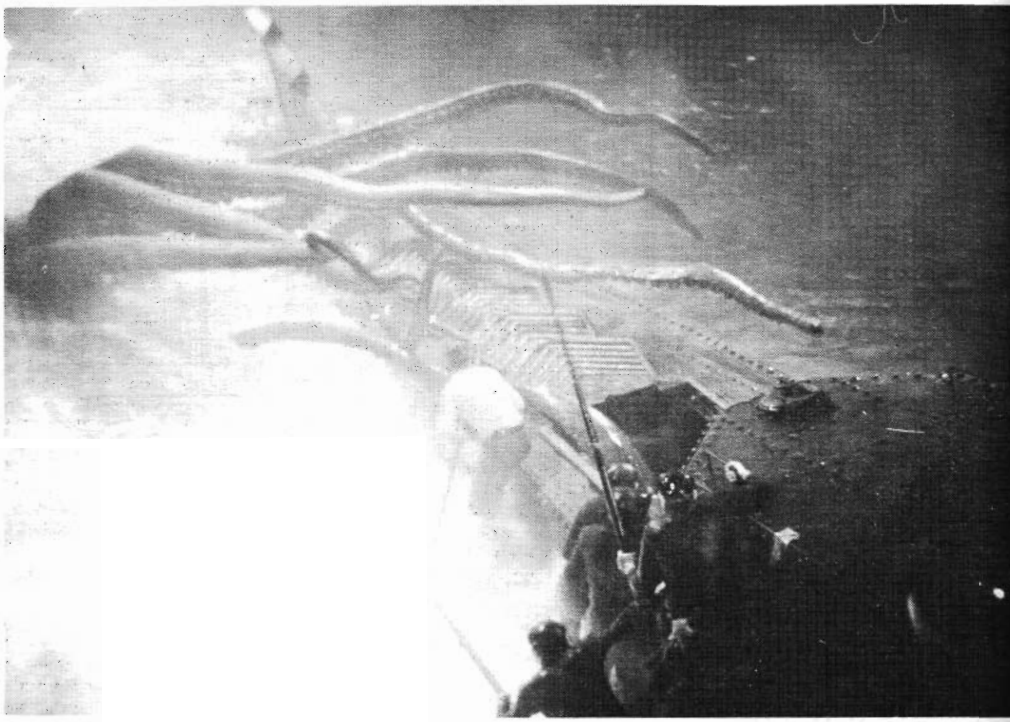


Figure 23. Captain Nemo and crew fight giant squid attacking NAUTILUS of "20,000 Leagues Under the Sea". (Courtesy Walt Disney Productions.)

Bauer built another vehicle in England that also met with disaster, killing several men. He then went to Russia and built LE DIABLE MARIN, 52-feet long with a 12-foot beam, and equipped with glove and arm pieces protruding outside the vehicle to allow the crew to fasten powder kegs on the hull of enemy ships. This craft was tested in the Baltic Sea and was reasonably successful; however, it was never put into service.

Less publicized was the 40-foot long, 4-foot diameter, cigar-shaped submarine built on Lake Michigan by L. D. Phillips in 1851 (Figure 24). This vessel was hand-driven and was designed to reach speeds of 4 knots using a two-bladed propeller; the inventor's plans for steam propulsion never materialized. The submarine was so well perfected, including air purification, however, that the inventor took

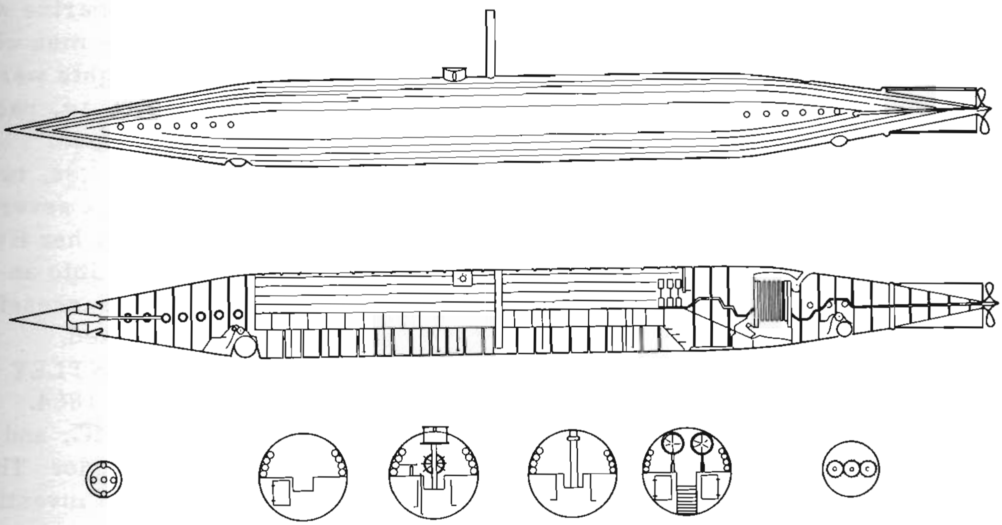


Figure 24. Submarine operated by L. D. Phillips in Great Lakes in 1851

his wife and two children on a whole day's excursion beneath the surface of Lake Michigan. A similar submarine, with somewhat larger diameter, was built as a weapon for war. It carried a 6-pound gun, recess for torpedoes, submarine gun, and a rocket system for air delivery of a torpedo equipped with diving fins. When the rocket reached its target and exploded, the released torpedo was designed to dive and burst under the bottom of an enemy ship.

Subsequently, in 1858, Brun, a French engineer, built LE PLONGEUR. This submarine was nearly 150 feet long, 20 feet wide, and 10 feet high, and had a displacement of 420 tons. It was equipped with an engine for propulsion, but still could not exceed 5 knots, and its range was limited by the small capacity of compressed air it could carry for the engine. LE PLONGEUR was provided with two vertical rudders, one horizontal rudder, and a 10-foot spar torpedo. Water ballast was employed for submerging, and plungers for varying the displacement. This submarine was widely publicized, but not very successful.

The first successful military submarine (i. e., successful from the point of view of sinking an enemy ship) was the Confederate Navy's HUNTLEY, nicknamed the "Peripatetic Coffin." This submarine was 50 feet long, cigar-shaped, and propelled by a crew of nine men who turned a screw shaft. Flood tanks and releasable iron weights were intended to control buoyancy. It carried a 10-foot hollow spar, packed with 60 pounds of powder and tipped by a chemical contact fuse. HUNTLEY had previously built at least three other submarines, two of which had been lost on test dives. The third submarine sank several times on practice dives, drowning 33 men; in at least two of her five unsuccessful dives, the crew suffocated when the boat went into an uncontrolled nose dive into the mud bottom. After each unsuccessful dive, however, a new crew of volunteers was easily recruited. Rather than risk further deaths in experimentation, the HUNTLEY was sent to destroy a Union ship blockading Charleston in early 1864. The HUNTLEY sank the 1,240-ton, 13-gun corvette HOUSATONIC, and in so doing destroyed herself in the explosion of the spar torpedo. Thus, the first naval submarine victory was claimed in 1864 by an inventive American (Figure 5). *

Shortly thereafter, the Union built several other semi-submarines (in addition to the ironclads), including the STROMBOLI, SPUYTEN DUYVEL, and KEOKUK. In 1864, a seven-year project was begun on a submarine nicknamed the INTELLIGENT WHALE. It was a disastrous failure.

In February 1875, John Holland submitted drawings to the U.S. Navy of a small, one-man submarine torpedo (Figure 25), which measured 16-1/2 feet in length, and had a surface speed of 5.8 knots and submerged speed of 3 knots. The submersible was divided into three compartments. Air, stored at the bow and stern, theoretically could supply the diver for 1-1/2 to 4 hours. The operator wore a diver's suit. Pedals were supplied to furnish fresh air, expel foul air, and propel the boat. When immobile in the water, the boat was submerged by flooding the middle reservoir. When the boat was moving, immersion was facilitated by sliding plates of lead along the bottom of the submarine. Small torpedoes were stored behind the operator for attachment to the hull of an enemy ship and subsequent electrical firing from a distance away from the submarine.

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*The first enemy ship of the United States sunk by an American submarine was not until 9 December 1941 when the SWORDFISH sank a Japanese ship.

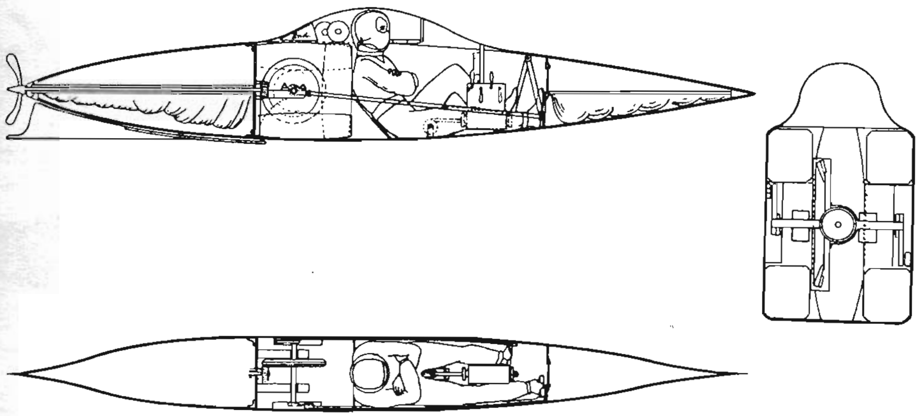

Figure 25. John Holland's one-man submarine torpedo

In 1896, a rather strange vehicle, the AQUAPEDE, was built by Alvery Templo of Brooklyn (Figure 26). Essentially this submersible consisted of a diving suit built into a streamlined body. Its length was 50 inches, and its diameter, 28 inches. Air for the diver was carried aboard (similar to Holland's submersible). It had electric air purification by means of chemicals, and reportedly was capable of staying submerged for 6 hours.

An enormous diving bell, 10 feet in diameter, was built by Piatti dal Pozzo in 1897 (Figure 27). Named TRAVAILLEUR SOUS-MARIN, or "submarine worker," it could operate at depths of up to about 330 feet. A number of devices for performing work were installed on the outside of the bell, including wrenches, grapples, and scoops, all operated by an exterior winch.

As the nineteenth century drew to a close, three great proponents of submarines made design after design of revolutionary submarines. These three were all Americans -- John P. Holland, (Figure 28), George C. Baker, and Simon Lake. Another leader during this early period was the Norwegian, Nordenfelt.

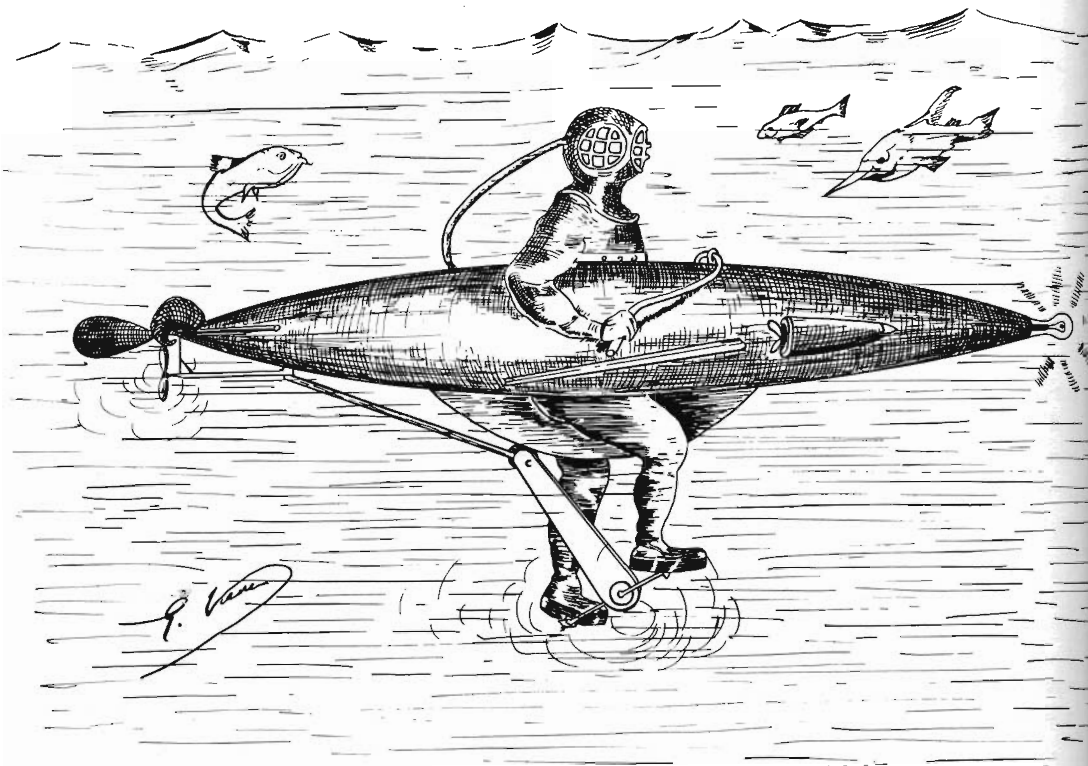

Figure 26. AQUAPEDE of Alvery Templo

Conclusions

None of the vehicles described in this historical review can be considered "deep submersibles" by any stretch of the imagination. Few men reached 300 feet and lived to tell about it. Thus, this review, while relating the early developments, ignores the fact that what we might call "deep diving" really started when Beebe and Barton descended in their Bathysphere in the early 1930's. Between their famous dives in 1931 to 1934, no one elsewhere in the world was doing anything comparable. Only after World War II, with the advent of the bathyscaphs of Piccard, did we see true deep submersibles. Historically speaking, therefore, deep submersibles are no older than 30 years.

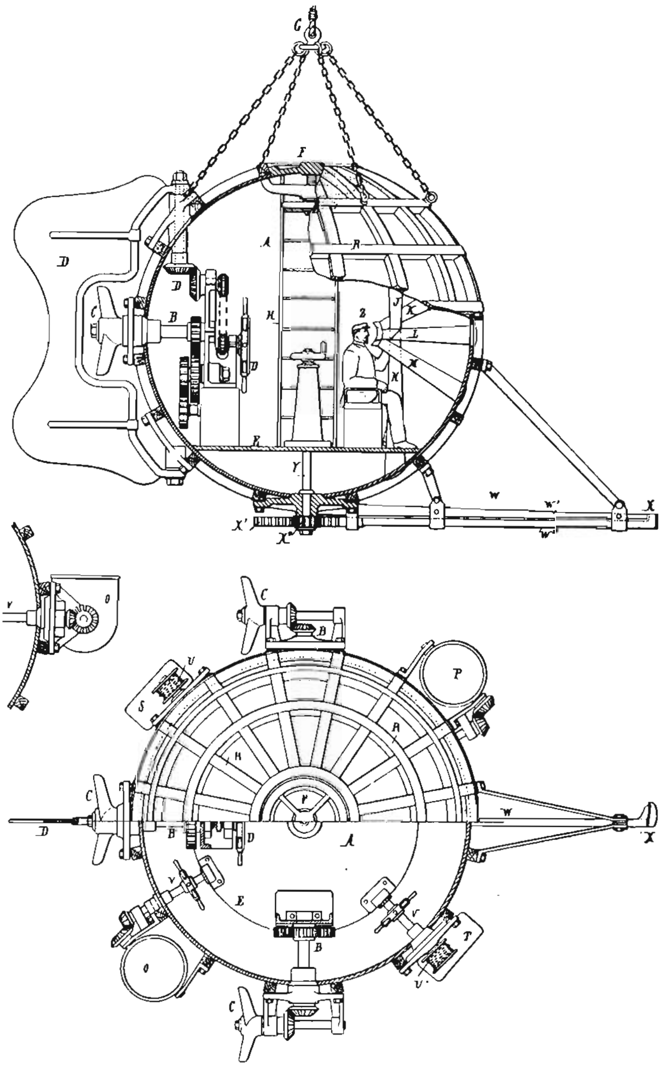

Figure 27. Piatti dal Pozzo's "submarine worker" (TRAVAILLEUR SOUS-MARIN)

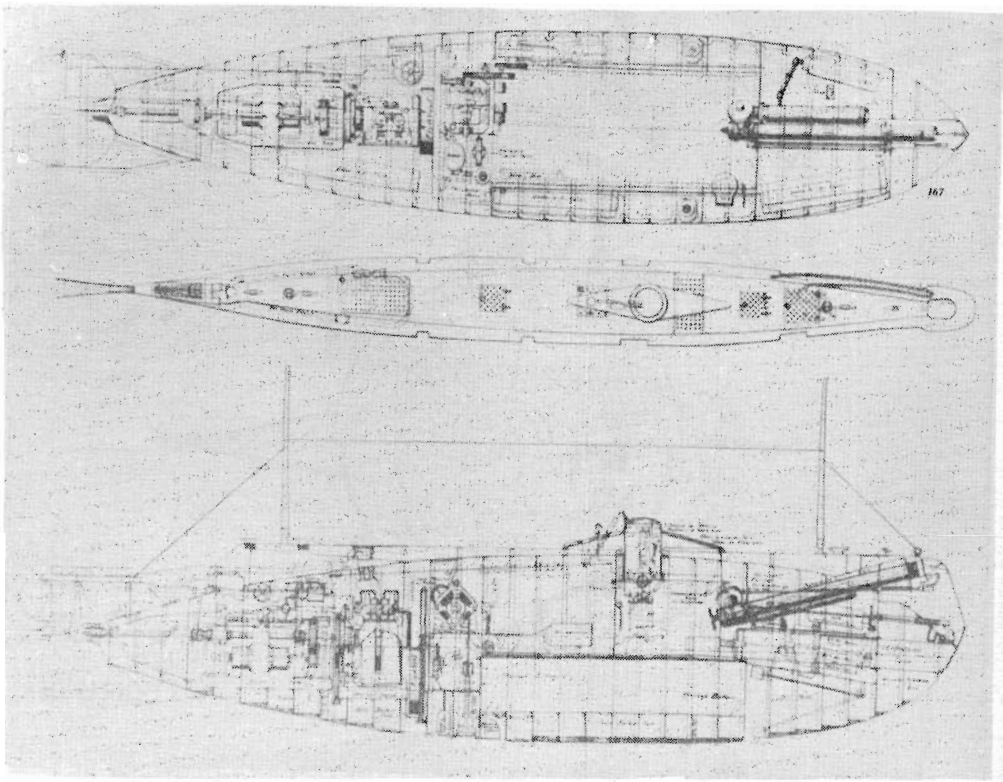

Figure 28. Plans of John Holland's submarine HOLLAND Drawn in 1896. It was 54 ft long, had a submerged speed of 7 knots, surface speed of 8 knots, and carried a crew of 8. (From "Dynamic America," General Dynamics Corp. and Doubleday & Co., Inc.)