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The Evolution in Propulsion of the Modern Super-Submersible Torpedo Boat.

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READ

On Tuesday, March 18, *at* 6 *p.m.*,

PART I.—HISTORICAL.

(ILLUSTRATED BY LANTERN VIEWS.)

CHAIRMAN: MR. A. BOYLE (Vice-President).

FOR years man gazed at the birds flying in the air and the fishes swimming under the surface of the water and not only studied carefully how their efforts were attained but busied himself with the design and construction of machinery intended to enable him to achieve the same results. Only lately, however, have his efforts been crowned with success despite the many experiments carried out with great losses in material and human life.

Up to the early part of the XIXth Century the destinies of the various large nations were decided on land and sea by means of armies and battleships which varied little in general principle during their various stages until the appearance of the steel battleships (independent of wind as a means of propulsion and all the heavy overhead masts and sailwork so easily destroyed in naval warfare), demanded guns of a larger calibre and some form of mine either mobile or immobile to prevent them creeping up to and bombarding stationary forts under the cover of darkness without being detected. One of the most important developments to neutralise this state of affairs was the locomotive torpedo which can certainly be regarded as the embryo modern submersible. Invented by an Austrian Naval Officer, Captain Luppis by name, in its first stage it appeared in the shape of a boat driven by mechanical means and directed from its base through the medium of light strings attached to the tiller arm. Luppis offered his invention to the Austrian Government who recognised the undoubted importance of the discovery, yet refused to accept it in general owing to its then somewhat crude condition. Undaunted, however, Luppis consulted Mr. Robert Whitehead, an able engineer at Fiume, who carefully dissected the whole apparatus and after bringing his inventive genius to bear, produced in 1868 the first locomotive torpedo, self-propelled and self-steered.

In 1869 the British Government approached Mr. Whitehead, invited him to bring two torpedoes to England for experimental purposes, and after having subjected the apparati to several severe tests entered into an agreement with him to manufacture torpedoes in Britain.

The possibilities of the torpedo were recognised from the first and the principal governments and navies designed and constructed small surface craft with low freeboard and high speeds to carry the new weapon with the idea of their creeping up to and launching their topedoes against the slower moving battleships under cover of darkness.

As a counter effect against these so-called mosquito craft the battleships were fitted with more powerful propelling machinery to overcome to some extent the difference in speed, and electrical searchlights to prevent the possibility of a surprise attack after dark. Further, a series of steel nets were suspended in the water around the larger ships a few feet away from the hull with the intention of diverting or exploding the torpedoes without damaging the vessel intended as target. The advent of the net cutting torpedo, however, rendered futile the installation of these nets and the more advanced naval authorities then realised the enormous possibilities of a torpedo boat, which whilst retaining all the properties of a surface vessel, would be able to submerge below the surface, noiselessly and invisibly propel itself towards an enemy ship, launch its torpedoes and with a margin of good luck escape unscathed. Evolution in naval warfare, therefore, created the demand for the submersible torpedo boat which although still in its early stages is to-day an accomplished fact and success.

Every surface vessel is buoyant, in other words it is equal in weight to the volume of water it displaces but greater in volume and as a result floats. A vessel, if it is to be submersible, therefore, must be capable of decreasing its buoyancy without altering its volume until it is very nearly equal in weight to the water it displaces, when by means of propelling machinery and fins or hydroplanes it can be made to travel below the surface of the water at any desired depth consistent with the structural strength of the pressure tight hull. A certain amount of reserve buoyancy must, however, always be maintained to ensure its coming to the surface again in the event of the propelling machinery breaking down whilst submerged in deep water. There are times when it is imperative for a vessel of this description to rest on the ocean bed in shallow water and to effect this purpose a submersible vessel must be capable of increasing its weight until it becomes heavier than the water it displaces, in other words becomes non-buoyant and sinks to the bottom. It is upon this theory that all submersibles have been designed and constructed.

The first generally accepted as historical mention of a submersible structure having housed a human being is recorded in the Bible, where a certain man named Jonah lived in the belly of a whale for a certain number of days and was afterwards discharged or ejected on dry land apparently little the worse for his experiences. No mention is made, however, as to what methods were adopted to cause him to be ejected from the animal nor is it known if compressed air was used to this effect as is universally adopted in the discharge of torpedoes from modern submersibles. A whale being nature's most prominent submersible, a short survey of the methods adopted to dive will not be out of place. As a warm blooded mammal it is not provided with means of altering its buoyancy without interfering with its volume as is the case with the ordinary fish, and it has therefore to recourse to other methods. When desirous of diving the animal decreases its volume by contracting its muscles until the whole structure is practically equal in weight to the water it displaces and by means of its horizontally placed tail or rudder and short fins performs the double action of propelling itself forward and submerging at the same time. To reach the surface again the whale reverses the action of its tail and fins and at the same time gradually relaxes its muscles in direct ratio to the pressure of water on the outer skin. Thereby it slowly increases its displacement without altering its weight until the surface is reached, when all its muscles are completely relaxed and the mass is again buoyant.

A search through the historical records reveals that the first description and account of a vessel intended to submerge below the surface of the water is credited to an Englishman, William Bourne, in 1578. Bourne's vessel was intended merely to sink below and rise again to the surface in very shallow water as no provision appears to have been made to effect propulsion when submerged.

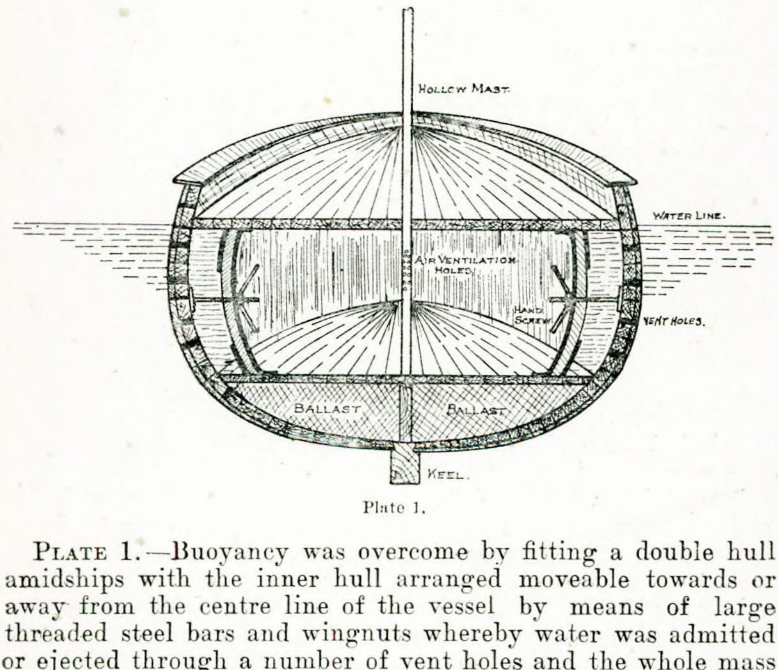


Plate 1.

Plate 1.—Buoyancy was overcome by fitting a double hull amidships with the inner hull arranged moveable towards or away from the centre line of the vessel by means of large threaded steel bars and wingnuts whereby water was admitted or ejected through a number of vent holes and the whole mass caused to submerge below or rise towards the surface at will. Leather packings were secured to the inner hull to form flexible

water tight joints. The first attempt to design and construct a submersible vessel with the intention of propelling it under water was undertaken by Van Drebbel, a Dutchman, in 1620. The vessel was constructed of wood, strengthened with iron, and covered with greased leather to ensure water tightness, buoyancy being overcome by the admission of water into the lower portion through a valve. Propulsion on the surface and when submerged was performed by means of 12 oars, arranged six each side, worked by human power and provided with greased leather hoods secured to them and the rowlocks to form flexible watertight couplings. Van Drebbel's Submersible is reported to have made several submerged trips at a depth of 3 feet, and history relates that the august monarch, James I., was present at an early trial trip, but it is easily conceivable that underwater navigation must have been exceedingly difficult owing to the action of the oars tending to cause the little vessel to rise and fall incessantly.

Several other types of Submersibles were constructed about this period, but as they were relatively copies of Van Drebbel's vessel are not considered worthy of particular mention.

The first Submersible, intended to be mechanically propelled in a submerged condition, was designed and constructed by De Son, a countryman of Van Drebbel in the year 1653. This vessel was 72 feet long, 12 feet by 8 feet amidships, tapering to a point at each end and provided with a peculiarly shaped paddle wheel, placed amidships, and driven by a clockwork mechanism to effect propulsion.

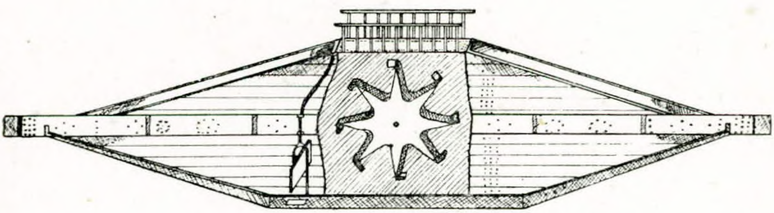


Plate 2.

Plate 2.—The inventor, however, in his calculations entirely overlooked the enormous differences in the specific gravities of air and water, as although the machinery was powerful enough to cause the paddle wheel to rotate freely before the vessel was

launched, no inducement would make it revolve in the water after the launching ceremony had been performed, and on this account the whole was declared a complete failure.

Years appear to have elapsed before any further attempts were made to construct a submersible, as it is not until 1747 that an Englishman, Symon by name, undertook further experiments with a new type of vessel. Symon resorted to oars as a means to propel his vessel under water and to overcome buoyancy, fitted a number of leather bottles with their openings secured to holes in the hull below the waterline. The design intended that when running on the surface the bottles were to be rolled up and secured, but opened and allowed to fill with water when a dive was desired. To rise to the surface again the bottles were to be squeezed out by hand and re-secured. Here again the inventor mis-calculated the design of his vessel as experiments after launching proved that the weight of water admitted into the ballast bottles was not sufficient to effect submergence. Symon, therefore, increased the ballast weights with the result that buoyancy was thereby completely overcome and the boat dived once and for all in deep water and became totally lost.

In 1775 the hard pressure of the British Fleet during the American War of Independence caused an American engineer, David Bushnell, to realise the necessity of a submersible type vessel to overcome the balance of naval power and to design the first all metal type Submersible. His little vessel was constructed of iron and caused to dive by the admission of water through a valve aperture in the bottom, whilst two hand pumps were provided to eject the water when a rise to the surface was desired.

Plate 3.—A small dome was fitted in the upper portion to form a conning tower with a compass to assist navigation and a depth gauge to verify the depth when submerged. Propulsion on the surface and when submerged was performed by means of a small horizontal hand-driven screw, situated forward, with an additional hand-driven vertical screw, placed in the upper forward portion, to assist in diving and rising. The vessel was designed with a warlike intent, and for this purpose a small detachable mine with clockwork firing mechanism was fitted in the after upper portion. Attached to it was a length of cord terminating at the other end in a small detachable auger operated by hand from the inside. Bushnell's intention was that the vessel should submerge, propel itself towards an enemy

ship, drive the auger into its under hull, release the mine and then propel itself quickly away to a safe distance whilst the mine exploded and blew up the hostile warship. The design only permitted one man to form the crew and the small volume

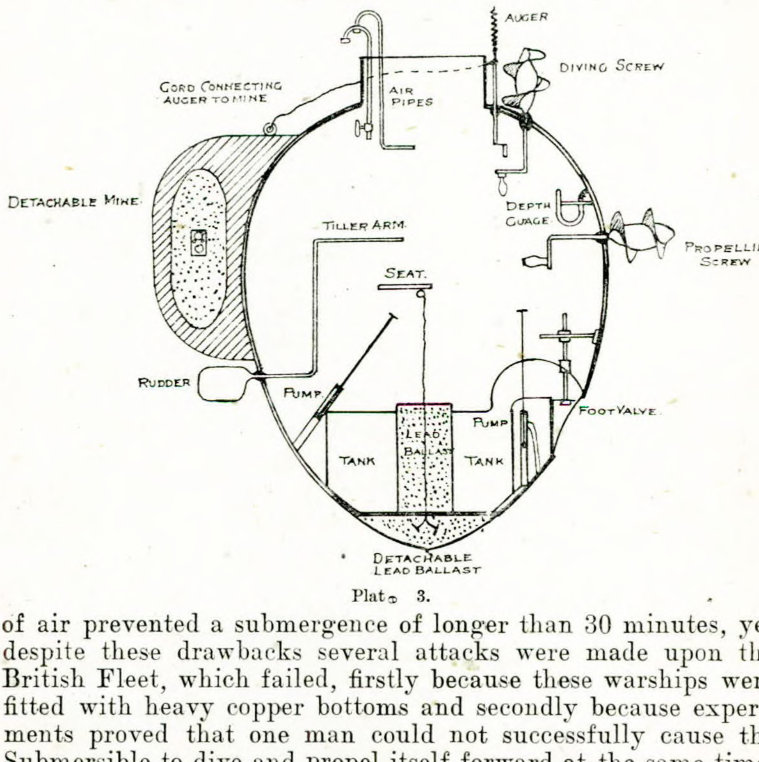


Plate 3.

of air prevented a submergence of longer than 30 minutes, yet despite these drawbacks several attacks were made upon the British Fleet, which failed, firstly because these warships were fitted with heavy copper bottoms and secondly because experiments proved that one man could not successfully cause the Submersible to dive and propel itself forward at the same time. It is interesting to observe, however, how later boats were built on quite the same lines, any improvements that may have taken place being mostly due to the general progress in engineering. Bushnell's experiments were advanced by another American, Robert Fulton, who from the first exhibited great inventive genius. His first Submersible, the *Nautilus*, laid down in the latter part of 1799 and completed in July, 1880, was 21 feet 3 inches long by 6 feet 6½ inches in diameter.

PLATE 4.—The hull, constructed of copper screwed to circular iron frames designed to withstand an external pressure of 25 lbs.

per square inch, had the shape of an imperfect ellipsoid. Below this hull was another metal hull 1 foot $6\frac{1}{2}$ inches deep terminating 3 feet from the bow in the shape of a curve to form a ballast tank designed to accommodate sufficient water to make the difference in weight of the whole vessel, and the weight of

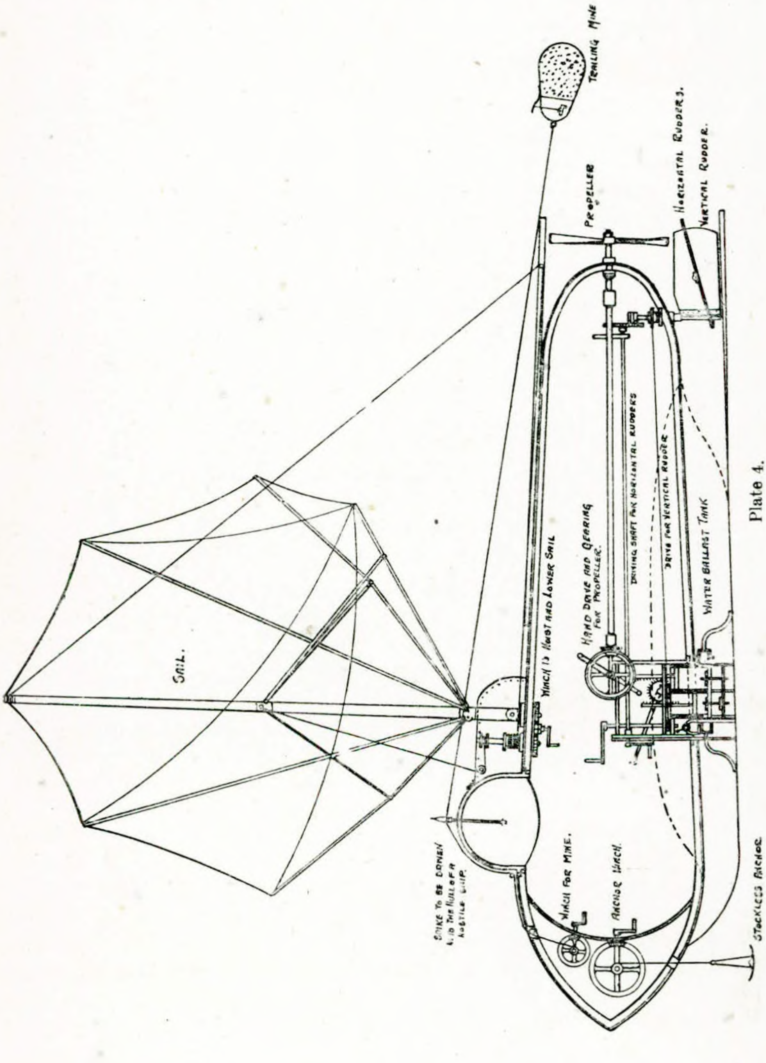


Plate 4.

water displaced by it not more than 5 kilograms. To eject this water a small hand-driven suction and force pump worked by lever pinion and racks was fitted. At the bow of the ellipsoid, on the upper surface was a metallic dome or conning tower pierced with sidelights of thick glass and furnished with a man-hole to serve as ingress for the crew and stores. A little over 3 feet from the bow a watertight bulkhead cut off a compartment housing the anchor gear, and a small winch, both of which were worked by shafts passing through stuffing boxes in the bulkhead. Propulsion was effected by means of a four-winged screw, 4·4 feet in diameter, designed to run at about 120 r.p.m. For propulsion on the surface and to save working the screw, a hinged mast was fitted having attached to it a fan-like sail furled by sheets on the ribs. Steering was effected by an unbalanced vertical rudder worked by a sprocket chain from a crank in the centre of the vessel. A second horizontal rudder was fitted hinged to a pin on the vertical rudder to maintain the vessel in a submerged condition whilst being propelled forward. It was actuated by a pinion working a sleeve on the vertical rudder shaft spindle. The crew consisted of three men, and the volume of air inside the vessel was sufficient to sustain them for three hours when under water. The attacking apparatus consisted of a trailing mine secured by a cord attached to the small winch forward and passing through a screw eye attached to the conning tower. The intention was for the *Nautilus* to be navigated under the keel of a hostile warship, the screw eye to be hammered into it and the Submersible then to travel forward until the trailing cord brought the mine into contact with the ship's bottom and was thereby exploded.

Fulton carried out several experiments in France clearly demonstrating the effectiveness of his Submersible and then offered to sell his invention to the French Government stipulating that he was to receive prize money for each English frigate sunk.

When he came before the French Admiralty, however, he was met with blunt refusal, one old bluff French Admiral saying "Thank God France still fights her battles on the surface, not beneath it," a sentiment which apparently has changed since those days, as France now has a large fleet of Submersibles. After several years of unsuccessful efforts in France to get his plans adopted, in 1804 Fulton was enticed over to England by William Pitt, then First Lord Commissioner to Great Britain.

Fulton built a vessel in England and succeeded in attaching a torpedo beneath a condemned brig, provided for the purpose, blowing her up in the presence of a large crowd of onlookers, and later carried out several unsuccessful attacks against the French Fleet but he was obliged to desist as the people in England were filled with indignation, not so much on account of his failures, but rather because they considered it was "An unfair method of fighting and against the laws of war." He then returned to New York and built the *Clermont* and other steamboats, but did not entirely give up his ideas on submarine navigation, for at the time of his death he was at work on the plans of a much larger type Submersible. Fulton's initiative and genius raised him to a level seldom reached by inventors and his efforts and ideas plainly show that he lived years before his time.

In 1850 during the war between Germany and Denmark, the rigid blockade enforced by the Danish Navy caused a Bavarian Artillery N.C.O., William Bauer by name, to turn his genius to the design and construction of a Submersible. Backed financially by several influential citizens, Bauer laid down the keel of his vessel at Kiel in 1850. The hull was constructed of sheet iron with ship-shaped iron frames, and when completed was 26 feet 6 inches long by 8 feet 6 inches broad amidships, with a displacement on the surface of $38\frac{1}{2}$ tons. Bauer christened his vessel *Le Plongeur Marin* (The Sea Diver) and adopted Fulton's method of propulsion, other than a sail, by fitting a 4-bladed screw aft, driven by hand-power through the medium of shafts and gearing.

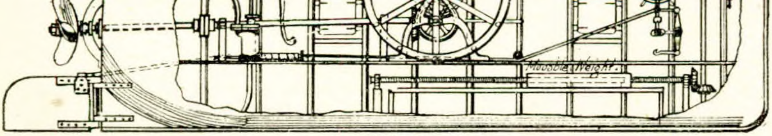


Plate 5.

PLATE 5.—A double bottom was fitted to form water ballast tanks into which water was admitted to cause the vessel to dive, with hand-driven pumps to eject the water when a rise to the surface was desired. His vessel varied little in general design from that of Bushnell or Fulton, except that inclination on

diving was increased by the moving of a heavy weight backwards and forwards. In December, 1850, Bauer carried out his first trials and was successful in causing the Danish Fleet to withdraw as the moral effect of a Submersible at that time was very great. In February, 1851, however, the little vessel was dived too deep, with the result that the pressure of water burst the sides in and the *Plongeur Marin* was lost.

Just about 57 years ago, civil war broke out in the American States over the question of the freedom of the slaves and as the Government of that country had allowed itself to become comparatively speaking, bankrupt, the navy became neglected, and both the Southern and Northern States lacked ships and men. The Northern States however quickly improvised a fleet by converting river steamers into warships by the addition of light armour plates and building other ships in the least possible space of time. With this quickly mobolised fleet they maintained a rigid blockade on the principal ports and rivers of the Southern States, who were forced to realise that while their surface craft would prove useless against this regime owing to their inferiority in numbers and armament, very sound naval defensive tactics could be established by a fleet of mine or torpedo carrying Submersibles operating in the near vicinity of those ports and rivers on which the enemy maintained the strictest blockade. At this time the steam engine had been universally adopted for the propulsion of ships, and it is not unnatural that the Southerners decided to instal this type of prime mover in their Submersibles, which owing to the biblical simile were christened " Davids."

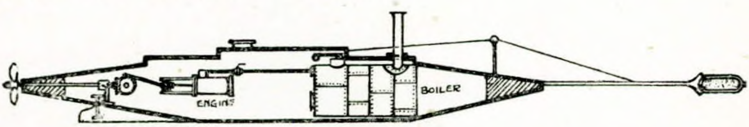


Plate 6.

PLATE 6.—The first of her type, laid down and completed in 1863, was circular in shape, tapering at each end to a fine point with a total overall length of 54 feet and a girth of 5 feet 6 inches amidships. Propulsion was effected by means of a small coal fired boiler placed forward and a single cylinder steam engine, situated aft, driving a propeller through a short shaft and bevel gearing. The combustion gases escaped through a short telescopic funnel which could be lowered to render the vessel less conspicuous when carrying out an attack. An entirely new and

very ingenious type of armament was fitted consisting of a copper cased torpedo 32 inches long by 10 inches diameter with hemispherical ends, housing 134 lbs. of gunpowder, the whole being mounted on a 32 feet long wooden spar rigidly secured to the bow of the vessel. The torpedo was provided with seven chemical fuses which exploded on impact with a hostile ship. For offensive purposes water was admitted into ballast tanks adjacent to the keel until the vessel was just awash. The effectiveness of this little vessel was considerably hampered by the fact that the endeavour to obtain high speed on the surface by the fitting of steam plant entirely eliminated any possibility of diving the boat and running completely submerged, because, had a watertight funnel hatch been fitted to render the hull watertight, propulsion under water would have been impossible for a longer time than the actual expansion of the steam already in the boiler could cause the engine to turn. Again the drawing of the fire would have filled the little vessel with smoke and sulphur fumes thereby rendering human existence under water impossible.

The first "David" was swamped on trials by a passing steamer causing a heavy swell to break over whilst the hatch was open and the officer was the only member of the crew saved. The Submersible was raised, however, and fitted out with a fresh crew who successfully attacked, in daylight, a Northern States ship which suffered considerable damage when the torpedo exploded, but the heavy column of water set up thereby again swamped the little vessel and only three of the crew escaped with their lives.

In 1864 the wooden ship *Houstanic*, attached to the Northern States Fleet, was attacked and sunk by a similar type of Submersible which foundered and sank when its torpedo exploded. Some years later divers were sent down to ascertain the damage done to the *Houstanic* and reported that a "David" was lying alongside at the bottom with the remains of the crew of nine men still inside. It was then discovered that the Submersible, although similar in external design to the steam driven "Davids" was in this instance driven by hand-power through a series of cranks arranged on the same shaft attached to a propeller, further that hydroplanes were fitted forward to assist underwater navigation.

During the progress of the war several other ships were attacked by "Davids" and although their record cannot be regarded as particularly good they clearly proved that the Submersible was destined to play a great part in future naval wars.

The greatest impetus towards solving the mastery of under-water navigation in its earlier stages was given by an American Engineer, Alstitt, who designed and built at Mobile, U.S.A., in 1863, the first Submersible to be fitted with two means of propulsion, viz., steam on the surface and electricity under water.

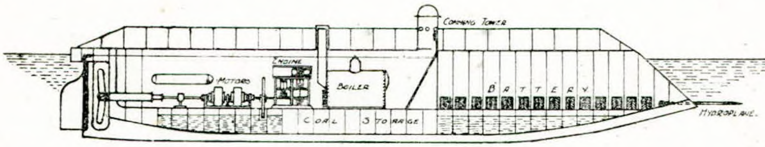


Plate 6A.

PLATE 6*a*.—His vessel was 21 metres long by 3 metres high, with its hull divided horizontally by a deck of thick sheet iron beneath which were two water tanks placed fore and aft and minutely sub-divided whilst the spare middle part was utilised as a coal storage space. The stern compartment above this deck housed two electric motors to propel the vessel when submerged and a steam engine for surface work. The boiler was situated in the centre of the vessel, the funnel being placed in a small tower which whilst diving could be hermetically closed. A small conning tower to which access was gained by a ladder was fixed in the upper centre portion, and provided with strong port-holes to enable a good all-round look-out to be maintained. Before diving the telescopic funnel was drawn down into the tower and the cover closed, the fires put out, all pressure of steam blown off, the steam engine disconnected and the motors geared on to the propeller shaft. The motor was then started and the vessel forced underwater by means of the hydroplane fixed in the bows. The armament consisted of large watertight cases of powder arranged along each side of the vessel and secured by iron chains connected with the interior. These mines were so constructed that they rose to the surface, their buoyancy being sufficient to sustain the weight of powder contained in them. When in contact with a hostile ship they could be fired electrically and in the event of the vessel to be attacked being under way the Submersible could scatter contact mines in its path, the mines being recovered and taken aboard again in the event of their not being exploded. The weakest part of Alstitt's vessel was the hydroplane which could never be expected to work satisfactorily, whilst the outward form of the hull is not one that lends itself readily to underwater navigation, but whatever its faults there is no doubt that his Submersible marks an epoch in the design of underwater craft, the wonder being that so many inventors who came after him did not realise the great possibilities of his ideas. It is just possible that in common with so many of the earlier type vessels the inventor kept the particulars of his design secret and thus prevented other engineers taking advantage of his ideas and improving on them.

About the same period, Captain Bourgois, an Officer in the French Navy interested himself in the study of underwater craft, and after giving the subject due consideration and thought came to the conclusion that the difficulties then experienced with steam driven Submersibles could be overcome to a great extent by substituting compressed air for steam. He placed his schemes before the French Government who realised the possibilities of his suggestions and at once invited designs for a vessel of this type from the leading engineers and shipbuilders of the day. The plans of a Monsieur Brun were finally accepted and the necessary financial approval having been obtained a Submersible with a length of 140 feet by 20 feet broad and 10 feet deep and a surface displacement of 420 tons was laid down at Rochefort and launched in 1863.

PLATE 7.—On top of the vessel was a superstructure, with a hollow to take a detachable boat. In the after end of the superstructure was a small hatch used when in harbour and in front of this a conning tower 5 feet high with a hatch on top which formed the only exit when the vessel was on the surface. A regulating cylinder was fitted in front of the conning tower with a piston to take in or expel water and thus alter the displacement slightly at will. The propelling machinery comprised an oscillating cylinder type engine driven by compressed air at 180 lbs. per sq. inch stored in 23 sheet steel flasks with a total capacity of 147 cubic metres. No arrangement was fitted inside the hull to load the air service and the vessel had therefore to return to harbour to be re-charged when the supply in the flasks gave out. The engine was capable of developing 80 h.p. at 180 lbs. pressure of air and was found to work very well under all conditions. The trials revealed that the engine was capable of imparting a speed of five knots per hour when running on the surface but no figures could be obtained when submerged, as the vessel behaved too erratically to allow of an even keel being maintained. The greatest difficulty was the

LE PLONGEUR

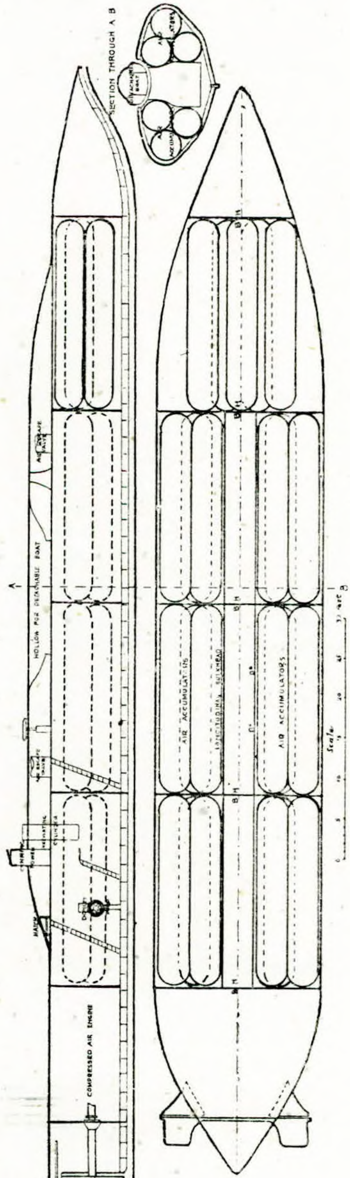


Plate 7.

regulation in the vertical sense as the vessel would often touch the bottom at 30 feet and rebound before the regulating cylinders and hydroplanes could be readjusted. With the object of improving the stability of the vessel when travelling submerged, Brun fitted a small horizontal propeller driven by a compressed air engine, to assist the diving rudders, but further trials revealed that this addition had made very little improvement, and as the high pressure air service was constantly leaking and causing thereby extreme physical suffering to the crew, the French Government declared that the experiment was not sufficiently successful to warrant the building of further Submersibles of this type. Bourgois evidently overlooked the low efficiency of the compressed air engine, and the engineers of that period do not appear to have reached the present day standard as modern Submersibles are fitted with steel bottles containing air compressed to 2,500 lbs. per sq. inch.

One does not usually associate the Church with Submersible Construction, and yet in 1878, Mr. Garrett, a Manchester curate, busied himself with the study and had built to his own designs a small Submersible 14 feet long by 5 feet maximum diameter with an egg shaped hull tapering at each end to a point. In general, Garrett appears to have copied Fulton's ideas, as his vessel was dived by the admission of water into special ballast tanks placed in the lower portion, caused to rise by pumping this water overboard, and propelled by a hand driven propeller in the stern.

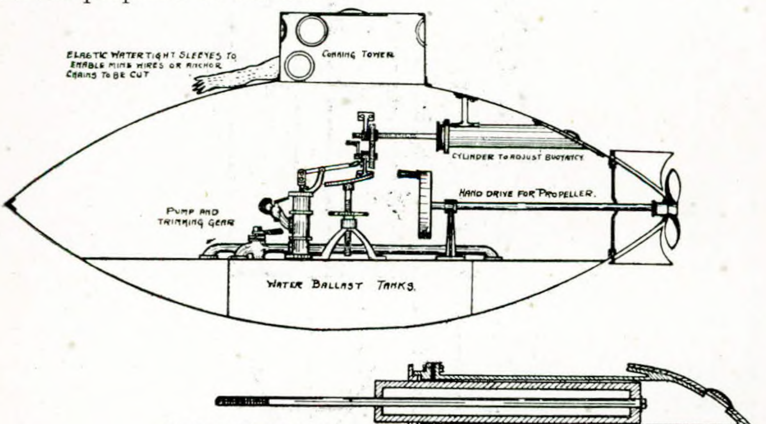


Plate 8.

SUPER-SUBMERSIBLE TORPEDO BOAT.

PLATE 8.—The principal amendment was the substituting of a metal cylinder and air-tight piston for the diving rudder or hydroplane. This cylinder was placed in the after upper portion and increased or decreased the weight of the stern as the piston was moved towards or away from the centre of the vessel whereby water was admitted into or ejected from the tube and the displacement and diving angle varied accordingly. This procedure was admittedly crude in comparison with Fulton's hydroplane, but found to answer well in actual practice. The first trials, carried out in Liverpool Docks, clearly showed Garrett that any attempts to construct a Submersible which did not allow of sufficient natural air in the interior hull to support human life for several hours would prove abortive, and he thereupon decided to construct a much larger type and entrusted the building to Messrs. Cochrane of Liverpool in 1879. The maximum diameter of 5 feet was adhered to, but the length was increased to 45 feet, and the hull made cylindrical instead of egg-shaped.

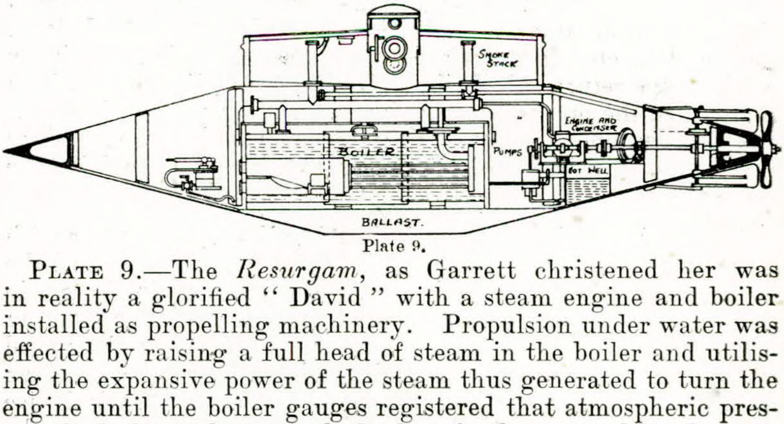


Plate 9.

PLATE 9.—The *Resurgam*, as Garrett christened her was in reality a glorified "David" with a steam engine and boiler installed as propelling machinery. Propulsion under water was effected by raising a full head of steam in the boiler and utilising the expansive power of the steam thus generated to turn the engine until the boiler gauges registered that atmospheric pressure had almost been reached when further propulsion became impossible. It is understood that this procedure enabled the *Resurgam* to travel about ten miles under water in about three hours, but as the vessel was lost off the Welsh coast whilst undergoing deep sea trials, no definite information is available. The temperature inside the hull when submerged must have been terrific, and it is more than likely that the crew were overcome by the heat and fumes from the furnace when the vessel was lost. Although a complete failure from a Submersible point of view the general design of the *Resurgam* showed a

considerable improvement on any previous vessels as the conning tower was large enough to accommodate the steering wheel as well as one member of the crew, and was provided with a light superstructure round about it to form a wavebreaker and thus lessen the resistance under water. After the loss of this vessel, Garrett, for advice and further help approached Mr. Nordenfelt, the gun expert, who became extremely interested and decided to afford him every possible help to pursue the study of underwater craft. At this period the locomotive torpedo had passed through its experimental stages and Nordenfelt was one of the first to realise the enormous warlike possibilities of a Submersible armed with this new weapon. The chief difficulty lay in producing a satisfactory method of launching the torpedo from a tube which would always be under water, but this trouble was finally overcome by introducing mechanical means.

Nordenfelt laid down his first Submersible at Stockholm in 1884 with a length of 64 feet, a maximum beam of 9 feet and a displacement of 60 tons. A 100 h.p. reversible compound steam engine connected to a surface type condenser and an ordinary marine type return tube boiler steaming at 100 lbs. per sq. inch constituted the propelling machinery. Motive power when submerged was obtained by storing steam in two large pressure chambers and utilising the heat released therefrom to drive the engine.

Plate 10.—The vessel was designed to lie on the surface with its conning tower and 3 feet of its upper structure out of the water, but a 4-ton water ballast tank was arranged in the centre which when filled caused the vessel to sink until the conning tower formed the only reserve buoyancy. To force the vessel under water statically two small horizontal propellers driven by 6 h.p. steam engines in conjunction with an automatic device consisting of a valve and lever actuated by the pressure of the sea water, which opened and closed the controlling steam valves on the engines, were provided. This combination automatically regulated the depth of immersion; if the vessel dived too deeply the pressure of the sea water on the valve and lever stopped the engines driving the horizontal propellers until such time as the reserve buoyancy had caused the vessel to rise to the regulated depth when the engines were again slowly started to counteract the upward direction. The trials were carried out on the Sound of Landskrona in 1885 when it was found that the propelling

SUPER-SUBMERSIBLE TORPEDO BOAT.

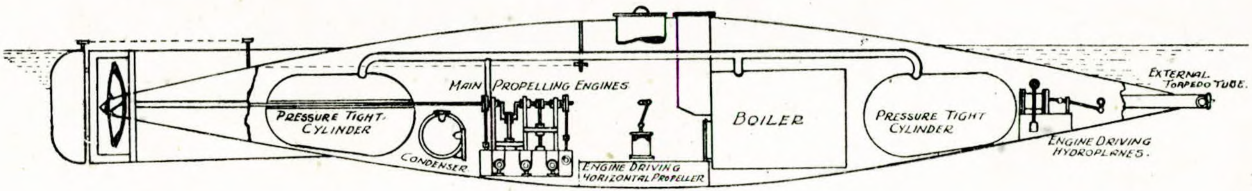


Plate 10.

machinery was capable of imparting a speed of five knots on the surface with all hatches open and a speed of four knots for three hours with the hatches closed and the vessel in diving trim. The Greek Government invited Nordenfelt to carry out further trials in the Bay of Salamis, and as these proved successful purchased the vessel in 1886 for £9,000 sterling.

In 1887 Mr. Nordenfelt secured an order for two Submersibles from the Turkish Government, which were completed and handed over, and in 1887 a further order from the Russian Government. Several minor improvements were made to these boats, but as the same methods for propulsion were adopted it is not proposed to consider them in detail. France has led Europe in naval designs for many generations, and it is not surprising therefore that, despite the experiments carried out in 1868 by Alstitt, the credit for successfully introducing the electrical system of propulsion for Submersibles must really be given to Mr. Claude Goubet, a French Civil Engineer, especially if, as already stated, it is possible that Alstitt's experiments were not publicly known at this period.

Goubet's first vessel was laid down in 1884 with a length of 16 feet 5 inches, a maximum width of 5 feet 10 inches and a displacement of 11 tons. The idea of building so small a Submersible was that it would be hoisted on board a battleship and made use of when the opposing fleets came to close quarters.

Plate 11.—The hull was of bronze pointed at both ends with a circular shape amidships, and had amidships a conning tower provided with 7 in No. ½ inch thick plate glass port-holes and a small hatch with rubber packing to render it pressure and watertight. The crew consisted of two men who sat back to back, and in this position were able to maintain control of the whole mechanism. To propel the vessel Goubet provided a small Siemens electric motor and a storage battery of Laurent-Cely cells, but no details regarding their sizes and outputs appear to be available. Specially constructed oars were provided, however, to form a standby in the event of the electrical gear failing. Submergence was effected by admitting sea water into two ballast tanks situated in the lower hull and a small pump driven off the propeller shaft through a clutch was provided to empty these tanks when a rise to the surface was desired. A very ingenious method was fitted to maintain the little vessel on an even keel when travelling submerged, which pumped a small quantity of water backwards and forwards between two

SUPER-SUBMERSIBLE TORPEDO BOAT.

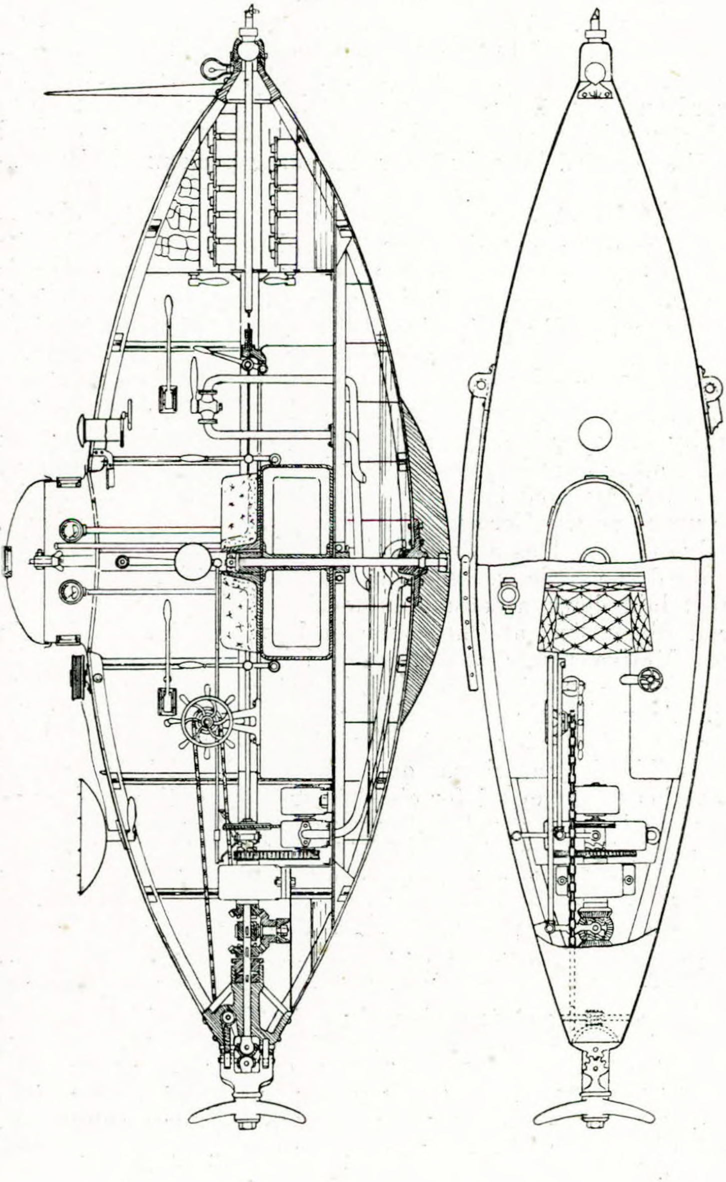


Plate 11.

small trimming tanks, placed fore and aft, through an electrically driven rotary pump, started, stopped and reversed by the action of a weighted pendulum suspended in the centre of the inner hull. If the bow dipped down, the pendulum swung forward and caused the starting switch to run the motor up to speed in one direction, whereby water was immediately pumped from the forward into the after trimming tank until the pendulum hung straight down again and the motor was stopped. If the stern dipped down the pendulum swung aft and water was pumped from the after into the forward trimming tank by the same means. In actual practice, however, this mechanism was not found to respond quickly enough to ensure an even keel being automatically maintained, a fact not to be wondered at when one compares the sinking velocity set up by the resultant of the propelling machinery and gravity with the time limit that must necessarily be allowed to elapse before a sufficient quantity of water had been pumped from one trimming tank into the other to re-instate stability in the lengthwise direction. An electrically fired immobile mine secured detachable to the after upper portion formed the only armament. Although not exactly successful as a Submersible the Brazilian Government purchased the little vessel from Goubet for £10,000 sterling. Goubet laid down a second Submersible with slightly larger overall dimensions at Cherbourg in 1886 and launched it in 1889. Motive power was provided by 24 Laurent-Cely cells and a Siemens traction type electric motor taking 9 amps at 48 volts. Assuming that its efficiency was about 69 per cent., the motor must have developed about half a horsepower. As a Submersible this vessel was quite successful and it is reported to have been submerged for eight hours consecutively, a by no means small feat for such a tiny vessel with a crew of two men. In general, however, the vessel did not fulfil the requirements laid down by the French Government, and Goubet was obliged to sell it to a private enterprise at a great loss. Although Goubet's efforts at that time were considered hopeless failures, modern engineers look upon his works with pride as they gave an enormous impetus to other inventors who followed in his wake in an endeavour to design a vessel which would ultimately conquer the laws of nature so far as the under-sea is concerned. Almost simultaneous with Goubet's first experiments in France, two Britishers, Messrs. Ash and Campbell, put forward designs for an electrically propelled Submersible of special interest, as it was the first of its type to be fitted with twin propellers. The building was entrusted to Messrs. Wolseley and Lyon, and the vessel when launched had an overall length of 60 feet, a maximum diameter of 8 feet, and a submerged displacement of about 50 tons. Out of respect to Fulton's efforts the inventors christened it the *Nautilus*.

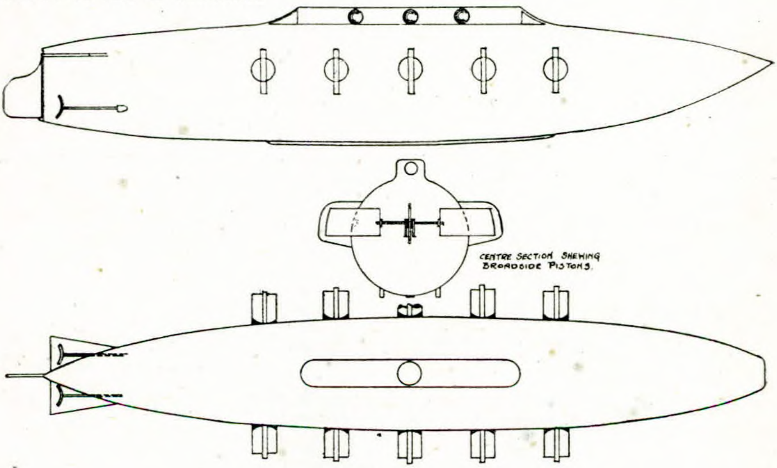


Plate 12.

PLATE 12.—The hull was built up out of 5/16 inch Siemens Martin steel rivetted to circular shaped frames placed 1 foot 9 inches apart. The propelling machinery consisted of two Edison-Hopkinson electric motors, capable of developing about 13 h.p. at 104 volts and an Elwell Parker storage battery consisting of two sets of 52 cells each coupled in parallel. To enable the vessel to overcome buoyancy the designers fitted five broadside cylinders on each side of the hull very much after the style patented by Garrett in October, 1878. The propelling machinery was calculated and designed to produce a surface speed of eight knots and a radius of action of about 80 miles.

The trials were carried out in the Tilbury deepwater dock in 1888, the vessel submerged quite successfully, but did not appear on the surface again until long after the specified time. It was then ascertained that when the broadside pistons were drawn in, the vessel sank too quickly and embedded itself in the mud at the bottom of the dock. As the moving of the pistons outwards did not cause it to rise, the occupants were instructed to pass quickly from one extreme end to the other to allow of the bow and stern in turn being lifted out of the mud.

This wheeze had the desired effect and the vessel was brought to the surface by its reserve buoyancy. Further trials were not undertaken as the vessel turned out to be a complete failure. In 1886 a Mr. Waddington, carried out a number of useful experiments at Seacombe, near Liverpool, with an electrically propelled Submersible 37 feet long with a maximum beam of 6 feet 6 inches. An electric motor with an output of 8 h.p. and a storage battery of 45 accumulators of the Electric Company's make were installed to drive the propeller. The method adopted to control the *Porpoise*, as Waddington christened the vessel, in the vertical sense, was similar to that invented by Nordenfelt, inasmuch that horizontal propellers were fitted to overcome the reserve buoyancy when diving and hydroplanes to maintain an even depth when running submerged. Although the *Porpoise* was a decided success as a Submersible, the design was not repeated.

Plate 13.—Several other electrically propelled Submersibles were constructed about this period, but as the methods adopted to effect propulsion were in each case almost identical, it is not proposed to enter into their respective designs and details.

It has been shown that in the earlier stages Submersibles were propelled by hand until the advent of the steam engine and the electric motor, and that an American engineer, Alstitt, in 1863, was the first to instal two separate prime movers to effect propulsion on the surface and when submerged. Further, that for several years after Alstitt's experiments a large number of other inventors carried out trials with Submersibles in which only one type of prime mover was installed, which fact proves almost conclusively that either Alstitt's work had not been made public or that his efforts were not given the full significance they deserved. Great credit for stimulating and advancing the evolution of underwater craft must therefore be given to another American, George Collins Baker, who introduced in 1893 a peculiarly shaped vessel fitted with a steam engine and boiler for surface work and an electric motor and storage battery for underwater navigation. In putting forward his claims, Baker stated "In a submarine boat, the combination with a steam generator, a steam engine supplied from said generator, a driving shaft having propellers and gearing between the engine and the shaft, a dynamo geared with the engine and also adapted to be geared with the main shaft and electrical storage batteries and connections between the batteries and connections between

SUPER-SUBMERSIBLE TORPEDO BOAT.

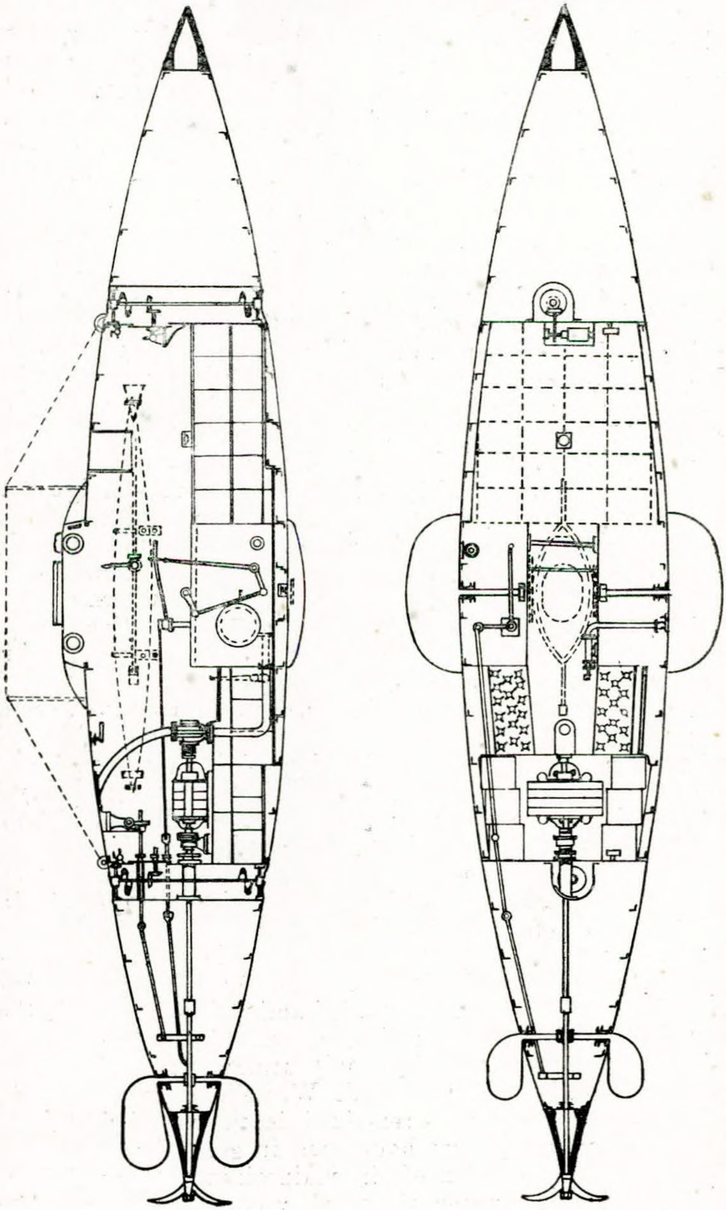
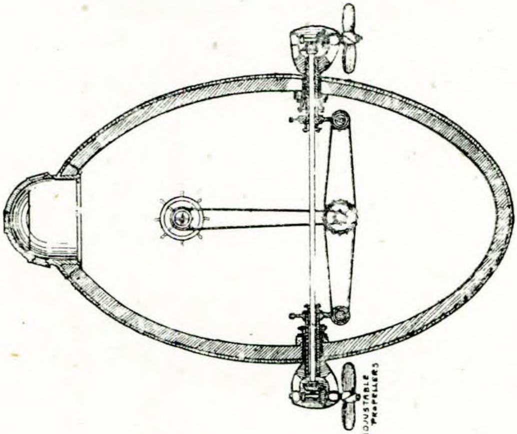


Plate 13,

the batteries and dynamo whereby the latter may be used to charge the batteries when run by the engine or may be used to drive the main shaft when supplied with current from the batteries substantially as described.

PLATE 14.—This " red tape " language implies that for propulsion on the surface a steam engine and boiler were provided to drive the propeller shaft through a gearing, for propulsion underwater an electric motor and secondary storage battery were installed, also driving the main shaft through a gearing, in each case a clutch being erected to allow of either or both of the prime movers to be connected to or disconnected from the propeller shaft. Further, that if the vessel were running on the surface and driven by the steam plant, the motor could be used as a dynamo to charge the battery. Baker's little vessel was 40 feet long, 14 feet in beam, with a surface displacement of 75 tons. The elliptical-shaped hull was constructed of oak, 6 inches thick, covered with waterproof cloth and designed to withstand an external pressure of 75 lbs. per sq. inch. The most ingenious feature introduced was the fitting of port and starboard propellers amidships driven by bevel gearwheels so arranged that they could propel the vessel ahead, astern or force it under water without in any way altering the direction of rotation of the prime mover. A small conning tower was fitted in the centre upper portion provided with glass scuttles for navigation purposes and a water-tight hatch to serve as entrance or exit for the crew. The engine was of the Willard marine type fitted with reversing links, developing 35 h.p., the necessary steam being supplied from a Roberts ordinary marine type boiler tested up to 220 lbs. per sq. inch. A small Worthington duplex pump was also provided to feed the boiler. The electric motor of the Jenney type was capable of developing 50 h.p. at 900 r.p.m. with 200 volts and the storage battery consisted of 232 Woodward cells arranged in four groups of 58 cells each with two groups electrically coupled in parallel. The starting, stopping, reversing and speed regulation of the motor was effected by a small controller, placed amidships, in conjunction with galvanized sheet iron resistance coils situated in the forward part of the vessel. The only armament consisted of a single torpedo tube firing a small Whitehead type torpedo. During the trials two men remained in the vessel when submerged for very nearly two hours, but in general owing to the great difficulties experienced in maintaining an even depth when running under water, the whole was not a success. Had

SUPER-SUBMERSIBLE TORPEDO BOAT.



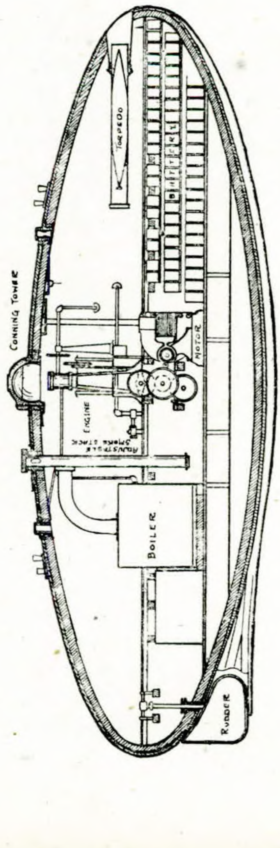


Plate 14.

Baker made his diving arrangements a distinct and separate feature without any connection with the propelling mechanism, then in all probability his Submersible would have been successful.

No paper dealing with the subject of Submersibles would be complete which did not make specific mention of the two great Americans, Messrs. S. P. Holland and Simon Lake, to whose great inventive genius, initiative, determination and undaunted courage in experimental work is due the great efficiency, seaworthiness and offensive power of the modern Submersible. Mr. S. P. Holland was originally a schoolmaster in Ireland, from which country he was expelled on account of his political beliefs. On arrival in the United States he became associated with the Fenian Societies and from them obtained the necessary capital to enable him to pursue the study and construction of underwater craft. After carefully noting the development of the armoured ships in the British, American and French Navies it occurred to Mr. Holland that the sea water could be used as a covering protection against an enemy's projectiles, and with this object in view devoted himself seriously to the study of underwater craft.

He started on a thorough study of the matter with a rough design on a sheet of paper giving due attention to the essential points concerned in producing a Submersible that would be practicable to live in and work efficiently under water in all weather conditions. A good engineering knowledge enabled him to calculate the thickness and weight of a spindle-shaped steel hull capable of withstanding the external pressure of seawater at a depth of 200 feet and to determine the change of trim required to regulate its degree of submergence. After completing his design, however, he was regarded as a dreamer, and accordingly deposited his plans in a safe place and dismissed the subject from his memory for the time being. During the winter of 1872, he slipped on the iced pavement in Boston and broke his leg, which accident necessitated him spending two months in hospital until the bone was knitted together again. Finding so much idle time on his hands he procured his old plans and commenced to study them again. It was not until four years later that he succeeded in obtaining sufficient financial backing to place his inventions to a practical test, and in 1878, launched his first Submersible at Paterson, New Jersey. It displaced about 4 tons and was propelled by a small steam engine and handled by one man who for safety reasons was dressed in a diver's suit filled with compressed air. Holland made several successful trials with this little vessel, and with the experience gained thereby commenced the design and construction of a larger vessel which he launched in 1881. It was 31 feet long, 6 feet beam, 7 feet 4 inches in depth and propelled by a Brayton petrol engine.

PLATE 15.—Its crew consisted of three men: the pilot, engineer and gunner. The first run on the surface, and whilst submerged, was made in the basin east of Lehigh Valley Railroad, Jersey, and proved the engine, clutch and gearing, etc., to be quite satisfactory. Later Holland carried out a great number of tests with this vessel, which he christened the *Irish Ram*, including the firing of torpedces 6 feet long out of a tube by means of compressed air. In 1883 the vessel was swamped at New Haven, Connecticut, and although recovered was abandoned. Holland then obtained a position as draughtsman with the Pneumatic Gun Company, and whilst there became acquainted with several influential gentlemen who were instrumental in placing his inventions before the United States Navy. As a result he built a third Submersible at Fort Hamilton in 1886 with a length of 60 feet and a beam of 6 feet. The hull was constructed of wood, but during the launching as soon as the Submersible commenced to move the ways broke down, and the little vessel was crashed into some obstacles near the waters edge and completely wrecked. Several other vessels were built and experimented with, and in 1893 Holland placed the designs of an entirely new type before the U.S. Navy and received the award based on a guarantee of performance. In 1895 he received instructions to proceed with the construction of a larger vessel, which was christened the *Plunger*.

PLATE 16.—The length overall was 85 feet, the diameter 11 feet 6 inches, the surface displacement 154 tons, and the submerged displacement 168 tons. The motive power consisted of triple screws, two of which were driven by triple expansion steam engines developing 1625 i.h.p., and the third by an electric motor developing to 70 h.p. The armament was two tubes and five Whitehead torpedoes. The enormous steam power that the authorities endeavoured to obtain rendered the boat uninhabitable for the crew and the *Plunger* was abandoned. Whilst the *Plunger* was under construction the eighth Holland Submersible was laid down with a length of 53 feet 10 inches, a diameter of 10 feet 3 inches, and a surface displacement of 75 tons.

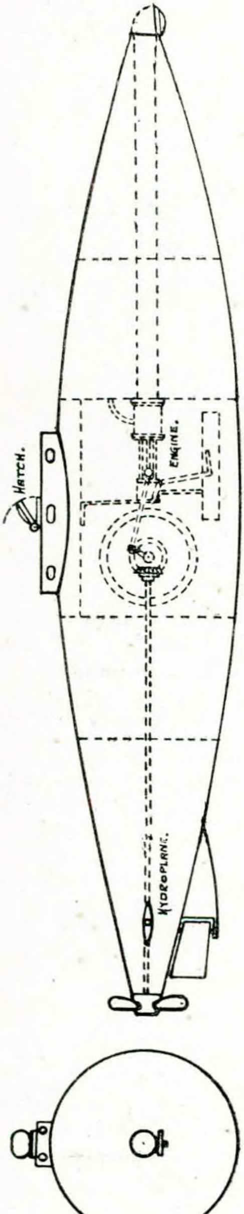


Plate 15.

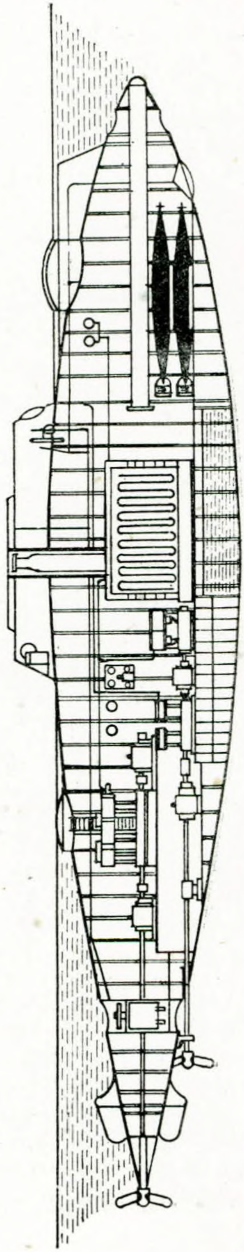


Plate 16.

PLATE 17.—Its propelling machinery comprised a single screw driven by a 50 h.p. Otto cycle petrol engine for surface work and an electric motor and battery consisting of 60 cells for submerged conditions. The trials of this vessel were a complete success in every way and it was sold to the U.S. Government for £30,000. In 1899 Mr. Holland joined the Electric Boat Company of New York, who built a large number of improved type Submarines for the American Navy but left them in 1904, after serving five years. He died on August 12th, 1914, just at the beginning of the Great European War, and consequently did not live to see the fulfilment of his prophecy that the Submersible would prove the superior of the battleship if ever they became opponents in actual warfare. There is no question, however, but that it is due to his initiative perseverance and bravery that the underwater type of war vessel was adopted by the

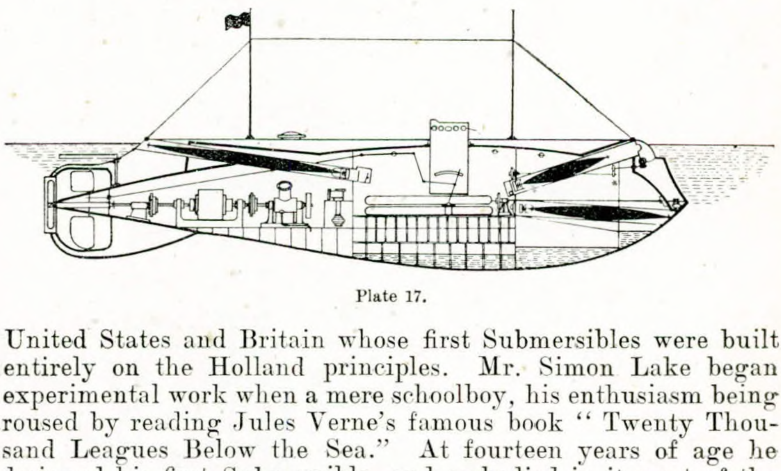


Plate 17.

United States and Britain whose first Submersibles were built entirely on the Holland principles. Mr. Simon Lake began experimental work when a mere schoolboy, his enthusiasm being roused by reading Jules Verne's famous book "Twenty Thousand Leagues Below the Sea." At fourteen years of age he designed his first Submersible, and embodied in it most of the elements successfully used to-day in the "Lake" type vessels. The plans were submitted to his father for perusal, but had cold water thrown on them, with the paternal advice that great engineers had already unsuccessfully tackled the subject and that the youngster would be well advised to confine himself to his school studies. Lake, therefore, did not pursue his endeavours until 1892 when, his attention having been drawn to an advertisement of the U.S. Government inviting engineers to submit Submersible designs to the Navy Department, he took up the

 EVOLUTION IN PROPULSION OF MODERN SUPER-SUBMERSIBLE TORPEDO BOAT.

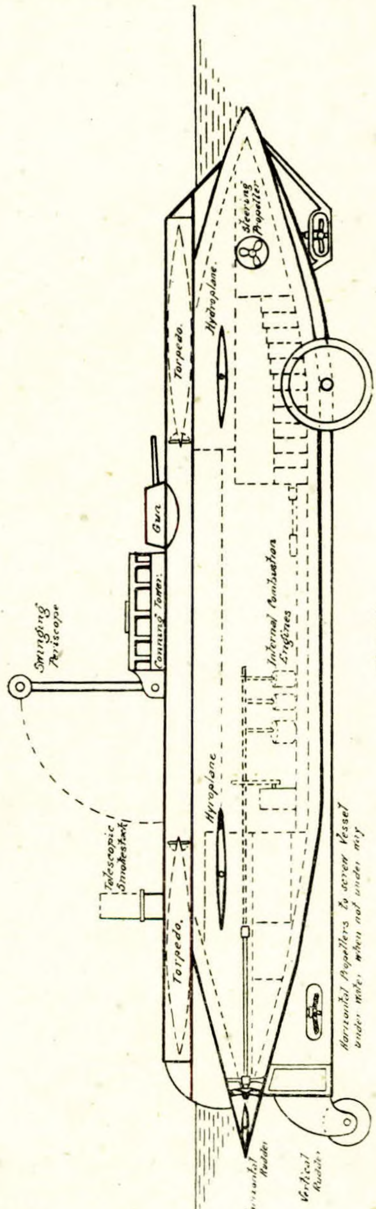


Plate 18.

study again, and in June, 1893, personally presented the plans of a Submersible to meet requirements at Washington, depositing them in the usual way.

PLATE 18.—Some time afterwards he received a telegram from the New York Tribune, stating that it had been informed that the Navy Board viewed his design very favourably and intended to adopt his type of vessel. Later Lake learnt to his great disappointment that the Board had been unable to come to a decision as to whether or not the construction of such a vessel should be commenced and that the matter had been shelved for the time being. Lake pressed his application and experienced the usual high-handed manner of Government Officials, who pushed him from one to another without really attempting to investigate his invention. The Navy Department treated him the worst, his enthusiasm was "pooh-poohed" all round, and finally the young inventor walked out vowing never to return unless sent for; a vow he most loyally kept. Realising the utter hopelessness of the Government Officials so far as interest and assistance were concerned, Lake in 1894, financed by his uncle and aunt, started experimenting on his own account by building his first vessel, the *Argonaut Junior*.

The hull was constructed of yellow pine planking, double thick, lined with canvas laid between the double layers of planking, the outer seams being caulked. No attempt was made to ensure the hull being capable of withstanding great external pressures, as the little vessel was intended primarily to submerge in shallow water and then travel along the bottom on three wheels, placed two aft and one forward, driven by a man turning a crank inside, the power being transmitted to the wheels by light chains. Several successful trips were made with this vessel and Lake had no difficulty in obtaining sufficient capital in 1897 to commence the construction of a larger type, 36 feet long and 9 feet in diameter, which he christened the *Argonaut*. This was the first Submersible to be successfully operated with an internal combustion engine, which developed 30 h.p. with petrol as fuel and drove a single propeller.

PLATE 19.—Two toothed wheels were fitted forward, driven through gearing, with a wheel attached to the rudder shaft to permit navigation in any direction on the sea bed. A divers' compartment was fitted forward to enable divers to leave or enter the vessel when submerged, to visit wrecks or recover shell fish. Electric lighting was installed throughout, the necessary current

being obtained from a small storage battery. The *Argonaut* was a complete success in every way, and in 1898 Lake decided to convert it into a sea-going vessel by fitting an outer ship-shaped hull and thereby increase its buoyancy and enable it to rise with the seas. The length was accordingly increased to 56 feet and a light superstructure fitted, open to the sea when

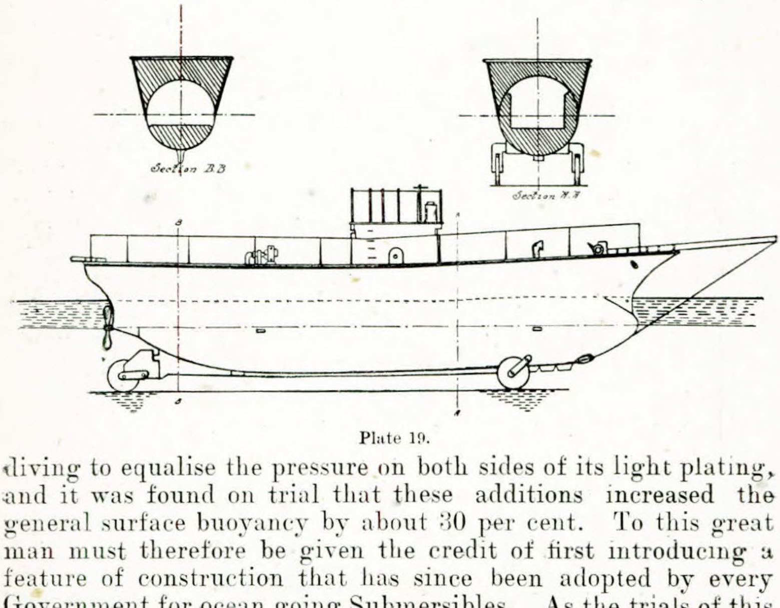


Plate 19.

diving to equalise the pressure on both sides of its light plating, and it was found on trial that these additions increased the general surface buoyancy by about 30 per cent. To this great man must therefore be given the credit of first introducing a feature of construction that has since been adopted by every Government for ocean going Submersibles. As the trials of this vessel were highly successful in 1901 Lake constructed a further vessel, the *Protector*, with much greater buoyancy, seagoing conditions and radius of action. Its length was 65 feet 6 inches, beam 14 feet 2 inches, displacement on the surface 136 tons and submerged 174 tons.

PLATE 20.—Wheels were again fitted to permit of travelling along the bottom, but in this case they were not power driven. Twin screws were fitted, driven on the surface by 120 h.p. four cycle, four cylinder petrol engines, and submerged by electric motors developing about 42 h.p. at 110 volts when taking current from a Gould type storage battery of 60 cells, having an output of 1,680 ampere hours at the three hour rate. Lake arranged the two prime movers in a straight line with their propeller shafts and fitted a coupling between the engine and motor

and an additional coupling between the motor and propeller shaft. When running on the surface driven by the engines both couplings were inserted and the motor armatures allowed to revolve idly as flywheels or made to generate current to charge the battery. When running submerged the engines were uncoupled and the propellers revolved by the motors only, and when charging the battery in dock the propeller shafts were uncoupled and the motors driven by the engines as dynamos in the usual way. The *Protector* on trials developed a surface speed of 10 knots and a submerged speed of $6\frac{1}{2}$ knots, and proved itself

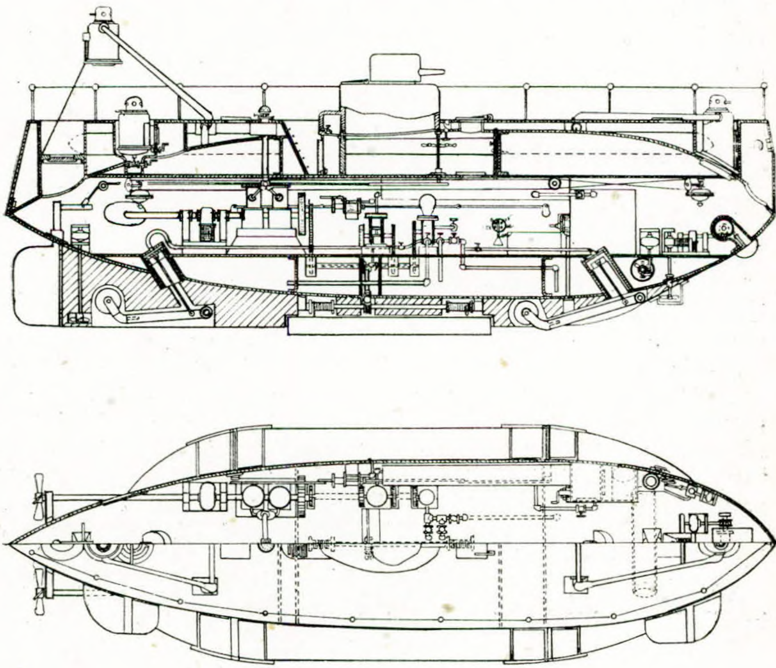


Plate 20.

to be a most reliable vessel, so much so that the American Navy Board condescended to admit that in their opinion it was a most efficient type of Submersible extant for attacking minefields and recommended in consequence of its conclusions that five in number of these vessels be purchased for use in submarine defence. Thus did Simon Lake by his own endeavours and perseverance faithfully maintain his vow, and at the same time place himself to be reckoned amongst the greatest engineers of the day. To-day the "Lake" type Submersible is largely used in the American and "other" navies as the following will show. When Krupps of Germany took up the construction of Submersible Torpedo Boats they decided to work on Lake's designs, as they considered them to be the most efficient, and accordingly entered into a contract with the Lake Company, which was accepted by wire from Germany. The contract covered the erection of plant in Russia for the manufacture of "Lake" type Submersibles on a division of the profits and also the construction of similar vessels in Germany on a royalty basis, it further covered the inventor's employment in an advisory capacity. As a result Lake submitted to Krupps various plans, copies of patents and even secret data to enable them to go ahead as the matter was urgent and the acceptance by telegram considered to be binding. Before the acceptance and agreement could be confirmed in writing, the revolution resulting from the Russo-Japanese war broke out in Russia, and the "honourable" Krupps stated that owing to this trouble they had reconsidered the idea of constructing Submersibles in Russia and withdrew from this portion of the contract. Soon afterwards their lawyer in Berlin stated that on going carefully into the patent situation he had discovered that the "Lake" type vessels were not yet covered in Germany and that therefore his clients were free to build them in Germany and expected to continue to do so without any question of royalty or payment. Having regard to the unscrupulousness and trickery of the Huns as produced in the Great War, this method of treating an honourable inventor is not to be wondered at, nor should credit be given to the Germans for the production of the first cargo carrying Submersible as Lake patented this type of vessel in 1892, and again in 1915.

The modern Submersibles, therefore, as built and used to-day in all the world's navies owe their final success to principles of construction and control devices invented and introduced into the art by two American inventors, who backed by the courage of their convictions willingly risked their lives an innumerable number of times to perfect their ideas.

Once that Messrs. Holland and Lake had proved that the ocean going type Submersible was an established fact, the construction of these vessels was taken up by all the principal Governments of the world who, however, kept their developments secret. In nearly all cases during the earlier stages of the modern type vessels, petrol engines with the Otto cycle were adopted as prime movers on the surface, and it is understood that the running of these type engines entailed considerable losses in vessels and crew owing to the terribly dangerous explosive properties of petrol.

The introduction of the Diesel type engine using crude oil and devoid of magnetos, sparking plugs and their attendant troubles solved the problem to an enormous degree, and the petrol engine as prime mover is now extinct in the Submersibles of up to date navies.

Two types of very modern Submersible Torpedo Boats built for foreign navies are shown. The single screw vessel has an overall length of 38·76 metres, a beam of 3·62 metres, a depth of 2·88 metres, a surface displacement of 165 metric tons and a submerged displacement of 204 metric tons.

PLATE 21.—When running on the surface the vessel is driven by a 6-cylinder double acting reversible Diesel type oil engine of 450 h.p. and 500 r.p.m., designed and built by the Maschinen Fabrik, Augsburg, Nürnberg, Germany. When submerged the motive power is obtained from a storage battery consisting of 60 cells built by the Akkumulatoren Aktiengesellshaft, Berlin, and a special light weight electric motor supplied by Messrs. Oerlikon, Maschinenfabrik, Zurich, Switzerland.

The battery is capable of delivering 3,500 ampere hours at the 5-hour rate or 2,380 ampere hours at the 1-hour rate, with all the cells coupled in series. The motor is capable of developing 300 h.p. at 110 volts and 400 r.p.m. for one hour with an armature temperature rise of 50C. or 165 h.p. continuously with a corresponding temperature rise of 40C. On trials the boat developed a surface speed of a little over 13 knots and a submerged speed of 9 knots with the battery discharged at the one-hour rate.

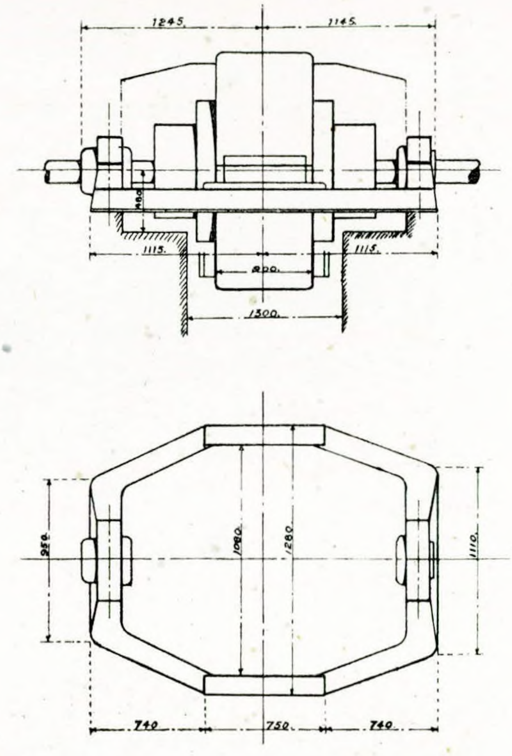
The twin screw vessel has an overall length of 48·58 metres, a beam of 4·43 metres, a depth of 3·64 metres, a surface displacement of 332·8 metric tons and a submerged displacement of 385·5 metric tons.

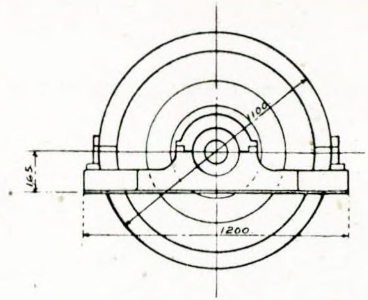
PLATE 22.—The surface propelling machinery consists of two 8-cylinder double acting reversible Diesel type oil engines capable of developing 850 h.p. at 450 r.p.m., also built by the Maschinenfabrik Augsburg Nürenburg. The motive power submerged is obtained from a storage battery of 120 cells supplied

by the Akkumulatoren Aktiengesellshatt, Berlin, and a special light weight electric motor built by Messrs. Oerlikon Maschinenfabrik, Zurich. The capacity of the battery is 3,830 ampere hours at the 5-hour rate of discharge and 2,340 ampere hours at the 1-hour rate with all cells coupled in series electrically. As the vessel was built to meet tropical conditions where the temperature of the sea water is often as high as 30° C., and at which temperature the batteries would froth considerably when charged, and cause large quantities of acid to be spilled; two small refrigerating machines were installed in the engine room to manufacture ice, over which the air to ventilate the battery tank is drawn by special light weight electrically driven suction fans. The motors, specially designed and built to meet tropical requirements, developed 315 b.h.p. at 315 r.p.m. at 220 volts for one hour with a temperature rise of 40°C. On trials the little vessel attained a surface speed of a little over 17 knots and a submerged speed of 11 knots when the battery was discharged at the one hour rate, truly remarkable figures when the small displacements are taken into account and reflect great credit on the designers.

In each case the vessels are of the single hull type, designed to obtain the greatest possible speeds on the surface and when submerged, fitted with light partially water-tight superstructures and bronze conning towers to enable magnetic compasses to be housed in them without being affected by outside influence other than that produced by the earth's fields. The batteries are housed in special light steel tanks covered with 5-ply wood treated with antisulphuric enamel and rendered gas tight by the fitting over the whole of a 3 m/m thick rubber sheet secured to the floor by wood strips and small metal cramps. Over the bottom of the tanks and 6 inches up each side is placed a covering of 1 m/m thick sheet lead soldered at the corners to form an acid tight tray. Over this and completely up each side is a further covering of 2 m/m thick pure rubber sheeting vulcanised directly on to the metal, thus rendering the tank completely acid tight and electrically insulated from the cells. Each cell in itself is specially ventilated by means of a small inlet valve and a flexible rubber connection joining up to a vulcanite tube running directly over each row of cells. These tubes in turn are connected together at the forward end of the battery tank and exhausted by two special high speed fans discharging the gases overboard when the battery is being charged by the motors driven as dynamos by the oil engines. A small porcelain pump

Plate 23.





OUPUT :-	315	B.H.P.,	AT	325	R.P.M.,	233	VOLTS
	145	"	"	240	"	233	"
	125	"	"	210	"	233	"

APPROX. NETT WEIGHT :- 7230 KILOS

ELECTRIC MOTORS FOR TWIN SCREW SUBMERSIBLE and sump are also fitted at the forward end of the battery tank to enable any acid that may leak out of the cells to be collected. The arrangement of the whole battery and tank is such that the vessels can assume an angle of 25° in any direction without the acid being spilled out of the hard rubber cell cases. The main motors are of the single armature and field type, but fitted with two sets of windings and two commutators to enable a large range in speed to be obtained with a small shunt regulation by coupling the armature windings in series or parallel across the half or full battery pressure. A small handwheel and gearing attachment is fitted at the after end of each motor to enable the brushes to be lifted off the commutators when the armatures are acting as flywheels only.

Plate 23.—To reduce the friction to the utmost, each motor is fitted with ball bearings and a ball thrust bearing to take up the weight of the armature in the event of the vessel's bow rising or falling whilst diving. The starting, stopping, reversing and braking of these motors was effected by very special water-tight controllers of Messrs. Oerlikons manufacture, which performed all the necessary actions in itself by means of a hand-wheel and interlocking levers which prevented the shunt regulator being brought into action unless the starting resistances had all been cut out or *vice versa* and also prevented the armatures being coupled from series to parallel or *vice versa* unless the full starting resistances were in circuit.

Plate 24.—The main resistances are housed in light cases and secured to the overhead frames whilst the shunt regulator resistances are arranged on each side of the controller casing as shown. The main cables are of copper insulated with pure and vulcanised indiarubber, lead covered and armoured with interwoven light steel wires passing through bronze stuffing glands at the water tight bulkheads.

As in the case of the later Holland and Lake type Submersibles the engines, motors and propellers are arranged in a straight line with a clutch coupling between the engine and motor and between the motor and propeller shaft, to enable the conditions of service already enumerated to be met. The method of starting the Diesel Engines usually adopted is to insert both couplings and to cause the complete line of shafting to rotate by using the motors as prime movers until such time as the Diesel valves come into action and the engines take over the load and the motors can be shut down. After diving, however, this practice cannot be resorted to as there is always the possibility of the valve used to prevent ingress of sea water into the exhaust boxes developing a slight leak and causing the engine cylinders to fill with water. Again in a crash dive there may not be sufficient time to permit of these valves being closed

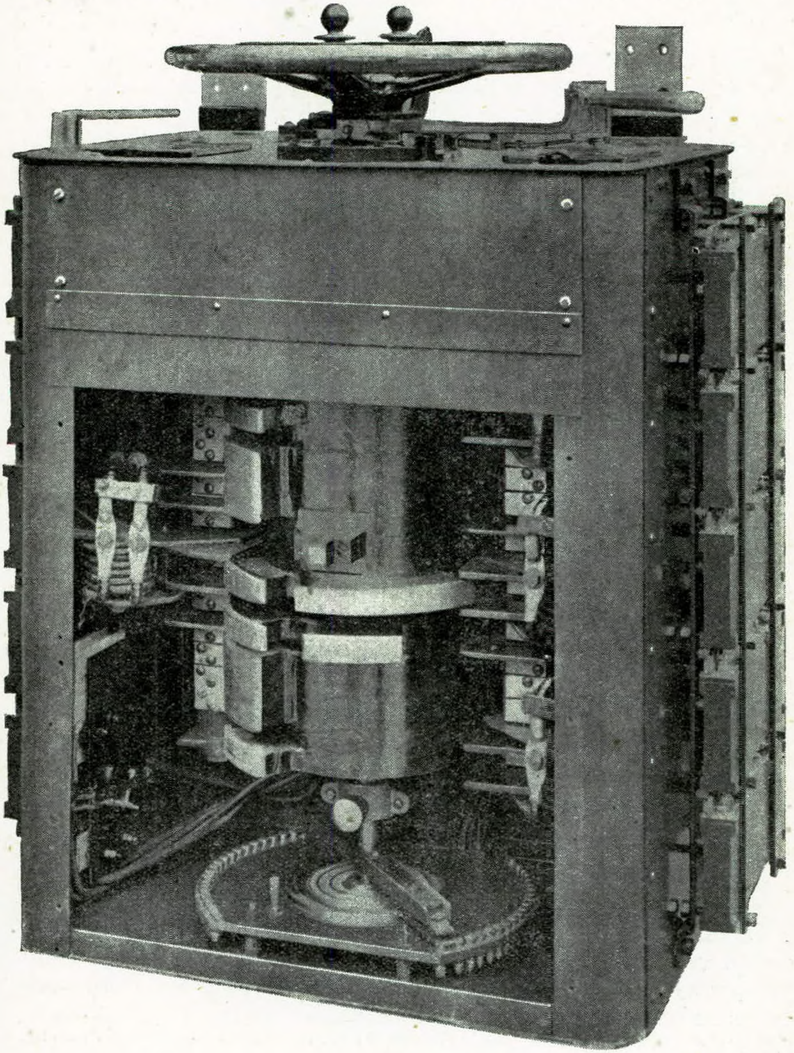
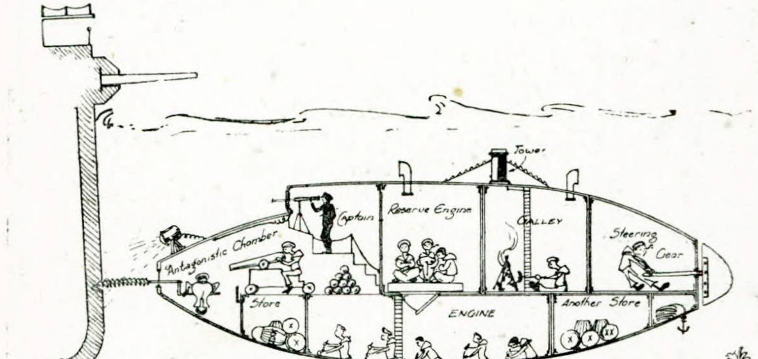


Plate 24.

before the vessel submerges, in which case large quantities of water would pass into the cylinders and exhaust piping with disastrous results to the engines if started up by the main motors. To obviate this difficulty high pressure air flasks are carried in the engine rooms and the engines are started pneumatically and any water that may have leaked into the cylinders or piping is very quickly discharged overboard. The air in the flasks is pumped up to 2,500 lbs. per sq. in. by high speed compressors driven off the main shafting through a gearing and provided with a clutch coupling to enable them to be disconnected as soon as the air in the flasks has reached the requisite pressure. Attached to each engine is a special scrubbing cylinder and a small chain driven rotary pump to circulate the cooling water round the cylinders and valves, the ordinary sea water being used for this purpose. Further, each engine is provided with a hand toggle gear to enable the engine to be coupled up to the main motors and revolved into its correct starting position for starting up after a dive.



. THE "BOOKER" SYSTEM.

The main feature being that the cumbersome hydraulic submerging gear is dispensed with all that is necessary being for the "Engine" to "Jump Altogether."

A humorous suggestion from one of our Members.

In these two vessels the fuel is forced into the cylinders on the compressed air injection system by means of the small compressor arranged at the forward end of each engine, the necessary crude oil being pumped from small auxiliary tanks placed adjacent to the starting platform. Owing to the high temperature of the exhaust gases, water cooled exhaust pipes and silencers are provided, the latter being housed in the superstructure to increase its radiation surface and to decrease the sound in the engine room. To prevent sea entering the exhaust pipes whilst the vessel is diving, a large valve is placed close to the silencer and the exhaust pipe is given a slight bend upwards. Reversing of the engines is effected by the manipulation of a single handwheel which operates as follows:—First of all the individual valve operating levers are lifted off their respective cams and firmly held in this position. Then the complete cam rod is moved in the horizontal sense until the ahead cams are moved out of position, and the astern cams come under the rollers of the valve operating levers, when the latter are allowed to sink down again and press on the astern cams and at the same time alter the timing of the valves.

The usual number of instruments to indicate the pressure of the air in the starting flasks, air compressor, bearing oil, etc., are provided, together with a clearly visible sign intended to indicate at any moment whether the engines are going "ahead" or "astern."

The CHAIRMAN: We have had an interesting evening listening to Captain Wood and seeing on the screen the illustrations showing the gradual developments in the submarine type of vessel. We look forward to our next meeting when the modern submersible will be described and discussed. The evening is too far advanced to add any further remarks. I propose a hearty vote of thanks to Captain Wood for his paper.

The Evolution in Propulsion of the Modern Super-Submersible Torpedo Boat.

BY CAPT. NORMAN H. WOOD, R.A.F. (Member).

READ

Tuesday, April 15, *at* 6 *p.m.*

PART II.—PRACTICAL.

(ILLUSTRATED BY LANTERN VIEWS.)

CHAIRMAN: THE HON. SECRETARY.

ALMOST without exception, modern Submersibles have their main propelling machinery arranged engine-clutch-motor-clutch-propeller shaft and to all outward appearances this procedure would appear to be perfect. In practice, however, it has been found to offer considerable drawbacks, especially in war time, due principally to the negative reciprocating action of the Diesel engine on the clutches. A clutch of any description which has to be very quickly coupled or uncoupled, transmits large powers and yet maintains a small diameter and weight offers considerable difficulties to the designer. Three main classes of coupling are open, the friction, magnetic or claw type, each of which are applicable and under ordinary circumstances reliable. Some of the Submersibles built about 10 years ago were fitted with friction couplings which it is understood were very successful where the powers to be transmitted through them were, relatively speaking, small, but even then their diameters were large. As the outputs of the prime movers increased the possibilities of resorting to friction couplings became less, and their use practically ceased. So far as is known, no Submersible has as yet been fitted with magnetic couplings, which, though ideal, would cause terrible anxiety and suffering to the Officers and crew of a vessel thus equipped owing to the likelihood of their failing at a critical moment.

The present great war has taught the Submersible Constructor that the slightest defect developing in the main propelling machinery may, at an inopportune moment, entail the loss of the vessel, officers and crew.

No stretch of imagination is necessary, therefore, to realise the utter helplessness of a Submersible fitted with magnetic clutches, which, owing to some defect or other failed when every attempt was being made to escape underwater from enemy surface craft or mines. The reserve buoyancy, though small, would bring the vessel to the surface when its career would very quickly be cut short. Thus the only type of coupling available is the claw, and no matter how carefully the machining of the dogs may be carried out, it is a physical impossibility to ensure their being of exactly the same size as their opposing openings, and at the same time assure an easy sliding movement into or out of gear.

Experiments have been carried out with triangular shaped dogs, but the results obtained showed very little improvement over those shaped parallel. Owing to the negative reciprocating action of the Diesel engine, the coupling between the engine and motor gives the greatest trouble and eventually a rattling and hammering is set up which causes considerable trouble to the machinery, and at the same time unnecessary suffering to the officers and crew. as the vibration set up thereby is transmitted through the whole vessel.

Further, during war time, it is only after nightfall that a Submersible can safely rise to the surface to charge its battery or high pressure air-service when in the enemy danger zone. But modern high speed surface craft are fitted with very delicate sound detecting appliances, and the hammering of the couplings would sufficiently amplify the somewhat subdued sound of the propellers to enable the position of the vessel to be very quickly determined. In the event of its exact position beng located before the battery had been fully charged, a long dive would be impossible and that particular Submersible could safely be crossed off the Navy lists to which it belonged.

One of the principal requirements of an ocean-going Submersible in war time is, that it shall be able to dive or rise to the surface without the slightest trouble and loss of time, being experienced in changing over from one prime mover to the other, or in the starting up and stopping of the same.

As already stated, under existing circumstances, after a dive, it is imperative to start up the Diesel engines by means of compressed air owing to the grave injuries that might be sustained in the event of water having leaked into the cylinders and the engines being brought up to speed by the main motors. The usual practise is to stop the electric motors, turn the engines by means of their toggle gear until the couplings can be inserted and then turn the engine, motor and propeller shafts through the same medium until the correct starting position for the pistons has been reached, and then to turn on the compressed air. This procedure demands either a small high pressure air compressor, usually three stage, and storage flask attachment to each engine or the taking of a supply of high pressure air from the vessel's main storage system. In the first case should the supply of compressed air in the auxiliary starting flask not prove sufficient to bring the engine up to speed, starting can be effected by means of the main motors, as by this time, any water that may have leaked into the cylinders will have been blown overboard, but a most valuable loss of time may have been caused thereby.

In the second case, trouble in starting the engine may cause large quantities of compressed air to be drawn from the main storage system in a few minutes, which may take as many hours to replace.

Last and not least every practical seagoing Marine Engineer will appreciate the very important disadvantages of having the main propelling shaft split up into three separate lengths, each connected together by a sliding dog-clutch, and the practical impossibility of maintaining these in true alignment under variable temperature and pressure sea-going conditions.

The starting up of the Diesel Engines by means of compressed air has been found to present a number of serious disadvantages as the following will show.

Experience has shown that the cylinder heads of Diesel engines often crack after the machines have been running some time and are then stopped and re-started with compressed air which on entry to the cylinders must (on expansion) be at a refrigerating temperature. This sudden chilling of the metal which has previously been at a temperature of possibly 1000° Fahrenheit contracts the metal of the cylinder heads and any web-like portions, such as narrow strips of metal between valve orifices which have to withstand the contraction of the body of metal, and hence give out.

The United States Naval Institute Journal of October, 1917, stated that " For the last batch of Submarines the U.S. Navy Department endeavoured to dispense with the air starting valves for the Diesel propelling engines, the main idea apparently not being to do away with the air compressors but to simplify the cylinder head construction and to reduce the number of orifices in the castings, thereby assisting to prevent the cracking of the heads."

One of the greatest drawbacks confronting the Submersible Constructor to-day is the fact that high speeds on the surface demand very greatly increased outputs by the prime movers. Efficient Submersible type Diesel engines of 150 to 200 h.p. per cylinder have been successfully constructed, but as soon as larger units are attempted difficulties multiply rapidly. Multiplicity of cylinders is undesirable because of the danger of breakdown as the mechanism becomes more complicated and extensive and unreliability is a deadly sin in a Submersible engine. Furthermore, in contradistinction to the steam engine, in which the weight per horse power decreases as the engine increases in size, the Diesel engine with irritating perversity increases in weight per horse power as the size of the engine increases. In designing a Submersible of greater displacement, therefore, it is not sufficient to increase the weight allotted to the engines in the same proportion as the displacement of the boat is increased, it must be increased in greater proportion, which, of course, implies that it must be increased at the expense of some other characteristic.

In the earlier modern type Submersibles owing to the great explosive properties of petrol vapour it was found essential to enclose the main motor starting switchgear in explosive proof watertight cases, as otherwise the heavy arcs set up when switching off the main motors or the bursting of a fuse wire might at any time fire an explosive mixture inside the vessel. Such an occurrence when running on the surface with all hatches open would have a terrible effect, but when submerged would in all probability entail the loss of the vessel. To overcome this difficulty as far as possible some Navies placed the main-motor-starting-gear in a different compartment to the engines, with a strong bulkhead between, but this procedure did not in any way mitigate the chances of a sparking set up by the motor brushes firing the mixture. However the application of the Diesel engine, using heavy crude oil as fuel, entirely overcame the possibility of an explosive mixture forming and thus permitted the use of open-type-quick-break-knife-type main-motor-starting-switchgear operated by hand. Some Navies still prefer to have this gear in the main controlling position, others claim that its best position is in the engine or motor room as close to the electrical machinery as possible, as this arrangement considerably reduces the lengths of heavy cable necessary to effect a reversal in the armature current and thereby a reversal in the armature rotation direction. Hand operated gear, no matter where placed, demands some system of verbal or instrument communication between the Officer on watch on the bridge and the Engineer Officer in the engine room and it is usual to find both voice pipes and engine room telegraphs fitted. But either system depends entirely on the instructions given being correctly interpreted or the telegraph on the bridge being placed in its correct position every time, no allowance being made for the error that is sure to creep in when the human element is entirely relied upon. As is well known the exigencies of service in a Submersible call for the greatest possible powers of human endurance, and it is only just and right that under all conditions the chances of a mistake being made should be entirely eliminated, or in the event of this being found impossible, reduced to the smallest possible limit or margin. An instance can be called to remembrance where whilst manœuvring down a narrow river an instruction was given from the bridge to start up the main motors "Astern," but the transmission of sound was so bad that the message was misunderstood and the motors started up full speed in the "Ahead" position. The language which thereupon flowed down the voice pipe was sufficiently vehement to interpret that a serious mistake had been made and the motors were switched off at once and a request put forward for the first instruction to be repeated; it was—accompanied by a wonderful flow of language and the motors thereupon started up in the "Astern" position. The court martial on board which resulted therefrom revealed that the sudden stopping of the motors prevented what might have resulted into a nasty accident, and one of the culprits realised there and then the utter folly of trusting entirely to the human element in such highly important matters. Again try and picture a large Submersible travelling on the surface during war time after dark and suddenly having a searchlight flashed on it. The Officer navigating from the bridge knows that whether friend or foe at any moment a shell may come singing over the water and at its first effort put an end to the existence of his little craft. He rings the diving gongs, jumps into the conning tower, closing and securing its hatch after him, the crew spring to their diving stations, the engines are stopped, the couplings undone and the main motors started up and the vessel is caused to submerge by the action of its hydroplanes. But the time taken to effect this latter condition may have been long enough for the searchlight to give the correct range and the quickly following shells to hit some vital part and thereby cause the loss of the vessel and its complement.

At one period it was considered advisable to carry compressed air in a Submersible with the intention of replenishing the air in the interior hull two or three times during a long submergence to allow human life to be sustained. As the compressed air was allowed to escape into the interior slowly, the vitiated air was gradually pumped overboard and rose to the surface. Under existing circumstances this procedure would quickly result in the underwater position of the vessel being very exactly located by aircraft or surface vessels with disastrous results. A much better method is to purify the interior air by passing it through some chemical which will collect the carbon and release the oxygen, in other words, split up the CO_2 into C and O_2. The discharging of torpedoes, raising and lowering of the periscopes and blowing out of ballast tanks quite apart from the starting of the internal combustion engines demand a large store of compressed air being carried inboard in light strong seamless steel flasks, usually arranged in 4 or 5 groups with piping and valves to allow of any one or all groups together being discharged at will. At any time, however, the presence of this compressed air constitutes considerable danger owing to the likelihood of a leak developing when all the hatches are battened down, over and above the unnecessary addition in weight. An instance, which will never be forgotten, can be recalled in which a flask pumped up to 2,500 lbs. burst in the vessel when on the surface with all hatches open. Apart from the great shock to the nerves, the sudden increase in the pressure of the atmosphere caused considerable suffering to the eyes and ears, and made it quite clear that the volume of compressed air carried should be reduced to the smallest possible amount consistent with efficient service.

Generally speaking most modern Submersibles are fitted with twin screws revolving in opposite directions to ensure the greatest possible speed efficiency being obtained and to obviate the chance of the vessel being given a list to port or starboard in accordance with the direction of rotation of the propellers. Should perchance one of the Diesel engines breakdown hopelessly on the high seas during war time apart from the speed reduction of the vessel there is immediately removed the possibility of steering correctly, a most important point in a high sea as will be readily admitted, and the impossibility of charging the battery quickly.

Again the amount of space in the engine room is so small that only very small minor repairs can be carried out effectively and quickly. In peace time the breaking down of a prime mover would not result in the probable loss of the vessel as help could be summoned by wireless, but modern Submersibles are designed with a warlike intent and every possible effort must be put forward to ensure the exigencies of service being faithfully met.

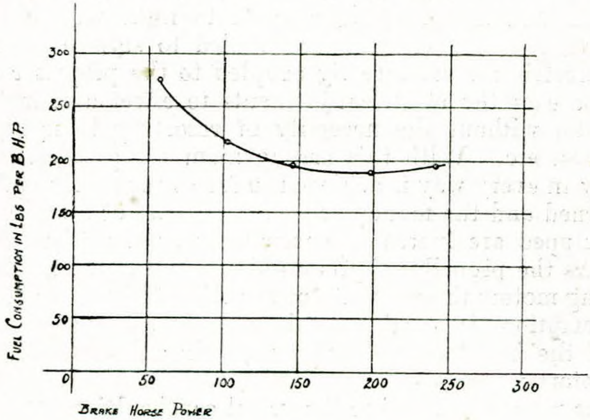
Perhaps the greatest disadvantage of the modern type Submersible is the fact that the rate at which the battery can be charged is practically in direct ratio to the speed of the prime movers and thereby the speed of the vessel. The Great War has further proved that the underwater craft are only dangerous when submerged and on the other hand that a Submersible's only chance of escaping from high speed surface craft lies in being able to submerge quickly and for a long period. On rising to the surface again there are times when all possible speed must be crammed on in an endeavour to escape, but after night fall it may be found advisable to cruise slowly about and at the same time charge the battery in the least possible space of time. As however this procedure is impossible with existing plant, two courses are open to the Commander: (a) to travel at a good speed and thus revolve the dynamos at high speed; (b) to uncouple the propeller shaft and utilise the full power of the engines to charge the battery. The first procedure entails the unnecessary consumption of oil fuel and thereby lowers the cruising radius of the vessel, the second places the vessel at the immediate mercy of enemy underwater craft as the modern torpedo travels so quickly and the time that must necessarily elapse before the engines could be stopped, the tail shafts coupled up again and the engines brought up to speed again would probably not be sufficient to allow of the vessel being navigated out of the line of fire of an oncoming torpedo. Again owing to its great weight and skin friction a Submersible does not answer its helm so readily or so quickly as a surface craft with the same displacement and a time might occur when, after the wake of an oncoming torpedo had been sighted, in the opinion of the Commander the greatest safety lay in going from full speed ahead to full speed astern. This would demand the stopping of the Diesel engines, the changing over of the cam shafts and the re-starting of the engines either by compressed air or the motors. In the event of the latter course being resorted to, what would happen if the motorman became unnerved owing to the sudden clanging of the engine room telegraphs, etc., and started the motors up in the "Ahead" position when the engines were intended to go "Astern," is best left to the imagination. Again there is always the possibility with hand-operated main-motor-starting-switchgear of the engines being driven "Ahead" and the motors started up to go "Astern," what would happen here is again best left to the imagination. This latter eventuality can, of course, be overcome by installing complicated locking gear, but this class of mechanism merely covers up a sin on the part of the designer that should never be permitted or tolerated in first class work.

Thus a short summary of the disadvantages claimed for the present system of propulsion are:—The couplings; difficulties experienced in starting up the Diesel engines and the dangers entailed by using compressed air to effect this purpose; the possible uncertainty of messages transmitted through the voice pipe or engine room telegraph being incorrectly given or received when reliance is placed on the human element; the necessity of carrying large quantities of compressed air; the probable loss of the vessel in war time should one of the prime movers break down hopelessly on the high seas; and lastly, the almost impossibility of charging the battery quickly when the vessel is proceeding slowly on the surface.

After carefully sifting and weighing up these disadvantages of the modern type Submersibles, the thoughtful engineer will immediately say "Cannot these difficulties be overcome by introducing better class gear," but the progressive engineer will unhesitatingly exclaim "Eliminate them entirely." With this object in view the "Wood" system of propulsion has been projected and is submitted for approval.

With this system a Submersible would be fitted with high-speed prime movers directly coupled to light weight electric generating sets and electrically coupled to slow speed light weight electric motors directly coupled to the propeller shafts, making use of the electrical elements to effect a reduction in speed ratio without the necessity of resorting to ugly heavy gear boxes, etc. With this arrangement the greatest possible efficiency in every way is achieved so far as the marine propeller is concerned and the manœuvring capabilities of a Submersible thus equipped are increased enormously as the following will show. As the propeller shafts are directly coupled to the main propelling motors the necessity of resorting to loose couplings of any description, type or make is entirely eliminated and the speed of the boat is regulated by altering the R.P.M. of the main motors without in any way interfering with the speed of the prime movers. Further the vessel can be driven "Ahead" or "Astern" full speed or any other speed by reversing the direction of rotation of the main propelling motors without in any way interfering with the speed or direction of rotation of the prime movers. It is possible therefore to fit high class reliable governors to the engines driving the dynamos, a most important feature that will be grasped by every practical sea going Marine Engineer conversant with the many unsuccessful attempts that up-to-date have been made to construct a reliable marine engine governor. Again, one of the most trying duties in the engine room is entirely done away with, namely that of standing by the main or auxiliary throttle valves to shut off the fuel in the event of the propellers coming out of the water and racing heavily, as owing to the peculiar characteristics of the shunt wound electric motor it cannot increase its speed by more than about 5 per cent. even when the full load is completely thrown off instantaneously. The cruising radius of a Submersible thus equipped is also considerably increased.

PLATE 25.—A glance at the curve shows that the fuel consumption per B.H.P. of the internal combustion engine increases very quickly if the load is taken off and proves that any system which demands the speed of the prime mover and thereby the propeller being reduced to effect a reduction in the speed of the vessel is extremely wasteful. In the "Wood" system each prime mover is kept always as fully loaded as possible and the R.P.M. constant as the following will show. At very slow speed the current consumption of the main propelling motors will be so



CURVE SHEWING FUEL CONSUMPTION OF A DIESEL ENGINE.

Plate 25.

calculated as to ensure one of the prime movers being fully loaded. At half slow speed the current consumption will ensure two generating sets being fully loaded and so on until full speed is reached, when all the generating sets will be in commission. It is, however, only on rare occasions that full speed is necessary, the ordinary cruising speed is about three quarters full speed so that one or more generating sets are always available to charge the battery up or act as "standbys." There will, of course, be times when the power absorbed by the main motors will be less than the output of the generating sets on load, but any surplus energy can be used to charge the battery or augment the lighting and light motor loads. The great drawback of the battery charging rate being in direct ratio to the R.P.M. of the propelling machinery is entirely eliminated by this system as one generating set can be utilised to supply the main motors and all other sets placed on the battery charging load. The great elasticity of the system is further proved by the fact that should the vessel be travelling at its slowest speed, and only one generating set be on load and this break down, no alteration or diminution in the vessel's speed would be possible as the battery would at once pick up the load and carry on until one of the other generating sets could be brought up to speed and switched on to the main bus-bars. Should engine trouble develop, little damage would be sustained as the dynamo would motor at practically the same speed in the same direction, and the failure of the set to supply current would immediately be recorded by the ammeter. Should the dynamo break down, the fuses would blow isolating the set and the governor prevent the engine from racing, and here again the ammeter would show that something was wrong if the matter was not noted or observed by the engine room staff. In the event of the ordinary internal combustion type engine being installed as prime movers, any delays in starting up quickly would offer very few, if any, disadvantages as the vessel could be driven by the battery until the engines could be brought up to speed and made to take over the load. It would still be necessary, after a dive, to start up the engines pneumatically, but starting is simplified enormously owing to the no load conditions. As the motors and generators are separate units the distribution of the whole plant is rendered much more elastic in every way. To save weight it is advisable to reduce the lengths of the propeller shafts to the utmost, which procedure demands that the main motors shall be placed as far aft as possible, but the generating sets can be distributed about the vessel at will and thereby prevent the whole Submersible from becoming inoperate as is the case under existing conditions if the engine room is flooded. The greatest danger lies in the main motor compartment being damaged by shell fire or other such cause and springing a leak. This eventuality is minimised to a great extent by the fact that the after portion of the watertight pressure hull in a Submersible is always well below the water line, even when travelling on the surface, so that the chance of such a trouble occurring can be accepted as a legitimate war risk.

To reduce their diameters and to facilitate starting and speed regulation, the main motors would be split up into two units, each capable of delivering half the total output required for each propeller shaft. The same methods of construction would be applied to the generators to ensure the base plates and diameters of the yokes not being greater than the width of their respective engines and thus allow of the complete sets being efficient so far as stowing space was concerned. Stress has already been laid on the fact that the general increase in speed of the modern type Submersible is greatly hampered by the fact that the Diesel engine increases its weight per H.P. with an increase in output and that the multiplicity of cylinders also entails unreliability in running, etc. As the electric motor, however, does not present these difficulties, the "Wood" system enables greater speeds with increased displacements to be achieved as an increase in the total output merely demands an increase in the number of main propelling motors attached to each propeller shaft and a corresponding increase in the number of generating sets which as has already been stated can be distributed at will to obtain the most efficient stability and inboard arrangements.

In all cases the main control switch-gears whether for the dynamos or motors would be placed as close to their respective units as possible to reduce to a minimum the lengths of heavy cable necessary to effect control.

Automatically operated switchgear would be made use of, however, with the operating auxiliary controllers placed adjacent to the conning tower and periscopes and so arranged that they could be worked from the bridge, conning tower or inboard steering position, and thus enable perfect control of the whole propelling machinery to be undertaken by the Officer on watch without the necessity of resorting to voice pipes, bells, telegraphs or telephones. Instructions would be issued to the engine room staffs to open the valves controlling the prime mover exhaust boxes after each dive as soon as the vessel was completely on the surface and to start up each engine pneumatically and to allow it to run on no load for a few seconds and then shut it down. This method of procedure would ensure that any water that may have leaked into the engines whilst the vessel was submerged will be blown overboard and thus enable the engines to be started up by the Officer on watch at any moment by switching the dynamos on to the main bus-bars and causing them to motor until the engines could pick up and carry on. The necessary current for the first set started up thus would be taken from the battery but the watt hour consumption would be extremely small as the engine would be started up light, but to ensure the whole set being brought up to speed slowly the starting resistance on the first few stops would be rated fairly high.

Should the vessel be proceeding at slow speed on the surface and a crash dive become necessary, the Officer on watch on the bridge would immediately ring the diving gongs to summon the members of the crew to their diving stations and then quickly take each generating set off load by means of the automatic control gear before leaving the bridge. He would then descend through the conning tower into the inboard steering position and take over the control of the vessel from this position. But no stopping of the propellers or starting up of the main motors as at present is the case would find place in the programme, because as soon as the generating sets were shut down the battery would pick up the load and the vessel proceed forward at the same speed.

A Submersible fitted with the "Wood" system of propulsion would therefore be able to dive very much quicker than hitherto-fore because as soon as ever the diving gongs rang the coxswain and his mate would immediately operate the diving rudders to cause the vessel to slip under water without waiting for instructions from the engine room to the effect that the engines had been stopped, their couplings undone and the main motors started up, etc.

This system would of course entail a great deal more work on the part of the vessel's Commanding Officer but at the same time wonderfully relieve his anxiety and trouble during a crash dive as the engine room staff would not, virtually speaking, be tumbling over each other to carry out their duties as under existing conditions. Again, in war time and during a moment of great anxiety it is perhaps wiser for the members of the crew inboard to know as little as possible of what is taking place on the surface as even the bravest and most disciplined men may inadvertently become hasty when in full knowledge of the fact that their lives are imperilled. With the "Wood" system practically the full responsibility for the correct operations, etc., of the main propelling machinery falls on the shoulders of the Commanding Officer and thus enables the duties of every other man to be considerably lightened in every way to the benefit of everybody on board and the safety of the vessel itself.

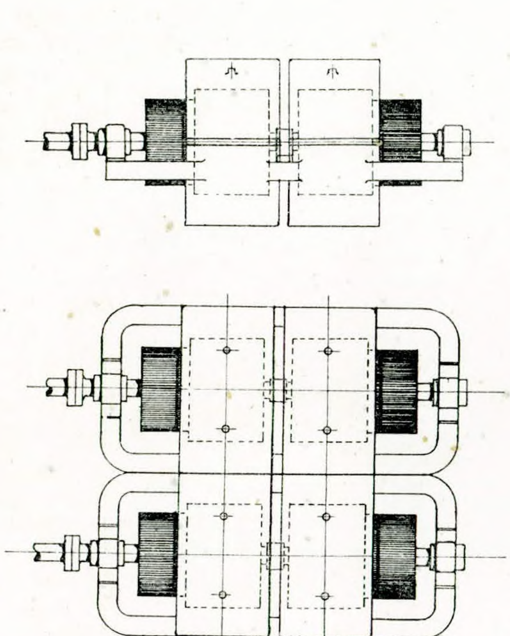
PLATE 26.—As an example it is assumed that the power required to drive a Submersible displacing 1,200 tons on the surface at 18 knots is—2,400 B.H.P. To comply with the requirements of the "Wood" system four high speed generating sets, each capable of delivering 530 K.W. at 220 to 300 volts with 750 R.P.M. continuously would be installed in conjunction with two electric motors, each capable of delivering 1200 B.H.P. at 220 to 300 volts with 50 to 200 R.P.M. continuously, together with two electric storage batteries of 120 cells each, coupled in parallel with the following total outputs:—

8,000	Ampere hours	at the	1	hour rate	of discharge.
11,650	,,	,,	3	,,	,,
15,100	,,	,,	10	,,	,,

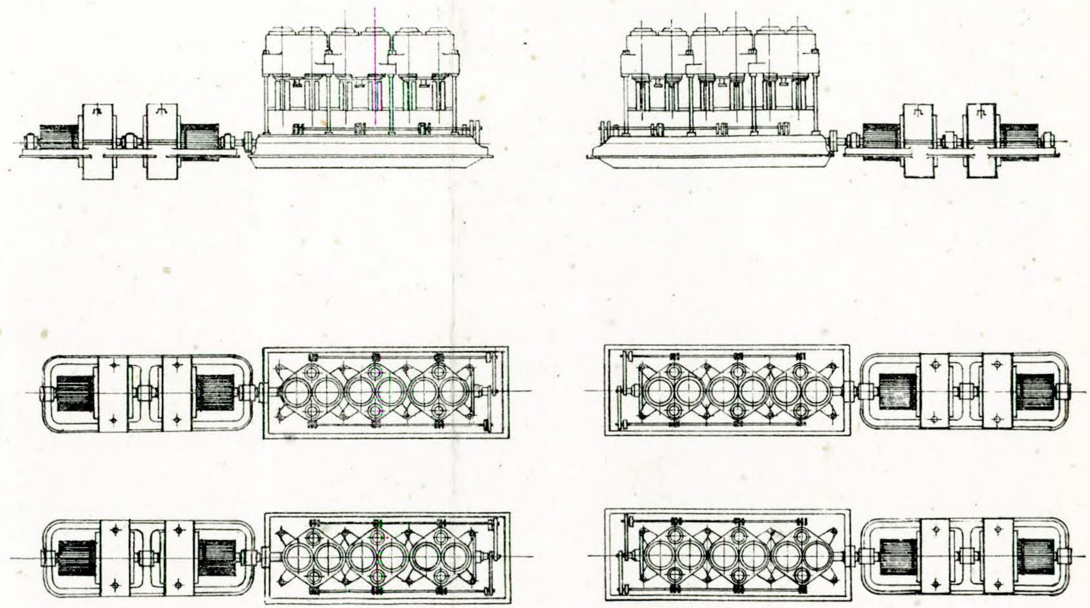
This battery would have a sufficiently large output to drive the vessel at very nearly full speed for roughly an hour or lesser speeds for greatly increased times before the voltage of each cell fell below 1·8 volts.

Each battery would be enclosed in a separate steel tank treated with sheet lead and pure rubber sheeting to render the whole acid tight and to prevent the creepage of electricity from the cells to the sides of the tank. All connections between the individual cells would be so arranged that they ran in straight lines fore and aft with the vessel's centre line to minimise any magnetic effect on the magnetic compass in the conning tower. Adequate ventilation for each battery tank would be provided by two electrically driven high speed exhaust fans which would cause a current of air to pass over the tops of the cells and at the same time take with it any explosive gasses formed whilst the cells were on charge, and discharge them overboard. Each individual cell would be enclosed in a hard rubber case and fitted with a cover, which, although allowing the gases to escape would prevent any acid being spilt out unless the vessel assumed an angle of inclination in any direction greater than 25°.

The battery tank cover would consist of multi-ply hard wood with a thick rubber sheet stretched over the whole to render



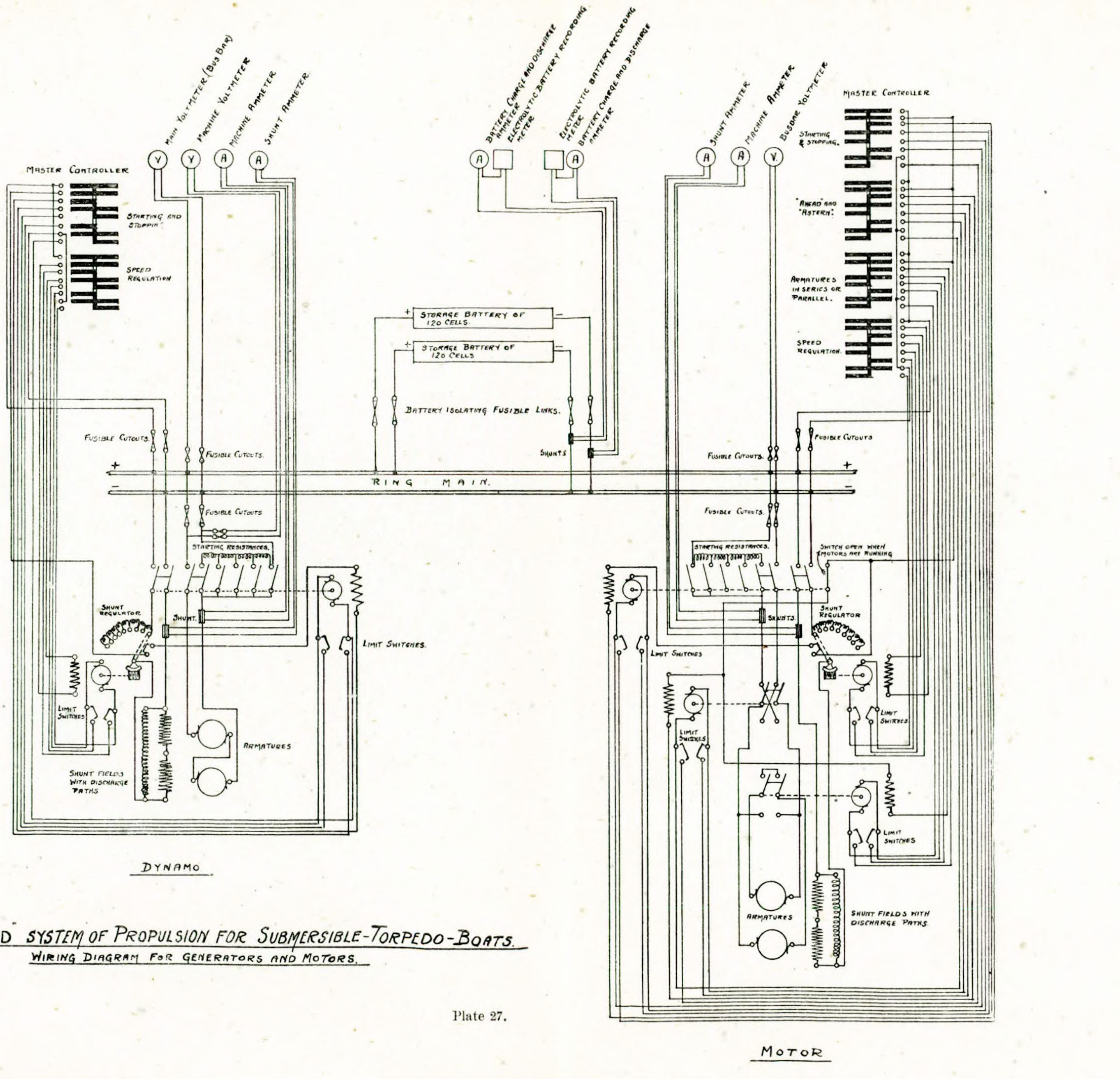
MAIN PROPELLING MOTORS.



PRIME MOVERS AND GENERATORS.

DIAGRAMMATIC ARRANGEMENT OF MAIN PROPELLING PLANT.
FOR "WOOD" SUBMERSIBLE.

Plate 26.



"WOOD" SYSTEM OF PROPULSION FOR SUBMERSIBLE-TORPEDO-BOATS.

WIRING DIAGRAM FOR GENERATORS AND MOTORS.

Plate 27.

it gastight and also prevent an explosive mixture escaping into the interior of the vessel. Any metal parts in the tank supporting this floor and exposed to the action of the acid gases would be treated with three or four coats of best antisulphuric enamel.

The main propelling motors would be split up into two separate units as shown, with the armatures mounted on the same shaft to facilitate manufacture and lining up. Each motor would be of the shunt wound open type fitted with compensated windings and commuting poles. For slow speeds the motors would be started with a full shunt and the armature windings in series with a corresponding speed of about 50 R.P.M. By means of the shunt regulator the speed could be increased to 100 R.P.M., should higher speed be desired the motors would be switched off the bars, the armature windings coupled electrically in parallel and the motors then re-started. On a full shunt the speed would be 100 R.P.M., but by working the shunt regulator the speed can be increased to 200 R.P.M. at will. The field windings are placed in series across the full battery pressure to simplify the speed regulation as only one shunt regulator becomes necessary.

The dynamos would be of the same construction as the motors, but with the armature windings always coupled in series so that each armature is only called upon to deliver its full load at 110 to 150 volts. Here again to facilitate the voltage regulation, the fields are placed in series across the full battery pressure.

To reduce to the smallest possible amount the lengths of heavy cable necessary to effect control, the automatic switch-gears controlling the main propelling machinery would be placed as close to their respective units as possible and as far below the vessel's centre of gravity as the space available allowed. Now nearly all modern types of automatic control switch-gear are operated by means of coils or solenoids which are caused to work the switches magnetically by the passing of current through them from a small hand-operated master controller or by one solenoid energising the next to it automatically. In any case the last switch to be closed or running switch has to be held constantly in position and demands that a small current must continuously pass through its operating coils to maintain contact. This current is to all intents and purpose a dead loss, a circumstance which must be rigidly avoided in a Submersible.

Plate 27.—To overcome this difficulty and yet to permit all the controlling switch-gears to be automatic-

ally operated from the Centre Control Position, in the "Wood" system, ordinary quick-break-knife-type-switch-gear would be installed, but the actual operating of the individual switches, in contradistinction to being worked by hand, would be caused to cut in and out very quickly by means of small gear wheels and clutches operated by small high-speed series wound electric motors with flywheel attachments to gather up inertia and discharge the same where needed whilst working the gears. The starting of these motors would be effected by means of the master hand-operated controllers in the Centre Control Position and stopping by the action of small limit switches attached to each switch-gear.

PLATE 28.—The four drums of the master controller for each main propelling motor switch-gear would be housed under the one case on the top of which would be fitted two hand-wheels and two levers, very much after the type of an automobile steering wheel. The right-hand lever would operate the switch-gear which caused the motors to revolve in the "Ahead" or "Astern" direction. The left-hand lever would operate the switch-gear which placed the armature windings in series or parallel. The upper hand-wheel would operate the shunt regulator gear and the lower wheel would operate the main starting and stopping switch-gear. To render the whole gear absolutely fool-proof, mechanical and electrical interlocking gear would be installed to prevent a wrong switching up, etc., and to assure the following:—

(a) That the starting and stopping switch-gear could only be operated when all the shunt resistance had been cut out, the armature windings were switched in series or parallel and that the right-hand lever was definitely in the "Ahead" or "Astern" position.

(b) That if the motors were on load the only wheel that could be operated was the one controlling the shunt regulator gear.

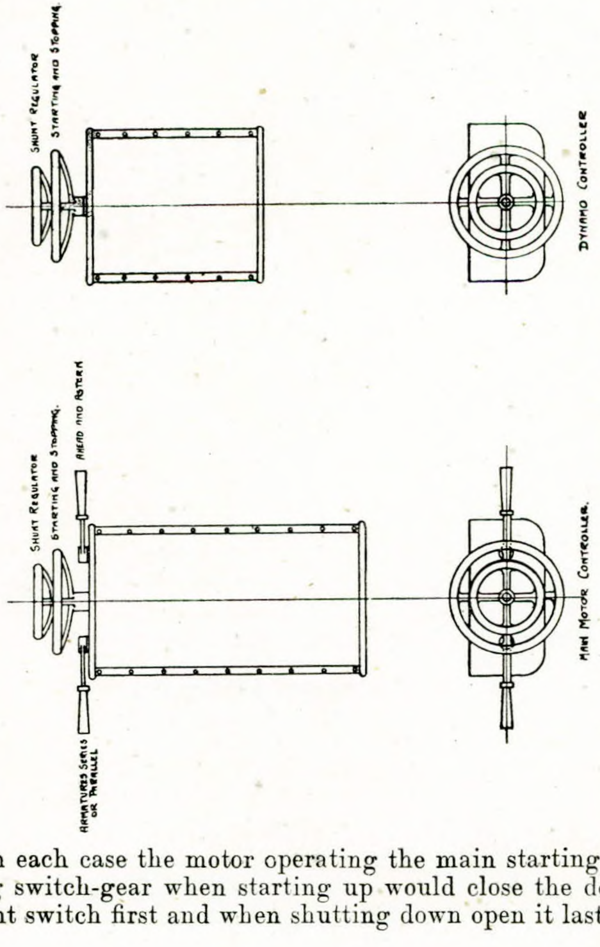
(c) That the lever operating the "Ahead" or "Astern" switch-gear could only be moved if the lower hand-wheel was in the "Off" position.

(d) That the lever operating the armatures series or parallel switch-gear could only be operated if the lower handle was in the "Off" position.

The two controllers for each dynamo would be housed in the one case, provided with two starting handles interlocked to assure that:—

(a) The starting and stopping handle could only be operated when all the shunt resistance had been cut out.

(b) If the dynamos were on load and a little resistance had been placed in circuit, the starting and stopping handle immediately became inoperative.



AUXILIARY HAND OPERATED CONTROLLERS FOR MAIN CONTROLLING SWITCHGEAR FOR "WOOD" SUPER-SUBMERSIBLE TORPEDO BOAT

Plate 28.

In each case the motor operating the main starting and stopping switch-gear when starting up would close the double pole shunt switch first and when shutting down open it last to ensure that no mistake could be made and the armatures placed under current before the fields had been fully excited. A small shunt discharge resistance, bifilar wound, would be placed in parallel with the shunt windings to absorb the self induction when the double pole shunt switch was opened.

All necessary electrical recording instruments would be placed directly above each controller to give a perfect clear and visible statement as to what the machinery was doing, together with two electrolytic recording instruments which would show at any time the exact capacity in ampere hours of each main storage battery.

To increase the efficiency and to decrease the slip and thereby the cavitation of the propellers the Submersible will further be fitted with the "Birkett Regenerative Stator" propellers. Now it is an acknowledged fact that the efficiency of the ordinary marine type propeller is comparatively low and that, with the present limitations in propeller design not more than 65 per cent. of the power transmitted to the propeller by the prime movers is realised in actual propulsion, the remainder being lost in friction slip and cavitation. During the last few years a great many experiments have been carried out with auxiliary devices in the shape of secondary guides or deflecting blades to overcome this difficulty but owing to the poor results obtained have generally been scrapped. The "Birkett" propeller, however, is based on a different theory which has been thoroughly tested experimentally and in actual practice on various types of vessels and has in each case wonderfully increased the speed without in any way demanding an increase in the revolutions or output of the prime mover.

PLATE 29.—As will be seen from the photos, the theory is based on the inverted action of the turbine rotor and stator blades, inasmuch, that whereas the ordinary marine propeller when revolving forces a fan-shaped rotating column of water in front of it, the formation of such a column is entirely prevented as soon as the "Birkett Stator" propeller is installed and fitted. The blades of the Stator propeller cause a non-rotating column of water to be forced out practically in a straight line with the fore and aft line of the vessel under way. This great advantage will be apparent to all Marine Engineers fully conversant with propeller design and practice as it assures a greater speed with the normal output and resolutions of the prime mover or in the

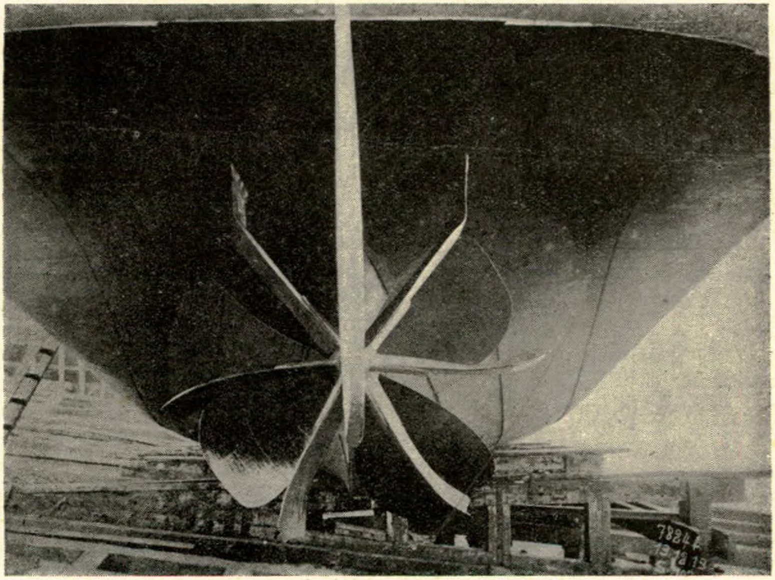


Plate 29.

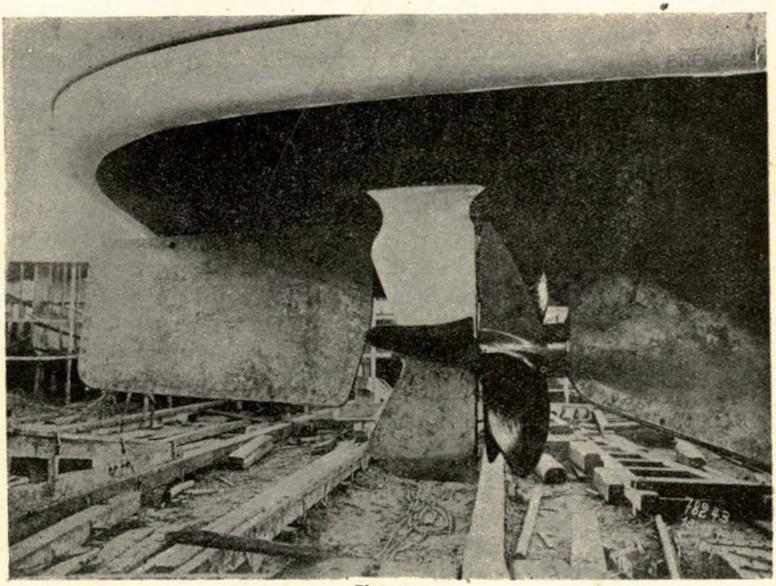


Plate 29.

event of the normal speed being maintained ensures less power requirement from the main propelling machinery and thereby a great reduction in fuel consumption. Experience has shown that the application of the "Birkett" propeller ensures an increase in speed of from 5 to 10 per cent. in the case where the existing propeller is used and from 10 to 15 per cent. in the case where a new propeller, designed to operate with the Stator propeller, is fitted without in any way increasing the normal output and revolutions of the prime mover.

On the other hand a saving in power from 10 to 15 per cent. can be guaranteed in the case where the existing propeller is used and from 15 to 20 per cent. in the case when a new propeller is fitted to meet the requirements of the Stator propeller.

A cargo steamer, displacing about 8,000 tons and fitted with prime movers developing about 5,000 I.H.P. modern watertube boilers, forced draught and using good quality coal will consume about $1\frac{3}{4}$ lbs. of coal per I.H.P. hour. Thus on a 10 days voyage the coal consumption will be about 935 tons. If the "Birkett" propeller be fitted, and it be assumed that a saving in power of 15 per cent. be realised thereby, and that the vessel makes 20 voyages per annum, the yearly saving in coal consumption will average about 2,805 tons, or with coal costing 30s. per ton an annual saving to the owners of £4,207 10s.

Plate 30.—The curves shown were taken during the trials of a motor yacht driven by an internal explosion engine running at about 1,260 R.P.M. when developing its full power of 40 B.H.P. It will be observed that with the Stator propeller fitted the slip increased with the engine speed from 30·8 per cent. at 850 R.P.M. up to 33·4 per cent. at 1,050 R.P.M. when the speed of the boat was determined at 10·8 knots. As the revolutions of the engine were increased it was found that the slip began to fall away until at 1,260 R.P.M. its value was as low as 30·2 per cent. when the yacht was travelling at 13·42 knots. The comparison of slip and speed without the Stator propeller is self-explanatory. The trials with and without the Stator propeller were however not made with the same rotor propeller, but in each case this was chosen to give the highest possible vessel speed in each instance, but it is quite clear that the fitting of the Stator and adjusting of the Rotor propeller increased caused an increase in efficiency equivalent to 28 per cent. on the run-

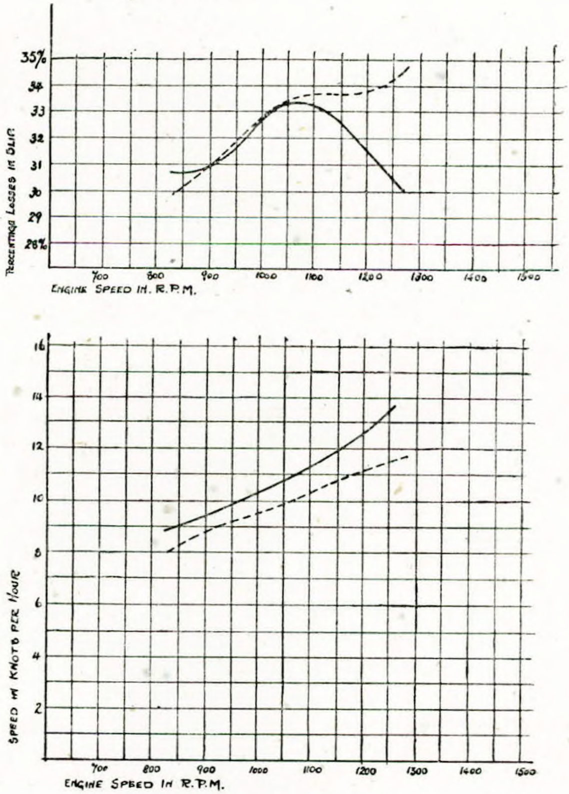
ning of the vessel under the best possible conditions otherwise obtainable, or an increase in speed of 13 per cent. for the same output of power by the prime movers.

The following are other tests that have been carried out:—

(a) Foreign Torpedo Boat.

Speed 29 knots I.H.P. of Engines 12,600.

Saving in power after the Stator propeller had been fitted and a new Rotor propeller installed = 20 per cent.



Curves shewing results of trials on a motor yacht, with and without the "Birkett Regenerative Propeller"
Trials without shewn. - - - - - .
Trials with shewn ———.

Plate 30.

(c) River Steamer.

Speed 10·5 knots I.H.P. of Engines 130 H.P.

Saving in power after the Stator propeller had been fitted and the original Rotor Propeller used = 15·4 per cent.

(b) Steam Tender.

Speed 12·5 knots I.H.P. of Engines 350 H.P.

Saving in power with Stator propeller fitted but using the originally fitted Rotor propeller = 17 per cent.

These results enable the great possibilities and advantages of the "Birkett" Stator Propeller to be fully realised, and it is considered that the speed of a Submersible fitted with this interesting device and a rotor propeller designed to act efficiently in operation with it would increase the speed of a Submersible by about 9 to 10 per cent.; so that assuming the vessel had a speed of 18 knots on the surface without the Stator propeller, the addition of this simple device would mean a final speed of about 19·75 knots without in any way effecting an increase in the output of the prime movers.

Among the remarkable developments in marine engineering which have taken place during the last few years, perhaps the design and construction of Internal Combustion Engines for operation in Sub-Aqueous vessels has produced greater changes in design and construction of Internal-Combustion Engines for operation in Sub-Aqueous vessels has produced greater changes regard to these vessels than any other piece of mechanism in use therein. After considerable study and research work to find a suitable prime mover for the "Wood" Submersible, a conclusion has been arrived at that an interesting type of engine, the invention of a well-known Member of this Institution, embodies not one, but many features which are highly desirable and significant.

Captain Wm. P. Durtnall, with his usual style of development, has in many cases proceeded along lines almost directly opposite to current engineering practice and has brought about improvements in his engine which certainly promise a rosy future.

In common with the Automobile and Aeronautical Engineer, the Submersible Engine Designer has endeavoured to get as much power as possible from a given weight by the many means of obtaining the highest possible indicated mean effective pressure for power and speed, and in many cases regardless as to fuel economy and other considerations, such as *Silent* and *Cool* exhaust operations.

In adopting the "Paragon" Cycle for Submersible prime movers, the fact has been taken into consideration that a very considerable increase in the travelling radius at various speeds is possible owing to the high thermal efficiency of Captain Durtnall's double acting engines. The six cylinder design shown is capable of developing 750 brake horse-power at 750 R.P.M. It operates on the 4-cycle principle, and is fitted with light weight pistons of ordinary steam engine design (but cooled by means of pure water circulation) and crossheads.

The engines are further fitted with balanced-piston-type valves, a feature that is possible owing to the better general heat conditions under which these engines will operate. As the valves are "pulled" instead of being "pushed" off their seatings their duty is considerably lightened, especially when borne in mind that the expansion is taken down to about 3 lbs. above the pressure of the atmosphere before the exhaust valve opens. The cylinder covers are detachable, as will be seen, to facilitate the quick withdrawal of the pistons, and are water-cooled, as are the interiors of both the inlet, and the exhaust valves, whilst the bottom ends are fitted with metallic packings also cooled by water circulation.

To meet the very heavy exigencies of service universally met in Marine Engine practice, the design consists of an open type stanchion structure on girder bases, giving great strength and rigidity combined with lightness, besides admitting of coolness and ease of accessibility to all working parts whilst running. The valve operating rods, being under "tension" instead of "compression," allow of a very light but efficient design and construction. The inlet and exhaust valves are placed on opposite sides of the engine in easily accessible positions together with their eccentric operating side shafts driven by ordinary gearing immersed in an oil bath. The crank shafts are cooled by water circulation forced through them, and the complete engine is automatically lubricated by forced feed oilers.

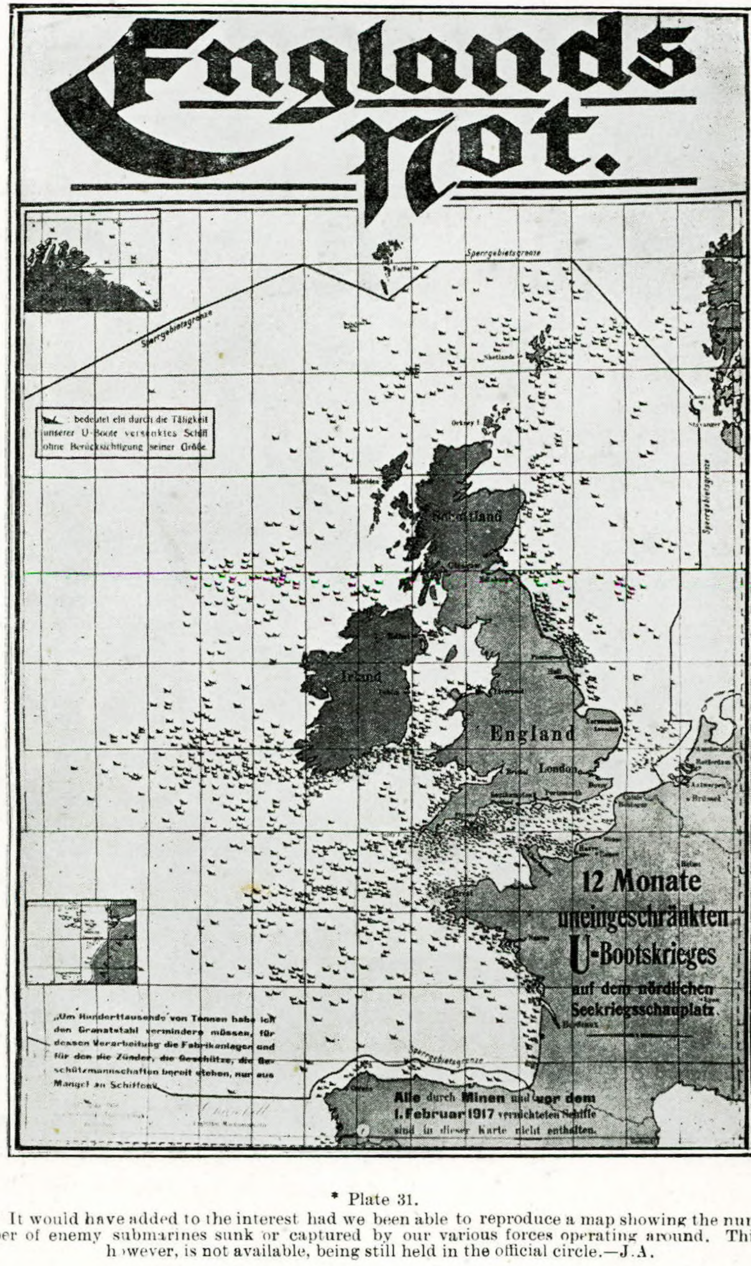
The cylinders are 11 inches bore by 10 inches stroke, and a very important feature in this design engine is the fact that being of the "double-acting" type, the cylinders are entirely sealed up and no burnt or other gases can possibly be liberated into the engine-room, a factor of safety not present in connection with any type of single acting trunk type open-bottom engine, and a feature which will contribute to the more comfortable operation aboard the "Wood" Submersible.

This "double-acting" design brings in its train some very satisfactory factors, for a given power and speed the height is less than the "single acting" type (even when designed on the "cross-head" principle) the moving parts are lighter, the momentum and inertia losses are consequently smaller, the bearing surfaces are reduced with safety, the turning moment is extremely even (in fact almost as good as a turbine) consequently no fly-wheel is required, and a minimum of vibration, whilst the engine is running. The design assures a splendid balance both from the explosion and mechanical points of view, whilst each engine is estimated not to exceed $3\frac{1}{2}$ tons nett weight, or in other words about 10·45 lbs. per horse-power.

In the "Wood" Submersible these engines would be started "Electrically" by means of the dynamo being made to run as motor from the battery energy; the ordinary atmospheric air being used and compressed to about 300 lbs. per square inch, the maximum pressure the cylinders will have to stand. Bearing in mind that the explosion pressure of the "Otto" cycle type of engine reaches this pressure and the cylinders have to be designed to withstand this, the "Paragon" engine need not be constructed to weigh more than the ordinary "Otto" type engine installed in the earlier type Submersibles. This very important feature combined with the fact that the necessity for a flywheel has been entirely eliminated, ensures the production of a light weight, simple, reliable and efficient type of prime mover, automatic in action and yet combining the maximum of output with the minimum of weight and stowage space.

These engines will operate on "Gas" made at about 400 lbs. pressure from a special liquid fuel prepared from coal or crude residue oil, in oil-gas producers, very small in size, yet possessing high thermal efficiency with the minimum of weight.

In conclusion, a few remarks regarding the future status of the Submersible. Prior to 1914 it was frequently stated by high Naval Authorities that the Submersible was essentially the arm of the smaller States and Powers. Even Germany when plunging Europe into the Greatest War that human beings have ever been engaged in, did not realise the enormous possibilities of her underwater craft. It was only when the blockade tightened



* Plate 31.

* It would have added to the interest had we been able to reproduce a map showing the number of enemy submarines sunk or captured by our various forces operating around. This, however, is not available, being still held in the official circle.—J.A.

and the utter folly of matching a numerically smaller navy against the combined fleets of the Allies was realised, that the "Marineamt" grasped the enormous possibilities of a ruthless submarine campaign.

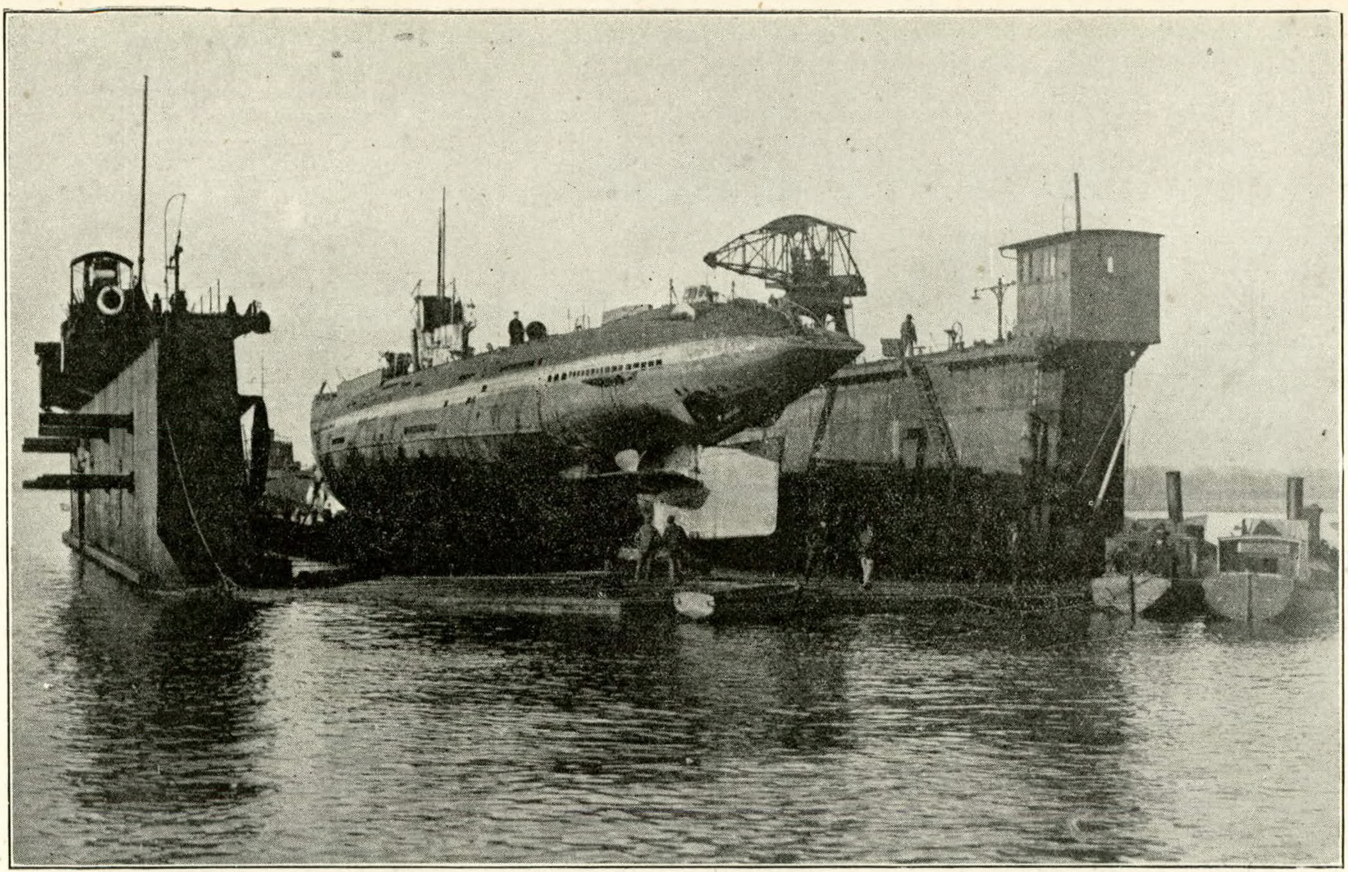
PLATE 31.—As to whether this terrible venture was successful or not is best answered by the map posted by the Huns in the large Belgian cities to intimidate the populace and to support foul propaganda work. The system of attacking and sinking peaceful hospital ships, merchantmen, fishing craft, etc., cannot be defended in the slightest degree, but it proves that the Submersible is indeed a truly deadly and masterful Service arm. Only a few details of the magnificent work carried out by the British Submersibles have up-to-date been issued to the general public, but such facts as are in their possession prove beyond dispute that these vessels are terribly effective, even when used with a purely warlike intent devoid of all frightfulness so far as naval war is concerned. It was probably the great and terrible destruction and havoc wrought by the Hun Submersibles that generated the proposal to prohibit utterly the future building and commissioning of underwater craft by any State or Power. Those responsible for this proposal do not perhaps grasp and realise to the fullest extent the great advance made by aircraft of all types during the last few years. It is more than probable that in 20 years time a huge battle-cruiser armed with steel plates, 18-inch guns, and steaming at 45 knots per hour will prove a fine helpless target for a seaplane or airship armed with a number of heavy bombs accurately fired out of sighted tubes by compressed air or other mechanical means and having a speed of 4 or 5 times as great as that of the cruiser. Should this state of affairs develop, what chance will the poor "tub" merchantman have against such tremendous odds. Very little, it can safely be said. It must either submerge or "go under." Countries like our own, dependent principally for food and other necessities on outside supplies will be placed in a most precarious and unenviable position. But the cruiser or merchantman that can submerge would stand a very good chance of running an air blockade, particularly as a dive would only be necessitated when the approach of hostile aircraft was heralded and submergence at a good depth would render them practically invisible from the air. It has already been shown that the development in displacement and speed of underwater craft using

the modern system of propulsion is bounded by the limited possibilities of the Diesel engine, but there is no apparent reason why this difficulty should not be entirely overcome by the "Wood" system of propulsion especially as it is claimed that the weight per horse power tends to become smaller as the output of the propelling machinery increases.

Unless unforeseen circumstances arise the Submersible will never have the same surface speed as surface craft with the same displacement owing to the greatly different structure work and weight of machinery necessary to effect submergence. But there would appear to be no reason why the former should not be fitted with guns of as large a calibre as the latter. In the present War the most deadly enemy of the Submersible, it is understood, was the Torpedo Boat Destroyer, which owing to its great speed and manœuvering capabilities possessed a decided advantage. This state of affairs, however, should undergo a complete alteration as soon as the Submersible is sufficiently developed to enable it to rise and battle with surface craft on more equal terms. Larger and more powerful destroyers will be necessitated which in turn may be found to be ineffective against large aircraft.

Lastly, the one great lesson that has been driven home during the last five years or so is that the second-rate vessel counts for little in naval warfare. It is crushed by the heavier armament and better manœuvering capabilities of the superior vessel in every instance. The Submersible is entering into a new era, shall it be wiped out to satisfy the requirements of those who are afraid to apply the test of the survival of the fittest, or shall it be developed and counted as the finest arm that any navy can possess? In Nelson's time, men were sent to sea to battle for the destiny of our Empire under conditions which to-day would be regarded as savagery and criminal, and yet thanks to the pugnacity of our race they won. Shall then this trait of character be entirely depended upon in the future or shall Britain send her men to fight her battles in vessels second to none in existence. Time alone will show.

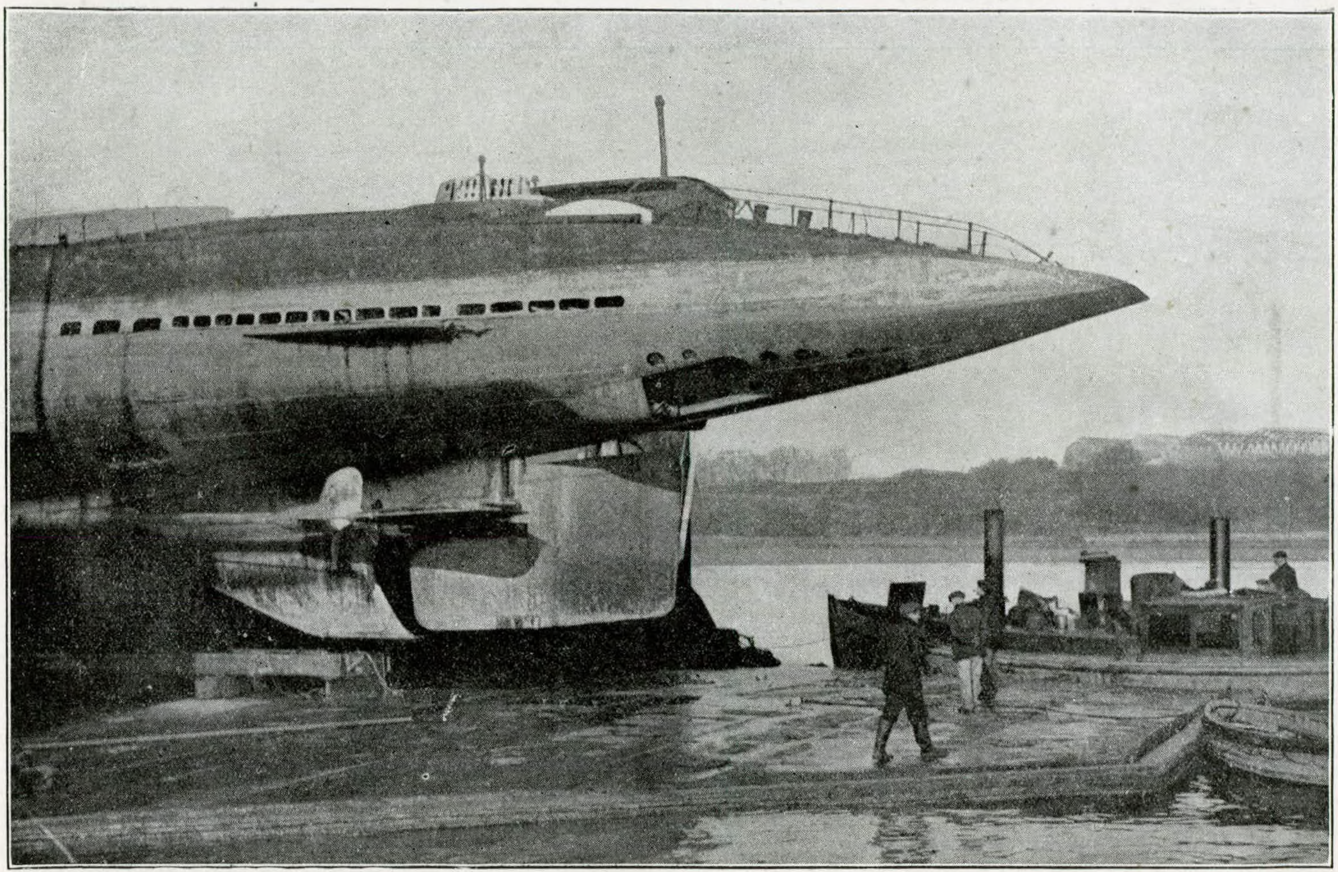
It is impossible in a short paper of this description to deal with the study of the Submersible as fully as might be desired, but those desirous of obtaining fuller and more complete details of these interesting vessels should avail themselves of the opportunities offered in the following works on the subject:—" The



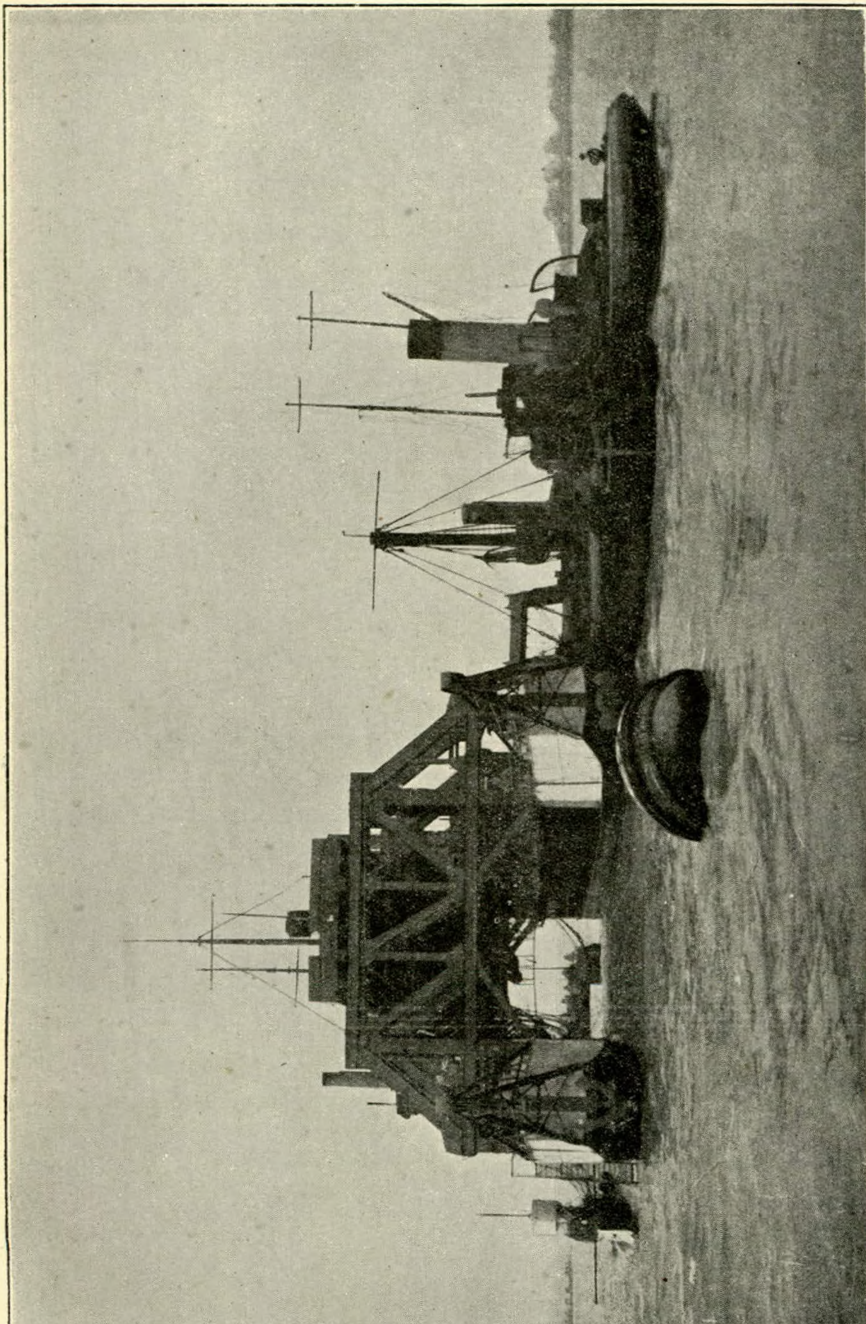
* General view of U boat in floating dock.

* Reproduced by the courteous permission of the Editor of *Shipbuilding and Shipping Record.*

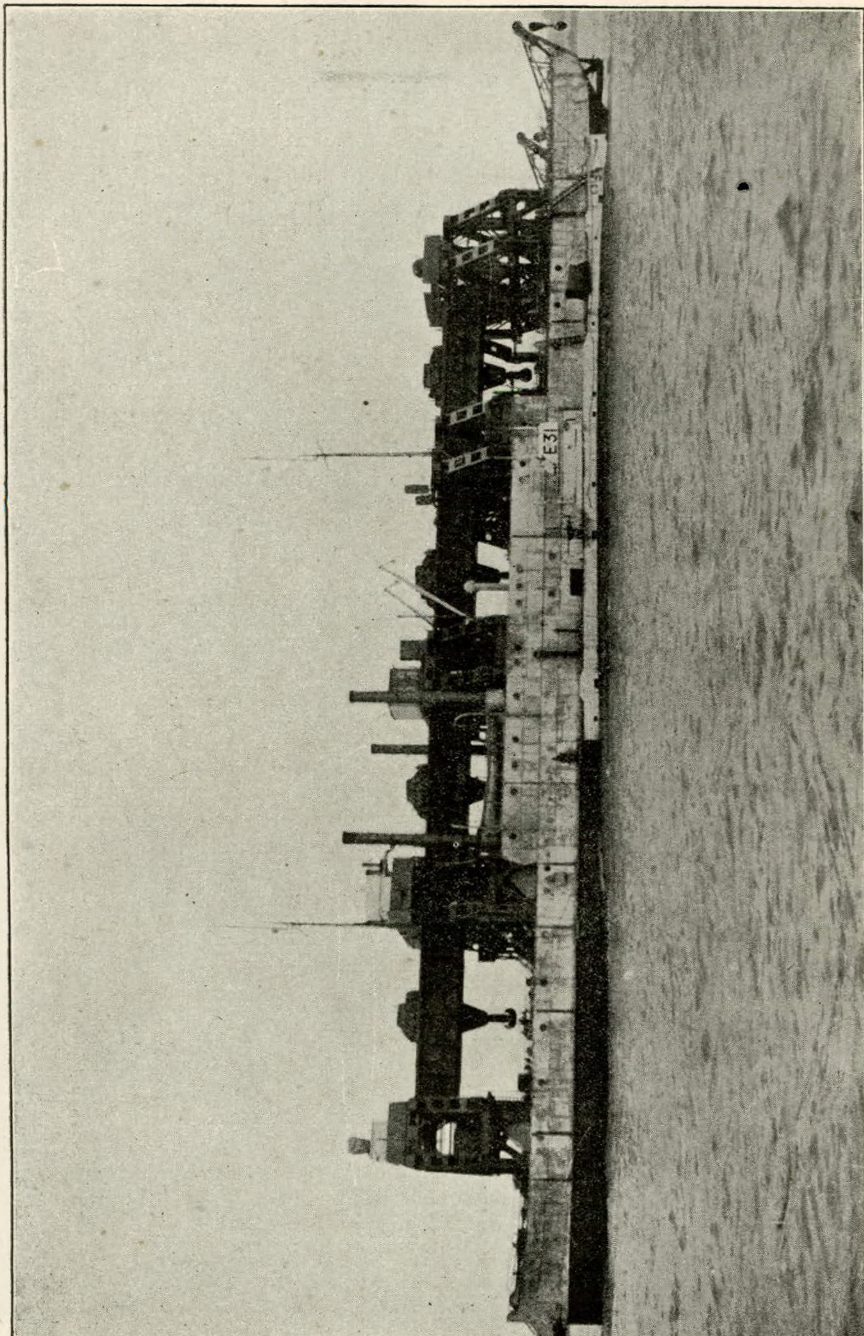
EVOLUTION IN PROPULSION OF MODERN SUPER-SUBMERSIBLE TORPEDO BOAT.



¹ View of stern of U boat showing rudder.   * Reproduced by the courteous permission of the Editor of *Shipbuilding and Shipping Record.*



Salvage Lifting Plant. Reproduced by kind permission of the Editor of *Shipbuilding and Shipping Record.*



Salvage Lifting Plant. Reproduced by kind permission of the Editor of *Shipbuilding and Shipping Record.*

Evolution of the Submarine Boat, Mine and Torpedo," by Commodore Murray F. Sueter, R.N.; "The Submarine in War and Peace," by Simon Lake; "Submarine Navigation," by Alan H. Burgoyne, M.P.; "The Secrets of the Submarine," by Marley Fotheringham Hay, and the various papers and pamphlets on the subject compiled and issued by Captain W. P. Durtnall, R.A.F.

The CHAIRMAN: We are indebted to Captain Wood for his interesting contribution to our Transactions, and we accord hearty thanks to him for his painstaking work in reproducing all his drawings to show these on the screen before us.

As there is not much time to spare those who can enter upon the discussion at once are invited to do so, and further comments may follow in writing subsequently.

Mr. R. BALFOUR: I rise to thank Capt. Wood for his most instructive lecture, to which it has been our privilege to listen. The value of it has been increased by the graphic lantern views. I particularly want to emphasise my appreciation of Capt. Wood's thoughtfulness for the comfort of the engineer. Many hardships have had to be endured during the war; but it is to be earnestly hoped that in the future, conditions will be improved and Capt. Wood's efforts will not have been in vain. I wish him every success in his new enterprise, and feel sure that I voice the feelings of all present that this will prove to be one of the most valuable contributions to the transactions of the Institute.

Mr. L. BLIN DESBLEDS: I do not know if, as a visitor, I may be allowed to say a few words in regard to a point raised in the very interesting Paper we have just heard.

The CHAIRMAN: Certainly.

Mr. L. BLIN DESBLEDS: The point to which I allude is the proposed employment by Captain Wood of the Birkett Regenerative Propeller. I am afraid I must confess I know nothing of the principle on which this propeller works. In fact my only knowledge concerning it, is what is contained in this evening's Paper. If, however, my memory serves me right the illustrations which we have been shown bear a great resemblance to the Wagner "Gegen" or "Counter" propeller which, I think, was being tested in Germany in 1910 or 1911.

From the results of the experiments which were then published it would appear that Wagner's device increased the efficiency of an ordinary screw by some 10 per cent.—a result so remarkable that it has since been a wonder to me why the counter-propeller was not universally adopted.

If I remember rightly Wagner's device consisted in a number of fixed blades, each placed at some correct angle and at a convenient distance behind the rotating screw. The object of the fixed blades is to force the water, thrown backward from the screw, to give a forward component in addition to the reaction of the rotating blades themselves.

It would seem that the water leaving a screw is possessed of a certain amount of rotating motion and, at the same time, of a backward motion not exactly parallel to the line of thrust, or reaction; and Wagner's counter-blades were designed with the object of transferring into the line of thrust a portion at least of the energy wasted, so far as propulsive efficiency is concerned.

The Curve of Efficiency against Translational Speed which was thrown on the screen shows how relatively small the propulsive efficiency of a screw is at slow speeds of translation. That low efficiency may in part be due to the fact that at a slow speed of translation the slip stream of the screw is not nearly cylindrical and is possessed of a rotational motion absorbing motive power which is not translated into thrust.

I was very much interested to hear of Mr. Birkett's efforts in designing a Regenerative Propeller. I am myself engaged, at the present moment, in studying the working of air-screws at slow translational speeds and, like Mr. Birkett, I feel that an appreciable amount of energy could be recuperated from the slip stream of screws working at relatively slow translational speeds.

Mr. J. Thom: The submersible has been proved equal to great development and value during the present war, and also proved itself a great menace to the merchant ship on her ordinary duties. I was very pleased to hear that the comfort of the engine room was not forgotten, because the very small space allowed for internal combustion engines, seeing the high temperature of same especially, with little ventilation, makes these spaces nearly unbearable to human life. This is one of the most up-to-date lectures we have had, especially with all the lantern views showing the improvements as they came along from the first ideas up to the present time.

I must congratulate the lecturer on the great attention he has given to the smallest detail in making the subject clear to the audience, which also shows he thoroughly knows his subject and takes a pride in it. I am sure many members at sea will appreciate the knowledge he has passed on to them so freely, and will thank him for the great trouble he has taken.

Mr. W. McLaren: The author is to be congratulated for bringing forward such a first-class paper on this modern sea-boat, commonly called the submarine. His historical reference to the whale and its ability to submerge and rise again to the surface by decreasing and expanding its volume reminds me there is one fish, the rock cod, which I have seen in my sea-life, when brought to the surface it cannot return to the deep and submerge owing to its volume increasing, as it has not the power to reverse, that is certainly bad for the fish but to the advantage of our friend the Chinaman and those who enjoy fish, especially when salt provisions become the order of the day with potatoes for the crew—when the call for "steward" is emphasised by holding up one finger of the hand, meaning "one." The first submarine I had the privilege of seeing afloat was off the Brazilian Coast in 1891; it had sailed from New York under its own power, whether it was a Goubet's or Holland design I am not able to state. It had a round conning tower, round hull which was awash, and tapered ends. It was intended for defensive action against the Brazilian Navy. What became of it I never heard, therefore I presume it cost much and did nothing, but seeing the flow Capt. Wood carries up along through the network of various designs of submarines and their internal mechanism, both dangerous and foolproof, the latter, including his own system, one marvels at the narrow shaves these craft have run. In my opinion the aircraft was, and is in the future, their element of doom in the daylight, as this seems to be their most effective and destructive power. I would recommend Capt. Wood with our esteemed member, Capt. Durtnall, to combine their energies and give us a paper on how to economise in ship propulsion, thanking Capt. Wood for his A1 and up-to-date paper, which has been clearly well illustrated, with his lantern slides.

Capt. W. P. Durtnall, R.A.F.: I have heard Captain Wood deliver his Paper with intense interest, I am sure that the Institute is to be congratulated in selecting this important Paper for the benefit of the members generally; it is a most advanced engineering work, and I know that Captain Wood has done his very best to make it of interest, not only to those who are present, but also to those who will, I am sure, read it with pleasure, on some of those long voyages which many of our sea-going members make, and who will appreciate the many points raised in this excellent contribution.

When I first approached Captain Wood as to his joining our Institution I did not think that in so short a time that he would be reading, what I think all will agree is, one of the most important and far reaching Papers, on the subject of submarine vessels, that I believe has ever been read before any technical institution. I know from personal observation that he endeavours to do most things thoroughly, and I think that most of us will also agree that he has written and delivered this Paper in a most thorough and up-to-date manner, and has put in a great amount of time in the preparation of it, while I may add the large number of valuable and highly instructive drawings which he is illustrating it with have been prepared by himself, together with the instructive description of them which he has so ably delivered to us this evening.

The historic features of his paper have been well put, and he has described the gradual development of what must in future be the most effective sea fighting weapon that can be owned by any country, and I am glad to see that it is through our practical Marine Engineering Institution that Captain Wood decided to give his valuable experience in submarine engineering to the world, it being all the more valuable owing to Captain Wood's practical experience in designing, building, and testing of these wonderful under-water vessels, and I note with great interest that he has illustrated his own special method of propulsion, and has described the improvements which he has brought about, in order that the submarine engineers shall have a better time in future. When I get my copy of our journal containing this paper I shall value it more than any other book on submarine work which I have, as I know that it embodies the very latest practice, and indicates the possible future lines on which we shall have to operate, if we are to keep abreast of the time in this country, and for that reason it will be observed that it is on the Marine Engineer, more than anyone else, that the future safety of the country will depend.

During the course of the war I have had experience with at least two types of submarine vessels, and I am pleased to see that Captain Wood has drawn attention to the dis-advantages of the "Diesel" type of engine, and also to the great flexibility of "Electrical Propulsion." I am particularly interested in his remarks, for it was at this Institution in 1908 that I first made public my original invention of polyphase alternating current "Thermo-Electric" propulsion for ships, and which has during the last ten years made so much progress, and is now being installed in some of the most powerful warships in the world. Those of our members who can remember this original Paper and the splendid helpful discussion which took place afterwards, did not at the time, anymore than I did, imagine that such a revolution would have taken place in these short ten years, but, I am very pleased that it is to our Institute of Marine Engineers that the credit of the first introduction of the new system to the world must be given, despite the fact that Mr. Daniels, the Secretary of the United States Navy, in some recent well-meaning words, practically claimed such honour for the United States, and in spite of the fact that I was awarded and presented with the highest award of this Institution in the form of the "Denny" gold medal long before the Americans entered the field of electrical propulsion for ships, and as most of you are aware my original Paper (for it was the first ever read in the world) was published all over the Globe, in fact, it was reproduced in September, 1908 in one of the leading electrical engineering journals of Chicago, U.S.A. I feel sure, however, that had Mr. Daniels known of such, that he would have given credit to this Institution, where it is due.

It was in September, 1910, that I was honoured by the Council and Members of this Institution by being selected to read a further Paper, before the Congress meeting of this Institution, at the Naval and Marine Engineering Exhibition, at Olympia, in London, in which I indicated as far as possible some of the developments which Captain Wood has so much appreciated in my "Paragon" Fire-proof-Silent, Cycle Internal-Combustion Engine, and which he has selected to meet the demands which he made in connection with the prime-movers for the "Wood" Super-Submarine. At first I was rather doubtful if the conditions which he demanded could be satisfactorily met, but on going into the details I put forward the type of double-acting 4-cycle engine he has so ably described to us this evening, and to further his remarks I will put on the screen an illustration of the type of engine which is similar to those which Captain Wood has adopted for his 2,800 horse-power type vessel; see illustration A.

It will be noticed that marine engineering practice has been followed, and that many well tried and experienced methods have been taken advantage of in the general design and construction, which differ from the ordinary marine gas engine in the fact that they are supplied with fuel at about 100 lbs. per square inch above the compression pressure which is 300 lbs. per square inch; it will also be observed that the expansion is taken down to almost the pressure of the atmosphere, the engines have a very high thermal efficiency consequent to the cycle of operations made use of, and that which will appeal to the practical sea-going engineer is the very low temperature of the exhaust gases, namely about 400 degrees Fahr. It will thus be obvious that the exhaust valves will stand up to their work much longer, and require less attention than most of the engines which I have used and handled previously at sea.

Just before the war I was in Russia, and had to deal with a number of small 300 horse-power double-acting gas engines on river boats, and considerable trouble was experienced at first owing to the fact that the Russian engineers were not used to the new type of prime-mover. They were started by means of compressed air, and ran at 350 R.P.M., developing 300 S.H.P., but after a short explanation of the operating theory and handling practice, the Russians handled these engines in splendid shape, swearing they would never go back to steam again, because of the easy work which these engines brought about. Indeed these little engines ran as sweetly as a sewing machine, they had no flywheels, these being unnecessary, they were six cylinder double-acting engines, and afterwards gave very little trouble, after a little schooling into the new ideas, which cost nothing, and went so far—it indeed pleased a crowd of sea-going men, and that was something. They weighed 7,000 pounds each, and a very noticeable feature was the fact that being sealed double-acting cylinders, the only way out for the exhaust gases was through the exhaust boxes, and the engine-room was a real pleasure to work in compared with some I have seen, and was indeed an engineers' palace, everything being kept clean and bright, and with little trouble.

The engine which I show is the one which I designed for a big "cheap electrical power" scheme on which I worked in 1915, proposed for supplying the London district, and with current at four units a penny, these engines having a high thermal efficiency (indicated) allowed of such a low price, and I still think that such a scheme will yet be the solution of the problem of the London Industries. Captain Wood considered the whole plan thoroughly in detailed discussion, before finally adopting this engine for his system, for submarine vessels, he, I believe, thoroughly appreciated the reduction in weight for power which I am able to get, by the double-acting design, a still further reduction will be obtained in my new double-acting, two-stroke, three-cycle method, for which I had such a fight in German Patent Courts in 1913, before my German patents were granted, all the Diesel interests were put up against me, but I was able to show that my invention had not been anticipated, and so demanded my patent rights, which were in the end granted. The highest indicated thermal efficiency I have ever obtained in a four-cycle Diesel engine was 48 per cent., this was one which was specially tested and tuned up for experimental work in connection with some research work on which I was engaged in 1913, and in practice on some generating stations as much as 44 per cent. is every day obtained, but owing to the reduction in the compression space volume and exposed area, together with the increased volume given in the "Paragon" cycle, I am in the position to-day to obtain as much as 60 per cent. indicated horse-power from the heat energy in the fuel, which can be either distilled coal or oil.

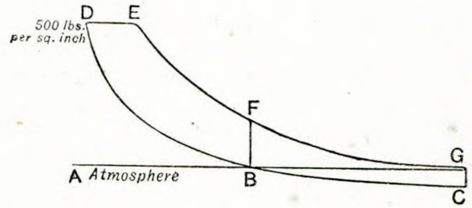
The CHAIRMAN: The engine is certainly very interesting, and I appreciate the marine engine features of the design, but how do you reverse, I do not see means for this essential function?

Capt. DURTNALL (Member): Yes, or course, if the engine was designed to operate with reduction gears, or for driving the propellers direct it would be essential to bring in the design suitable reversing mechanism which is carried out in a novel method indicated in my original Paper on the "Internal Combustion Engine," in 1910 (February issue, 1911, Institute of Marine Engineers' Transactions, page 412) in the reversing type of "Paragon" engine, the valves are all operated electrically, and the running "Ahead" or "Astern" or "Speed regulation" is controlled from the engineer's control platform, by means of an electrical controller, similar to that used on tramcars, etc. The engine shown, however, is one for the previously mentioned "Cheap Electrical Power Public Supply," and has piston type induction and exhaust valves, which are variable in a similar manner to that applied to most marine engines, they are controlled from two eccentrics lined up between each pair of cylinders, which are actuated by the speed governor. These engines, however, were not designed for "Reversing" as they only drive the "Paragon" alternators and always run at one speed and in one direction. It will be observed that they have no fly-wheels, they are each of 2,000 brake horse-power, with eight double-acting cylinders 14in. × 14in., one set of engines run right-hand and the other left-hand, and by means of two special flexible spring couplings they jointly deliver 4,000 brake horse-power to the short-circuited rotor of the asynchronous generator, which is 12 pole and delivers three-phase current at a periodicity of 48 per second.

The complete set is 39 feet long, is 4 feet 8 inches wide, and stands 8 feet from floor level to top of cylinders; practical engineers will appreciate the fact that I have split up the length of the crank-shafts and alternator shaft, but at the same time held them in line in their bearings, the former being each of 16 feet 3 inches long. Apart from the fact that the whole embodied an installation of special "Paragon" gas-producers, the interesting scheme also provided for taking a certain amount of surplus gas from the London and District Gas Companies, at a very low rate, this gas being pressed up to 400 lbs. per square inch, before being supplied to the engines for duty.

I append here a very interesting set of remarks made by Captain H. Riall Sankey, M.I.C.E., on my "Paragon" internal-combustion engine cycle (as applied to high pressure oil engines) in connection with his Howard Lectures on heavy oil engines read before the Royal Society of Arts, London, in October issue of their transactions, 1912:—

"An engine has recently been proposed by Mr. Durtnall, which is of the Diesel type, but the suction valve is arranged to close before the end of the out stroke, so that, as shown in Fig. 65, pure air is drawn in from A to B, and this air is expanded along the line BC to the end of the stroke at G. The reduction in pressure at the end of the stroke acts as an air cushion, arresting the motion of the parts and reducing the bearing pressure. On compression of the stroke the indicated diagram follows the line CBD, and the compression space in the cylinder can be so arranged that the pressure at D shall be 500 lbs. per square inch, needed for heavy oil ignition. DE shows the full admission as in a Diesel engine, and the expansion EFG is extended to atmospheric pressure. The exhaust of this engine would therefore be at constant pressure. BDEFB would be the diagram of the corresponding Diesel engine. The theoretical thermal efficiency of this type of engine would therefore be greater than that of the pure Diesel engine."



It will be observed that in this case the compression pressure is taken up to 500 lbs. per square inch as in the "Diesel" cycle. I was very pleased to see Captain Sankey draw attention to my work in such a very kindly manner, producing the diagram himself, and for the first time publicly explained and appreciated my invention, which is all the more significant coming from such a well-known authority on heat prime-movers.

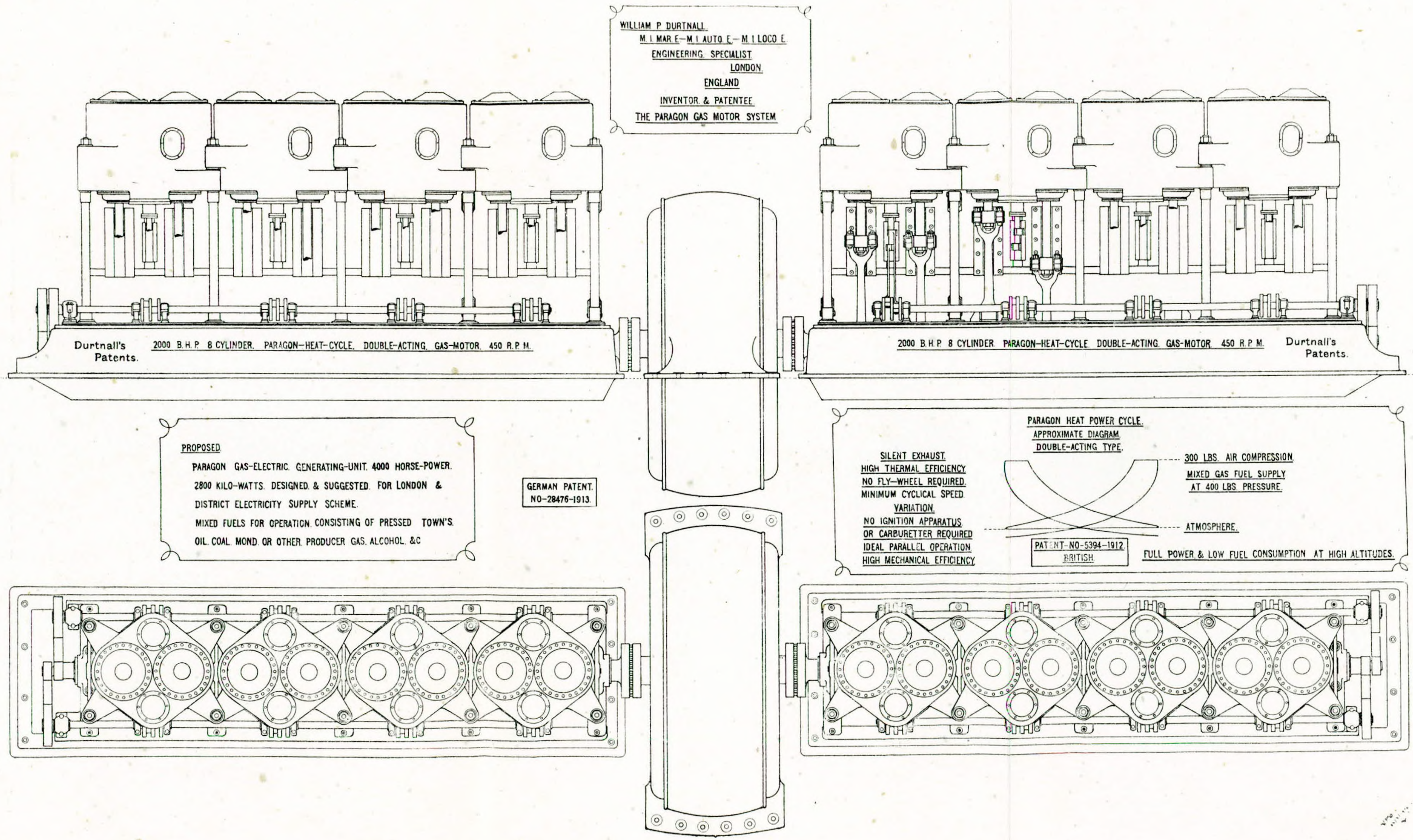
Captain Wood's remarks concerning the possible future of the submarine vessel are of high interest to me, especially as I have also been working on research work in connection with the engineering part of the subject, and illustration B shows the rough design of a submarine destroyer which I got out in 1914. It was submitted for approval, however, nothing was done to encourage the matter in this country, although many Naval Authorities in Russia and Sweden appreciated the possibilities, and a well-known authority in America came over to see me about it, and it will be perhaps in that go-ahead country that my first "Paragon" submarine vessel will be built.

It is propelled by special "Paragon" beater propellers, same as were also described in my original Paper on the internal-combustion engine, in 1910, before this Institution; it has no screw propellers, rudders, or planes, these are not required, but is able to sink or rise by prime-power although in a stationary condition. There is no such thing as "steering way" in connection with this boat, because these functions are efficiently carried out by changing the angle of beating which is electro-magnetically carried out from either of the two control stations. Reversing is also carried out in a similar manner, and by the same control apparatus; the vessel can be made to "beat down" to bring it up, and to "beat up" to pull it down; further can turn on its own centres, and after ramming, or running into mud or other obstacles can wrigle itself loose and get away. The exhaust funnels, the wireless masts, air intakes and periscopes are telescopic, and the latter being of my special type, arranged designedly so that "night" or "day-light" signalling can be carried out even though the body of the vessel is submerged—a point of high interest, and on that I put into practice during the war on other type vessels. The fact that the driving power is split up in this case in 14 units, provides the means of taking the utmost advantage of "cellular" construction, it is in fact a floating girder, which runs the full length of the boat, the cells containing the driving machinery and other apparatus are suspended from this girder, producing the stream-line form shown, and in the development of the special form of bow lines, I was assisted by the investigations carried out by Lord Rayleigh, Past President of the Royal Society, London, and these are well worth the study of every Engineer who really has the marine engineering industry at heart, and I can recommend them to my fellow members of the Institute.

This little vessel, which is 300 feet long, 38 feet beam, and has a depth of 23 feet, and can carry an armament of several heavy guns, 12 24in. torpedo tubes, internal-combustion driven torpedoes, has a displacement "awash" of 1,850 tons, a displacement "submerged" of 2,250 tons, a surface speed of 20 knots, a spurt speed submerged of 15 knots, a two hours speed submerged of 13 knots, and a six hours submerged speed of nine knots; the cruising speed is 14 knots for 4,500 miles, and the bunker capacity 90 tons of heavy oil fuel. Four "Paragon" cycle engines are fitted, each developing 400 horsepower and driving double current generators, alternating current for the driving motors, and direct-current for the charging of the accumulators (Edison type). The combination of accumulators and engines can be made use of for spurt work in getting away, etc., whereby 4,000 horse-power, the total power of the motors, can be developed. I estimated that it could be made to sink from "light load" condition in 50 seconds, and from "awash" condition in 20 seconds, and could turn on its own centres in $1\frac{1}{2}$ minutes. It is fitted with my special "wireless" outfit, and which also embodied the "Paragon" high frequency generator, which I believe will make clear speaking by telephone at sea possible before many years.

This is the first publicity that I have given to my work in this direction, and I feel sure that Captain Wood will appreciate many of the points raised from an experienced submarine operator's point of view, at least it is a step in the right direction. It would be indeed interesting to witness a scrap between such a fighting machine, and the ordinary type of submarine vessel with their slow movements in control and diving, although I notice that Captain Wood has increased the manœuvring ability of his machine far away above that obtained in the ordinary vessel, as he points out the all-electric drive permits of facilities in this direction which are impossible in the methods used at present.

There are many who discredit the serious nature of the submarine, with its at present limitations as to power and length, but, the march of engineering progress is irresistible, and I believe that I have branched out in a direction through means providing that very long submarines will be able to dive even in shallow water. It must be remembered that there is a limit to the length, and thereby the diving angle, otherwise it would be possible for a long vessel to touch the bottom with her bow. before her stern was down, the design of machine which I describe above should therefore be of interest if only from that aspect. The uninitiated still believe that the submarine vessel is very risky and dangerous, and feel that the principles of operation and construction have not yet been brought to a final state of perfection; most of the accidents which have occurred with submarines can be traced to faulty construction or carelessness, and in my views, these engineering fighting machines should always be operated by engineers, who understand the mechanical merits of the apparatus under their charge. For instance it will be appreciated by many who study the matter, that the "Cellular" construction method, with all its cross bulk-heads and strong compartments, makes for a much stronger vessel, capable of descending with safety to depths as yet unknown so far. Whilst I am also of the opinion that with the modern high-speed turbine pumps now available, that research work in connection with "hydraulic" or "jet" propulsion will in time be an asset to the Marine Engineer who many yet traverse the submarine engineering world, and the modern screw propeller will then descend into the depths in the limbo of things forgotten. I am, however, grateful to Captain Wood, and to the Institute of Marine Engineers for bringing up the


WILLIAM P DURTNALL.
M. I. MAR. E.—M. I. AUTO. E.—M. I. LOCO. E.
ENGINEERING. SPECIALIST
LONDON.
ENGLAND
INVENTOR & PATENTEE
THE PARAGON GAS MOTOR SYSTEM
Durtnall's Patents.
2000 B. H. P. 8 CYLINDER. PARAGON—HEAT-CYCLE. DOUBLE-ACTING. GAS-MOTOR. 450 R. P. M.
2000 B. H. P. 8 CYLINDER. PARAGON—HEAT-CYCLE. DOUBLE-ACTING. GAS-MOTOR. 450 R. P. M.
Durtnall's Patents.
PROPOSED.
PARAGON GAS-ELECTRIC. GENERATING-UNIT. 4000 HORSE-POWER.
2800 KILO-WATTS. DESIGNED. & SUGGESTED. FOR LONDON &
DISTRICT ELECTRICITY SUPPLY SCHEME.
MIXED FUELS FOR OPERATION. CONSISTING OF PRESSED TOWN'S.
OIL. COAL. MOND. OR OTHER. PRODUCER GAS. ALCOHOL. &C
GERMAN PATENT.
NO-28476-1913.
PARAGON HEAT POWER CYCLE.
APPROXIMATE DIAGRAM.
DOUBLE-ACTING TYPE.
SILENT EXHAUST.
HIGH THERMAL EFFICIENCY
NO FLY—WHEEL REQUIRED.
MINIMUM CYCLICAL SPEED
VARIATION.
NO IGNITION APPARATUS
OR CARBURETTER REQUIRED
IDEAL PARALLEL OPERATION
HIGH MECHANICAL EFFICIENCY
300 LBS. AIR COMPRESSION.
MIXED GAS FUEL SUPPLY
AT 400 LBS. PRESSURE.
ATMOSPHERE.
PATENT-NO-5394-1912
BRITISH.
FULL POWER & LOW FUEL CONSUMPTION. AT HIGH ALTITUDES.

THE "PARAGON" SUBMARINE DESTROYER

THERMO-ELECTRICALLY PROPELLED.

DIVING & RISING BY DIRECT—CONTROLLED POWER.

DOUBLE-ACTING HEAVY OIL-GAS ENGINES AS PRIME-MOVERS.

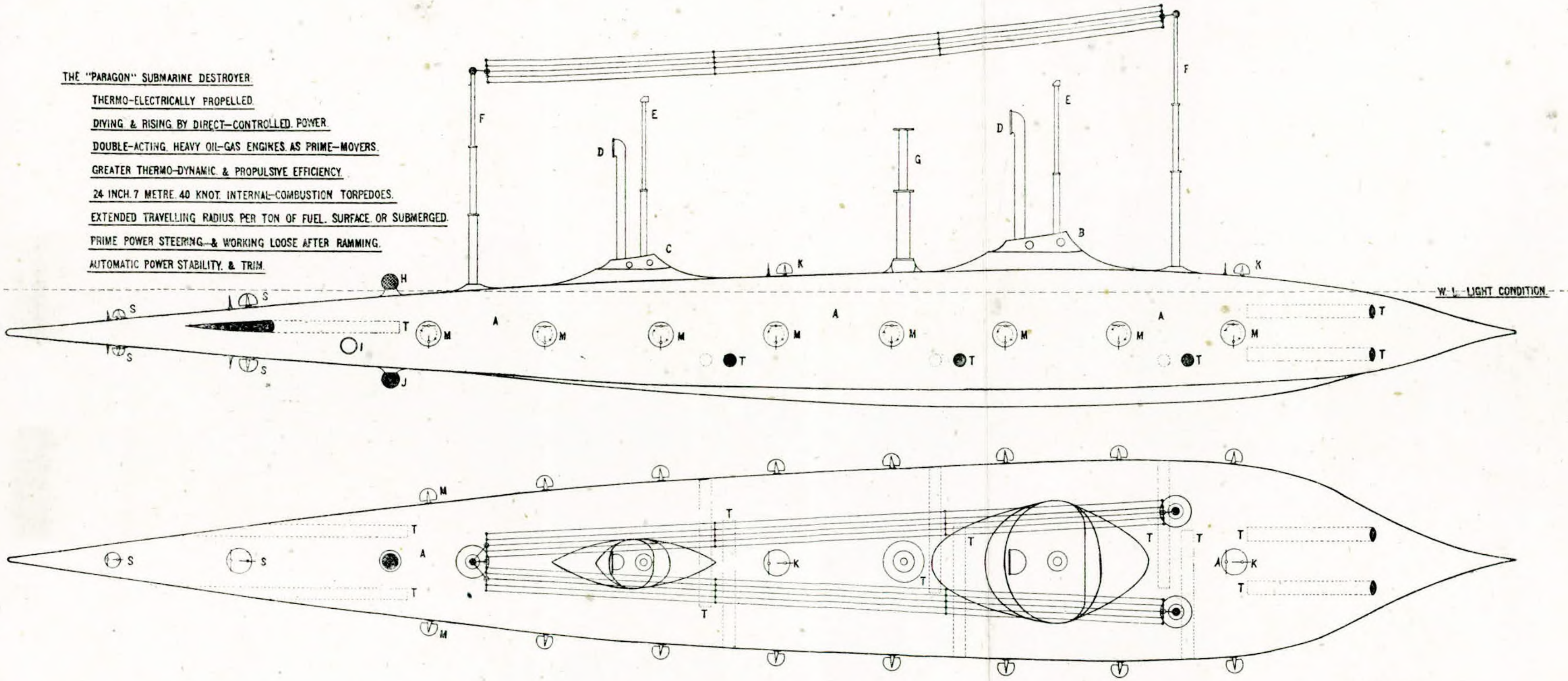
GREATER THERMO-DYNAMIC & PROPULSIVE EFFICIENCY.

24 INCH. 7 METRE. 40 KNOT. INTERNAL-COMBUSTION TORPEDOES.

EXTENDED TRAVELLING RADIUS PER TON OF FUEL. SURFACE OR SUBMERGED.

PRIME POWER STEERING & WORKING LOOSE AFTER RAMMING.

AUTOMATIC POWER STABILITY & TRIM.



THE PARAGON SUBMARINE TRANSPORTATION COMPANY.

ENGINEERS & CONSTRUCTORS

11 WATERLOO PLACE

PALL MALL

LONDON S.W.

DISPLACEMENT. TONS.

SURFACE. [redacted]

SUBMERGED. [redacted]

LENGTH. 300 FEET.

BEAM. 38 FEET.

DEPTH. 23 FEET.

HORSE POWER.

ENGINES. [redacted]

MOTORS. [redacted]

CELLS. [redacted]

AMPERE HOURS.

APPROXIMATE PHYSICAL DATA.

ESTIMATED SPEED KNOTS.

FULL POWER SURFACE. [redacted]

FULL POWER SUBMERGED. [redacted]

ONE HOUR. [redacted]

SIX HOURS. [redacted]

TIME SINKING. SECONDS.

FROM LIGHT CONDITION. [redacted]

FROM AWASH. [redacted]

TIME TURNING ON CENTRES. MINUTES. [redacted]

FUEL CAPACITY TONS. [redacted]

TORPEDOE TUBES.

FORWARD. FOUR.

AFT. TWO.

EACH BROADSIDE THREE.

Durtnall's Patents.

CELLULAR CONSTRUCTION.

subject for discussion, and I am sure that I convey the best feelings of all the members that read his paper and their thanks for the trouble that he has taken, to interest them in this wonderful new field of skilful and practical marine engineering.

Capt. Wood: I am very pleased to see that Captain Durtnall has favoured us with his presence to-night and stated the general principles on which his famous "Paragon" cycle engines operate. Having regard to the fact that the modern submersible is bounded in displacement by the increase in weight per h.p. developed by the Diesel Engine, I was obliged to have recourse to some other type of internal combustion engine as prime-mover if my idea and invention was to be a practical possibility. No other type of engine, so far as has been brought to my notice up to date, so evenly meets the requirements and exigencies of service demanded as the "Paragon" type prime-movers adopted by myself in the "Wood" system of propulsion. Captain Durtnall has so carefully described and illustrated the methods and principles on which this engine operates, that any further remarks by myself will merely develop repetition work, a feature to be strongly avoided by "go-ahead" engineers. Regarding the "Paragon" submersible, I must admit that Captain Durtnall has developed and produced a decidedly new and interesting type, and if the qualities claimed can actually be produced in practice there is no doubt but that it would assure the most perfect type of vessel attainable. I observe, however, that he has made use of the double current system of propulsion, whereby the main dynamos are fitted with sliprings and commutators, whilst the main propelling motors, it is assumed, are of the squirrel cage type. Whilst running on the surface, the engines would drive the dynamos and deliver alternating current to the motors, and, if required, direct current to the battery. It is not quite clear, however as to the methods adopted to drive the vessel when submerged unless the dynamo is used as a rotary convertor, in which case some sort of loose coupling will be demanded between the engines and generators. As the principal intent of the "Wood" system is to cut out and entirely eliminate clutches of any kind, whatever efficiency may be gained by the adoption of alternating current machinery is, in my opinion, entirely outweighed by the necessity of clutches with all their attendant evils.

Perhaps Captain Durtnall will someday be kind enough to let us into the secret of how he proposes to vary the speed of the motors driving the beater propellers, and what type of clutch is absolutely reliable under all circumstances; particularly having regard to my lengthy remarks on these troublesome items. I further observe that Captain Durtnall proposes to use telescopic periscopes fitted with his system of submerged day or night signalling, here again perhaps he will be good enough to also state how he proposes to overcome the vision, focussing, vibration and range finding difficulties so prevalent with this most important fitting. Still there is no doubt that an officer of Captain Durtnall's standing, so conversant with all matters appertaining to the engineering field in general, as well as optical research work, has most carefully dissected and investigated his ideas and proposals before launching the same on to the public platform. Before closing, permit me to state how very keenly I appreciate the kindly remarks by the various members who have entered into the discussion and to assure them that my only hope is that they have enjoyed listening to my proposals as much as I myself did in compiling them.

Further, I would like to publicly thank Captain Durtnall for his great, kindly and personal interest in the whole matter particularly as regards the solution of the prime-mover problem and to assure you that but for him this paper would have been almost impossible. Lastly, my deepest appreciation and thanks for the magnificent personal help and assistance rendered by our esteemed and well respected honorary secretary, and to assure him that I am only voicing public opinion when I state how very much we appreciate the up-to-date business methods on which our famous Institution is based.

Mr. F. O. Beckett: Capt. Wood has full confidence in governors that does one good to hear, and in this connection I refer to page 51, he says it is possible to fit reliable governors. Well, I am glad to hear of one; most of my trouble in investigating breakdowns is faulty governors or gearing in connection with the governing gear. About nine out of ten breakdowns I have traced to this cause that I would like to know the governor he recommends. Mr. Balfour put the case well as to providing space for the engineers on watch in the new submersible to enable them to have visual inspection of all working parts or for local adjustment. The most inaccessible heat-producing space allowed in the earlier submarine is so bad that I heartily endorse his remarks—having sympathy for the engineer on watch. Imagine Red Sea temperature 90°F. seawater, to be bottled up and the quantity of soda required to collect the carbon and release the oxygen to fit the place for human endurance!

I cannot see why gimbals cannot be brought down from the beams to carry his battery tanks where the angle assumed is 25° inclination; flexible cables and connecting gear would keep a fairly steady surface under practically any condition of rolling, of course the pitching is a different matter, but I would suggest to extend the batteries and plates a little higher to overcome the rise and not for creep, that I assume is understood, but gimbals can be made to carry a great weight with perfect safety. Is the magnetic compass preferable to the gyroscope compass, which could be secured on bottom of ship and tell-tale carried to conning tower?

I hope we will hear further of the Birkett Stator Propeller in the future, as it is evidently efficient, if fixed to hold on in a gale and not drop off at the very time of greatest distress to ship, as we have unfortunately suffered heavily in loss of arms, brackets, etc., in twin-screw ships in stress of weather, and those shown on the screen seemed very flimsily attached, and I suggest should be more strongly secured.

The sketch of tail shafts did not show any thrusts, but I assume they are allowed for, with such a short shaft I would suggest ball-bearing thrusts, with the idea of reducing weight.

Mr. R. W. Birkett (By Correspondence): Having had the pleasure, as a visitor to your meeting on the 15th instant, of hearing Captain Wood's paper and the subsequent discussion, I hope it may be allowable for me to refer to some remarks by one of the speakers who dealt chiefly with the matter of the "Regenerative Propeller," some explanation of which was given in the paper. The speaker was quite correct in his recollection of experiments made in Germany in 1910-11 with a device on somewhat similar lines, which was then called the "Gegen Propeller" or "Counter Propeller." Those experiments were regarded as successful, inasmuch as they showed a gain of about 10 per cent. in propulsive efficiency. This was considered remarkable, because previous experiments, and particularly those made in England, had shown so little advantage, that the idea of influencing the propeller currents after they have left the surfaces of the propeller blades had been practically abandoned and condemned by British Engineers. The "Counter Propeller" experiments, however, showed not only that it added something to the efficiency of the ordinary propeller designed on the accepted formula, but that it also rendered possible modifications of that formula, otherwise impossible, so that when designed together the combination of Counter Propeller and special revolving propeller increased the 10 per cent. to as much as 25 per cent. gain in efficiency of propulsion in any vessel to which it was applied to replace its original propeller. Further experience confirmed this, and I can state that up to the period of August, 1914, about eighty vessels of various types and sizes (and including torpedo boats and naval craft) had been fitted with the device, and in every case with beneficial results.

The advantage of applying some device, the effect of which would be to break up the rotatory movement of the currents from the revolving blades, and convert such rotational energy into useful re-active effect is thus established, and it then remains to decide upon the best form and disposition of the fixed guide-blades to be employed. My "Regenerative Propeller" is therefore based upon the same theory as the German "Counter Propeller," but with some improved constructional features which will enable its easy adaptation to any existing vessel and ensure the fullest possible advantage being obtained in every individual case. The speaker also referred to the curve diagram and his explanation of the first part of the curve was, of course, quite correct. But the remarkable feature is shown that with the device an increased speed of revolutions is actually beneficial to the combined propeller, and the efficiency of propulsion increases with the speed—an exactly opposite effect to ordinary practice. This would seem to show that with a "Regenerative Propeller" the main propellers may be run at very much higher speeds than is now economically possible—a feature that would be particularly valuable for example, in electrically propelled ships. I was interested to hear that the speaker was himself engaged upon experiments on somewhat similar lines to my "Regenerative Propeller." If those experiments refer to air propellers he may be interested to know that I have proposed in my Patent Specification, No. 1,707, of 1918, an application of the theory to aeroplanes, wherein I think it might serve a useful purpose. I should like to add in conclusion that, although as mentioned, considerable progress had been made in Germany with the "Gegen Propeller" (all the largest shipowning companies having had experimental boats fitted with success) neither it, nor my improved device, the "Regenerative Propeller" have as yet been introduced or experimented with at all in this country. I have available, however, a good deal of interesting data concerning it, and should any of your members be specially interested in the subject, I should be very pleased to give them any further information desired.

Mr. M. PRENDERGAST: About 1869 the two Spanish engineers, Narcisco Monturiol and Cosmo Garcia built a submarine of a very advanced type, considering the date of evolution. About three years ago the Spanish mercantile paper *Vida Maritima* published a description (with plans) of the Monturiol boat. I had a copy but perhaps I sent it to Lieut.-Col. Alan Burgoyne, M.P. Two of the latest Spanish submarines have been named *Monturiol* and *Garcia*, in commemoration of these two pioneers. About four years ago a friend showed me the manuscript of an unpublished book on extinct warship types. In it were details of the "Improved Davids," which were building when the Civil War ended, and were abandoned on the stocks. My friend was very jealous of his work—it covered fifteen years research—and he would not let me take notes. But the "Improved Davids,' so far as I can recollect, were much better and bigger than the original boats. One small experimental boat was ordered for the U.S. Navy in 1916, being known as "No. 106" in the series of U.S. submarines. I am doubtful if she is being proceeded with. About 1909-13, the French built a single propulsion system boat, *Charles Brun*. She had a "chemical boiler" fired by acetate of soda. She was a pretty big boat, and was an utter failure, and was scrapped early in 1914. The telescopic type (periscope) is said to have first been tried by the French about 1903, in Toulon Harbour. Legend runs that the device came down all right, but the first time they put the periscope up it went right through the bottom of a boat on the surface. The French Fleet was greatly interested by the sight of this boat rushing about the harbour, without any visible means of propulsion.

Lake's assumption that the Huns cribbed his plans has never satisfied me. The German engineer d'Equivilly secured plans of the French *Emeraude* class, and of the early French double-hulled *Laubeuf* type. The Huns compounded their first boats from these plans—hence their predilection for the double hull Laubeuf type, which they used in nearly all U-boats from U1 to U157 (excepting mine layers U71-80 with saddle tank hulls) Laubeuf found that Krupps were offering to build submarines of his design for the Rumanian Navy, though he never gave Krupps any license to do so. *Boche serait toujours Boche*! Apropos of diving, there used to be rather a neat stunt in the U.S. Navy. The boat was closed up and anchors dropped, then ballast tanks were all filled till only a few pounds positive bouyancy was left. Then the capstan gears were set going, and as the anchor cables came in, fore and aft, the bouyancy was extinguished, and the boat was gradually drawn down to the bottom in a kind of "vertical dive." It was rather good for scouting, as the boat was practically on spring moorings. You could rise gently to the surface and have a look round. No periscope wake, no exhaustion of batteries, and a quiet time all round.

I was rather disappointed not to find any notes on the work of Romazotti and Gustave Zede. These two men did more for the development of French submarines than Claude Goubet ever did. Considering that "Hollands," "Laubeufs," and "Laurentis" are about the only three proprietary types now built, it is a pity you did not give a line or two to Laubeuf's double hull type and Col. Cesare Laurenti's saddle-tank hull type. All modern submarines are either (*a*) single hull type, like Holland boats (*b*) pannier tank type, like the British E boat (*c*) saddle tank Laurenti type or (*d*) double hull Laubeuf type. Mine-laying submarines have become a great vogue during the war; practically every big Navy has these boats now. The Russians proved the mine-laying submarine to be a really practicable type by their "Krab." Drzveyki, the Russian engineer, did a lot of experimental work between 1897 and 1905, but it has been impossible to get details of his schemes.

Capt. Wood: The governors fitted to the high-speed engines in the "Wood" type submersible would be of the ordinary high-speed steam engine type; that is to say, fitted with the ordinary swinging balls held together by a spring, and by their movement operating a small valve which would admit the gas, according to the requirements of the engine. It should be carefully borne in mind that the Paragon engines it is proposed to use, are almost an exact replica of the high-speed steam engine, as the mixture is forced into the cylinders through the piston valves at a pressure of approximately 400 lbs. per sq. inch, and can therefore be regarded as sister to the steam engine. Amongst my many experiences with steam engines, I must say that I have had very little trouble, if any, with high-speed engine governors with this type of controlling apparatus. Perhaps Mr. Beckett, in referring to gearing, etc., intends to imply the Diesel engine, which will, I hope, be an *avis rara* in future submersibles.

Regarding the proposal to swing the battery on Gimbal brackets. In a submersible the greatest difficulty opposing the designer is the attainment of a good metacentric height, and to this purpose the battery is always placed as low down in the vessel as possible, and is very securely wedged and packed in to prevent any possible chance of the whole slipping or moving, and thereby upsetting the stability and metacentric heights of the boat. Were Mr. Beckett's proposals installed in a submersible in the event of the vessel turning turtle the battery would swing round on its Gimbal brackets and thereby absolutely prevent the little vessel from righting herself. Again, the suspending of roughly 500 tons on Gimbal brackets is a feat that would require very careful execution in a vessel of the submersible type.

It is the practice of most submersibles to carry both the magnetic and the gyroscopic compass. The magnetic compass is usually placed in the conning tower as high above the steel structure as possible owing to the likely effect of magnetic influences causing distortion, etc. The gyro compass, on account of its peculiar characteristics, can be installed anywhere in the boat, but no first-class navigator would trust entirely to one unit only to steer a vessel of so important a nature as a submersible, and it is understood that instances have occurred where the vessel would have been lost had the gyro compass entirely been relied upon.

Regarding the Birkett Stator Propeller, the inventor of this interesting device assures me that it is of the greatest assistance to the vessel when travelling at sea in water strewn with ice, as owing to the peculiar characteristics of the water when drawn off the stator propeller, any objects are caused to be sucked past the propeller quickly and not into the propeller, so that the possibility of the blades, etc., being broken by lumps of ice, wood work, or other floating objects is almost entirely eliminated.

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Mr. H. C. Bailey (Member), who served in the submarine named, has forwarded *The Daily Colonist* from British Columbia containing an account of experiences which illustrate vividly some of the comments made in the course of the paper and discussion. There were two sets of two-cycle Diesel engines of 1912 design, with six cylinders fitted in the submarine.

Victoria to Halifax on two new Submarines.—With practically all of the crew of twenty-six men sick or unconscious from the fumes of burning storage batteries; with the engineer braced between the two engines while the submarine rolled over to sixty or sixty-five degrees and back again; with another of the crew making sardine sandwiches and feeding the men on duty; with the engine running for ten minutes and stopped for twenty in order to ventilate the craft; the Canadian submarine *CC*2 made her way ponderously from Esquimalt to San Francisco, bound for Halifax. It will be remembered that back in 1917 the two submarines, *CC*1 and *CC*2, bought by the Government for defence of this port at the time when it was threatened by German cruisers, were ordered to proceed to Halifax via Panama with the patrol ship *Shearwater*. The story of that trip has not been told. The facts set out below were related by one of the crew. The two underwater craft were made for coast and harbour defence, and the story of the 7,000 mile trip is one of dogged effort to keep going and to remain alive.

Going to the end of the story at the beginning, it may be said that the boats reached their destination and were ordered to go on across the Atlantic to the Adriatic. They were so strained and battered that such a thing appeared impossible. The submarines have lain ever since chained up at Halifax. Some of the men in the crews have not yet recovered from the trip. The story deals mainly with the *CC*2. The *CC*1 ran a short distance under her own power and broke down. With the exception of spasmodic efforts to use her engines, she was towed the rest of the way by the *Shearwater*, but the boys of the *CC*1 never slackened their efforts to get their craft going. The officers of the *CC*2 were as follows: Commander-Lieut. G. Lake, First-Lieut. Edwards, Torpedo Gunner Briscoe, Coxswain Purvis, Second Coxswain Forman, Leading Torpedoman Porteous, Chief Engineroom Artificer Bailey, Engineroom Artificer Conroy, Engineroom Artificer Scoble, and Chief Stoker Roberts.

Leaving Esquimalt harbour quietly on the morning of June 21st, the three vessels started on their long voyage. Two days later bad weather set in and the submarines were battened down with the decks just awash. In order to keep the engines from racing it was necessary for the *CC*2 to keep charging the storage batteries. Then the submarine would use her motors until the batteries were run down. The only ventilation obtainable was through the operation of the engines. They would be run for ten minutes, drawing fresh air into the craft, and in twenty minutes time they would again be started and would draw in a fresh supply. It was not often possible to keep both engines running at once. While one was moving the submarine the engine crew would be working feverishly on the other. When the running engine showed signs of weakening and then quit entirely, the idle engine would be started while the disabled one was fixed. Then came another horror. The storage batteries, through weak construction, were short-circuited time and again and caught fire, giving out chlorine gas that laid low the greater portion of *CC2's* personnel. For one night the craft was navigated by the coxswain, while only one or two others were fit for duty, the others lying around in an unconscious state. Sardine sandwiches were the only sustaining power given the men for their all-night vigil. Sometimes they wondered if the game wasn't up for them. That was one of the worst experiences of the whole trip. The menu on the *CC*2 was standardised—Rainbow brand salmon and pork and beans, washed down with water, fuel oil and perspiration.

On the morning of the 26th the two submarines and the *Shearwater* made San Francisco, the *CC*1 being in tow of the mother ship. The engine crew of the *CC*2 submarine was signalled by the *Shearwater's* commander, who praised the men for their work during the awful time they had. The next day the trio went on, reaching San Diego two days later. There the British boys were given a great reception by the Americans. The sailors from the United States cruiser *San Diego* treated the submarine crews to concerts and picture shows. On July 4th the British sailors marched at the head of the big parade through San Diego. The San Diego Union next day ran a big photograph of this scene and said:—

"For the first time in the history of the American nation British blue-jackets yesterday celebrated the fourth of July as comrades-in-arms with the fighting forces of Uncle Sam. A company of stalwart blue-jackets from H.M.S. *Shearwater*, flanked by a regiment of American jack tars, had the position of honour in yesterday's epochal Fourth of July military and naval parade. The crowd, realising the significance of the presence of the representatives of America's greatest ally in the world war now raging, gave the British tars an ovation along the entire line of march. The Britishers were clad in white uniforms with leggings and straw hats."

Speaking of the Corenado Beach regatta the publication said:—

"In yesterday's mammoth Tent City celebration, representatives of the British Navy stood out conspicuously. When the water sports were at their height a launch, carrying nearly a hundred men from the British sloop of war *Shearwater* and the British submarines now in port, came right into the thick of things. With the launch brought to a stop near the judges' boat the Britishers sent up three rousing cheers. Attired in white and with each face beaming with enthusiasm they presented a pretty picture. From other boats in the bay and from the shore the cheers were sent back. The Englishmen waved their caps in response, and handkerchiefs and headgear fluttered from the shore. As each race was run the Englishmen shouted their approval. It was like a big family gathering. And the spirit of friendship seemed to extend everywhere."

The submarine got away from San Diego on July 6th and right down to the Canal the weather was fine, with blue skies and blue water. Getting down toward the tropics the heat became excessive. The three craft anchored in Magdalena Bay on the 9th, Manzanillo Bay on the 13th, Isla Grande and Istapa Bay on the 15th. The two subs. went alongside the U.S.S. *Brutus* on the 17th at Acapulco for oil, and tied up to a buoy in Salina Cruz on the 20th. The temperature was rising to tropical and the engines were getting foul. The crew were "all in" with gas from the batteries and the heat. Fresh fruit obtained at the port proved a welcome change to salmon and pork and beans.

Arriving at Balboa on the 30th, the men went ashore. This was their first liberty, as on the one other occasion when they landed they had to go back aboard as soon as the parade was ended. Marching formally is not the ideal way to go sightseeing or to have a good time. A great welcome was given the men by the natives and Americans in the Canal Zone. The Britishers went for motor drives along the Canal to the various points of interest. After filling up with fuel and stores the submarines passed through the Canal. The *Shearwater* went through ahead of them and was the first British warship to use the Canal since the war began. Diving in Colon harbour with American submarines, the *CC*2 took an involuntary descent for quite a distance before being got under control. The mishap took place on the 13th.

As the two submarines were built only for coast and harbour defence they were not fitted to berth the crew, as the men were supposed to return to port each night and sleep there. Leaving Colon on the 15th of August the subs. ran into a heavy sea and a head wind. The aft torpedo tube was flooded to keep the *CC*2 steady, and the craft was battened down, travelling with decks awash. In the very heavy weather that followed water was shipped down the main hatch.

On the 17th the batteries caught fire, but the hatches could not be opened owing to the seas. Arriving off Kingston, Jamaica, the submarines found the beaches dark with natives who had gathered to welcome them. The extraordinary thing was that the negroes, who were British subjects, sang "Rule Britannia" in greeting. Engine repairs were effected at Kingston by the *CC*2, and on the 29th of August the submarines continued on their journey up the east coast. After very heavy weather through the Bahamas the *CC*2 arrived at Royal Island with the engines choked up and the engine crew all ill. Poor oil taken at Kingston had left large deposits of carbon in the cylinders, and it had to be dug off with crow bars later before the engines would run.

Once more the repairs were effected and the submarines made Charleston, South Carolina, where they went to the Navy Yard for further repairs. Leaving this port on September 10th, heavy weather was experienced. All battened down, the *CC*2 made 25 miles in 24 hours, and was forced to return to Charleston with bridge rails twisted up, ventilators washed off, and engines badly strained. Leaving Charleston once more the underwater boats made Norfolk through heavy weather and all battened down. At Portsmouth navy yard repairs were again effected.

On October 14th the *Shearwater* and the submarines made Halifax. and the latter were promptly ordered to refuel and proceed across the Atlantic to the Mediterranean. This was impossible, and the order was later cancelled. The *CC*1 and *CC*2 were badly strained and their engines run down and out of sorts. A pile of piston heads, cracked, and other parts discarded, bore testimony to the difficulties of the long trip. The *CC*2 made 7,000 miles with her own engines, a wonderful tribute to the men who coaxed and enticed the machinery to endure the strain which it was never designed to bear. The engine room staff was repeatedly complimented by the *Shearwater's* commander on the fine performance. "Never again," and they say it with fervent feeling. Some of the engine room men are now with Yarrows, the Foundation Company and the Harbor Marine Company.

The *CC*1 was towed most of the way by the *Shearwater*, and the feverish effort of her engine room crew proved unavailing in getting her machinery to perform as it should. The engines were practically wrecked. Both the submarines had lain so long beside the copper sheathed *Shearwater* here that galvanic action had badly pitted the hulls, weakening them. The submarines have lain in Halifax harbour since they went there. Their crews were in dangerous proximity to the big Halifax explosion, being only several hundred yards away from the *Mont Blanc* when she blew up. None of the men were hurt seriously, nor were the submarines injured. The *CC*2 was formerly named the *Autofagasta*, being built for the Chilian Government. Her dimensions are: Length, 151 feet 6 inches; dia., 14 feet 5 inches; surface displacement, 310 tons; submerged displacement, 373 tons.

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Visits to Works.

Submersible Motors Works, Southall.

Our visit to the Submersible Motor Works at Southall on May 31st was most serviceable in respect to giving a better understanding of these motors which have proved of great value in the salvage operations so well carried out, even amid the risks of war, and still carried out with a view to bringing again into being the vessels sunk in waters not too deep for the diver. A tribute of praise is due to the salvage operators for their daring and the success which has attended their efforts in salving vessels under apparently hopeless conditions. We were courteously received on the threshold of the Works by the managers and staff, and escorted to view an enlarged drawing showing the latest design for the successful manufacture of the motor to hold at naught the sea water, when submerged; these details were explained by the manager, after which the company separated into groups, each conducted by one of the staff, to examine the details of the motors and connections in the different departments. The following were exposed to view and explained:

8in., 6in., 4in. and 2in. submersible motor-pumps under construction and complete. Portable weather-proof oil engine-driven generating sets for driving one 6in. or two 4in. motor-pumps, as fitted on Admiralty salvage vessels (with engines by Thornycroft and W. H. Allen and Co.). The set with Allen engine was shown at work driving one 6in. pump.

Rotary transformers for converting the direct current electric supply on ships to the three-phase current necessary for submersible motor, as supplied to the British, French, and American navies. One set shown running 4in. pump. These machines are designed to stand either vertically or horizontally. Motor-alternators for the same purpose. Water-tight electric cable couplings in different stages of manufacture, illustrating the care necessary for these details.

Small direct current motors for electrically-propelled canoes. Small motor-generators for Cumberland process for prevention of corrosion in boilers. Small vertical motor-alternators for "Hummer" signalling circuits in warships.

To illustrate the services rendered by the submersible motor pump, the undernoted cases were cited:—

A torpedoed vessel valued at £2,500,000, including cargo, was saved, being sunk in such a position that it was impossible to get any other type of pump to work. Pumping operations were successfully carried out on a vessel 600 feet away from the salvage vessel, the pumps being dropped on board the wreck and connected to the electric generators on the salvage ship by means of cables. An oil ship caught fire, and these pumps were used to pump water into the vessel to put out the fire, and when this had been effected, were lowered into the holds to pump out what they had just pumped in.

A great feature of the motor is its simplicity, as it consists of a squirrel-cage induction motor with stator windings insulated in a special manner to withstand continuous immersion in water, either salt or fresh. The rotor runs on roller bearings fitted in gunmetal housings charged with stiff grease forced in under pressure, which effectively keeps water out of the bearings. When used in connection with a centrifugal pump, the water which is by-passed through the motor is taken off from the delivery side of the pump through a filter, which prevents any grit passing into the motor. The water passing through the motor is regulated by needle-valves on entering and leaving the motor case, and passes back into the suction side of the pump. The motor is either fitted with a water-tight cable coupling box for the electrical connections, or the ends of the stator windings are brought out through a gland in the motor case for some distance, usually 50 feet, and a cable coupling attached at the end, the leads from the windings being protected by armoured rubber hose. This latter method is usually preferred where the duty is very severe, as in salvage work, or when the motor is left submerged for long periods and is difficult of access.

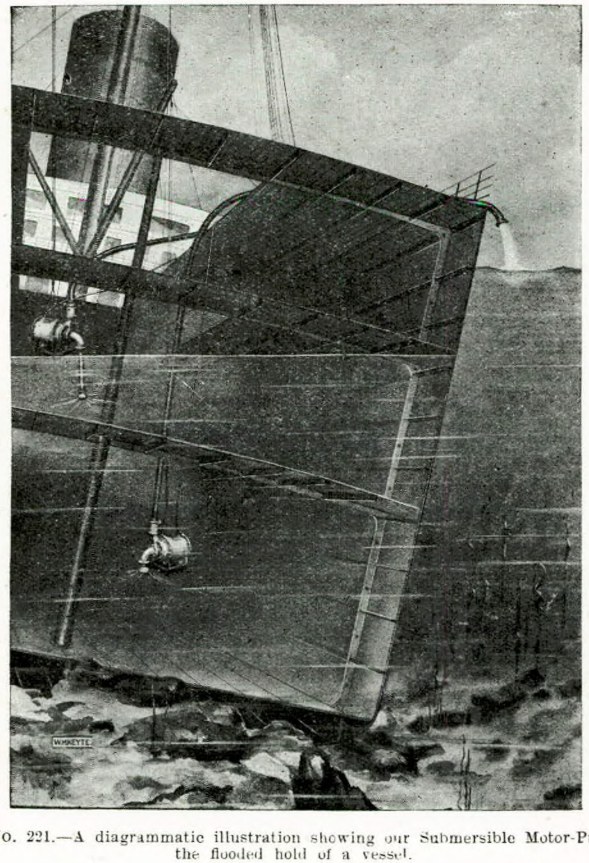
Owing to the motor and pump being air-tight, with grease packed bearings, the pump can draw water up to 30 feet and maintain a lift to over 32 feet when the pump and pipes are primed, while 28 feet is a very good performance for an ordinary well-made centrifugal pump.

Since their value was recognised in 1914, the Admiralty and War Office took over all that were made, and 600 were ordered. These have been without exception single-stage pumps, giving a total manometric lift of about 80 feet, but designs have been got out for multi-stage pumps up to 500 feet lift for use in collieries, mines, etc., for which the demand is very promising. They are at present being used in clearing the harbours on the Belgian coasts, and their adoption is under consideration in connection with the pumping out of the flooded mines of France and Belgium. Another application of these motor-pumps is under consideration for emergency pumping equipment in ordinary vessels.

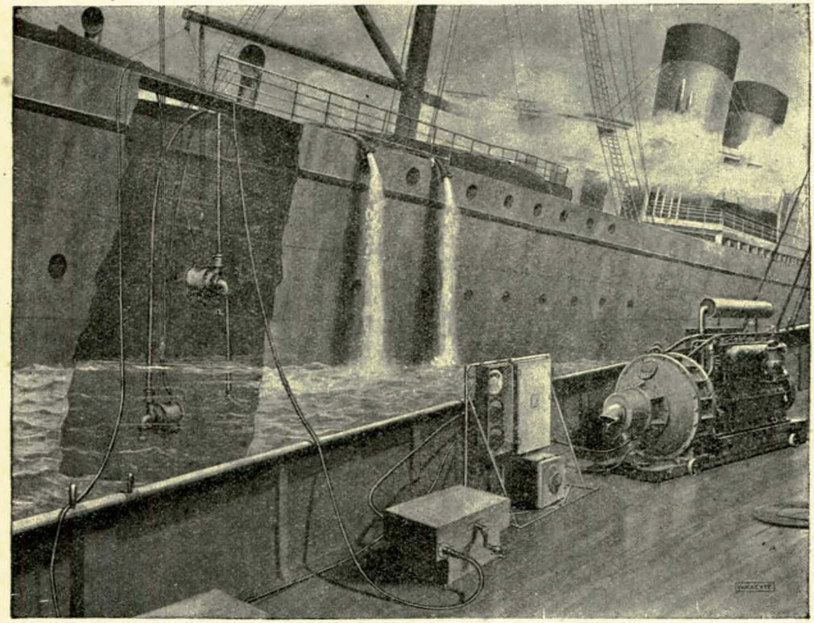
Good water-tight compartments no doubt minimise risk, but the majority of ships have not pumping power available to cope with serious leakage, and the value of submersible pumps which can be easily moved and lowered into a flooded compartment is apparent; while most efficient help to disabled ships can be rendered, as submersible motor-pumps may be put on board the damaged vessel and connected to the generator on the vessel rendering help. The *Wide World Magazine* for June contained an interesting illustrated article on the salving of vessels.

The motor-pump is so portable that it can be lowered for work into flooded excavations, and be left standing either partly or entirely submerged without fear of damage; so also in mines liable to flooding or in abandoned workings which ordinary pumps have not been able to deal with. In the restoration of the mines in France and Belgium these pumps may have an important part to play.

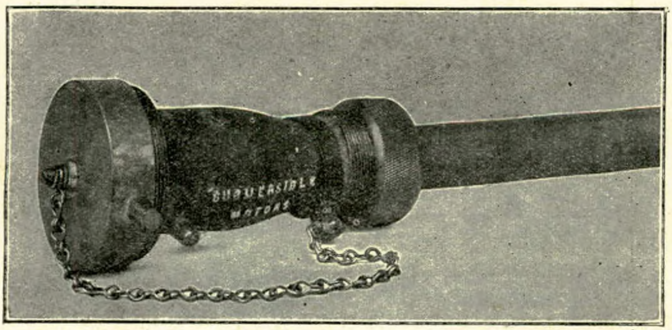
Before leaving the Works a hospitable tea was partaken of with hearty appreciation of the kindness of the Company in thus adding to their courtesy. A vote of thanks to the Submersible Motors Company, the managers and staff, proposed by Mr. J. G. Wells and seconded by Mr. A. Robertson, was cordially applauded and responded to by the manager of the works.



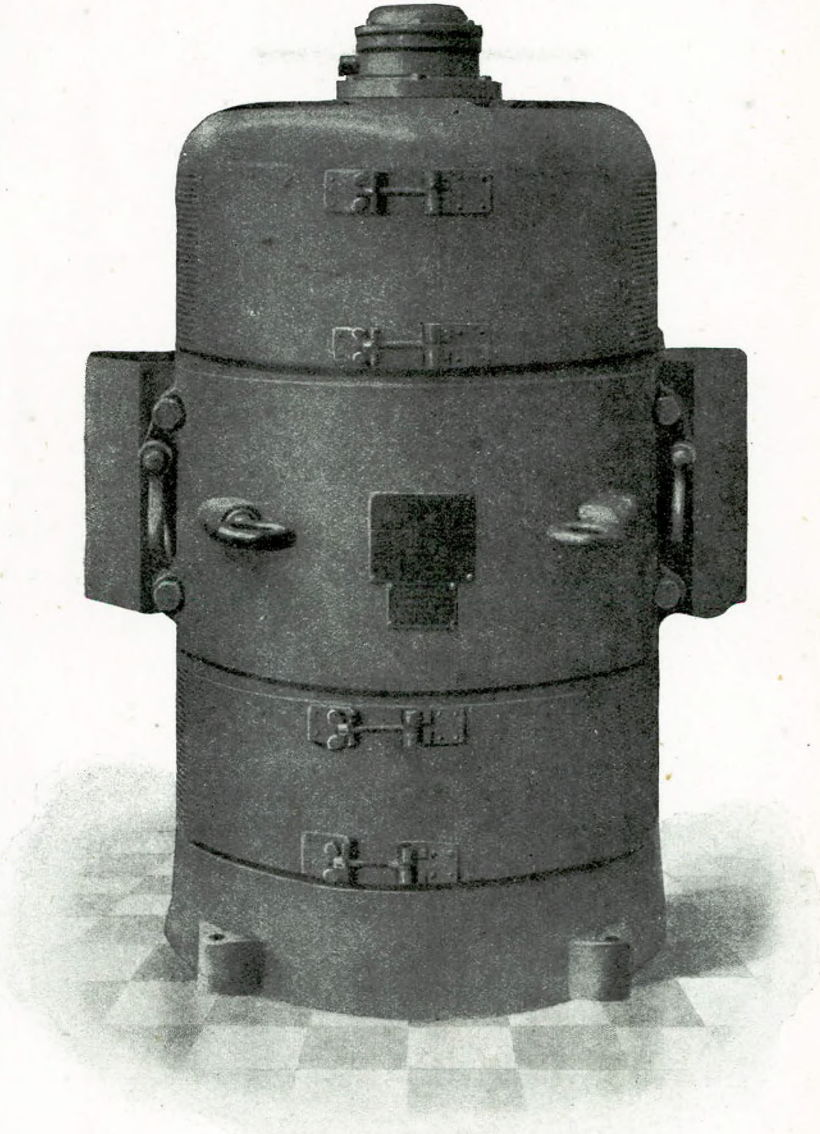
BLOCK NO. 221.—A diagrammatic illustration showing our Submersible Motor-Pumps in the flooded hold of a vessel.



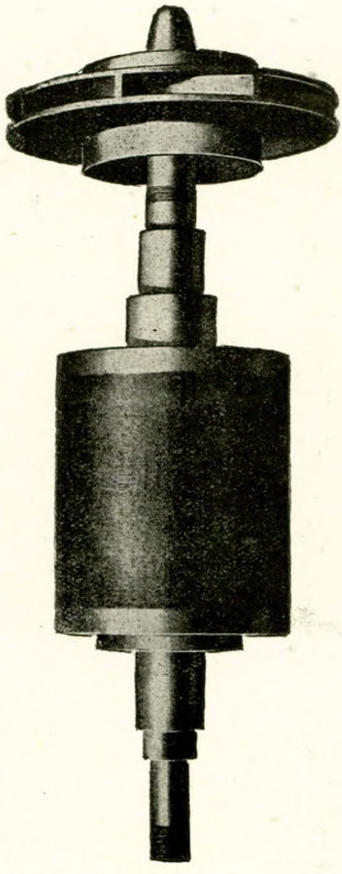
BLOCK No. 222 is similar to block 221, but shows the salvage boat in attendance.



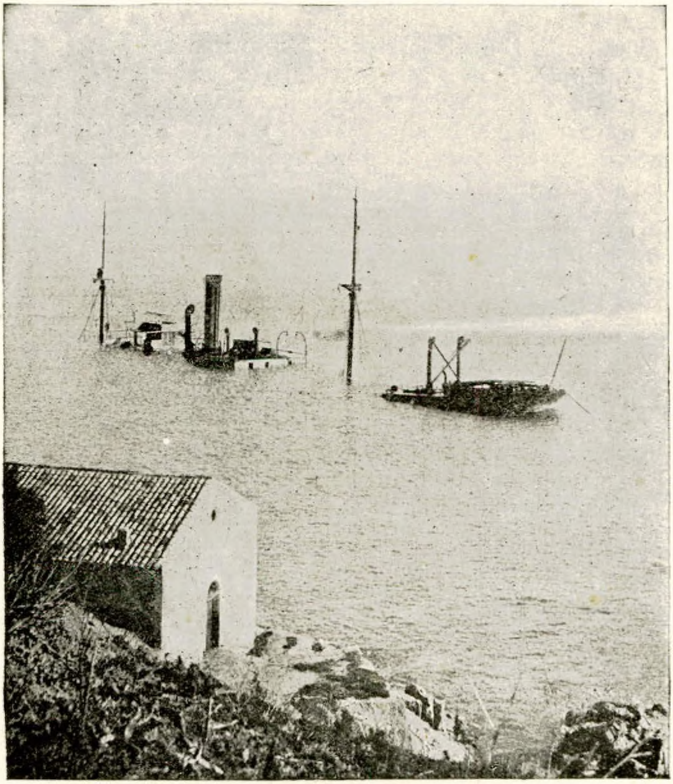
An illustration showing one of our special three-pole "Submersible" Cable Couplings attached to a length of "Submersible" cable.



An illustration of one of our standard rotary transformers shown in a vertical position. This machine is as supplied by us in large quantities to the British Admiralty, and is for use in cases where an A.C. supply is not available. The particular machine will give sufficient power to drive one 4 in. Submersible Motor-Pump.



An illustration of the impeller of pump and rotor of Submersible Motor, from which you will see that these parts are mounted on one shaft and constitute the only moving parts of our Submersible Motor-Pumps.



An illustration of a cargo boat wrecked off the coast, and which was afterwards salved by means of our Submersible Motor Pumps.

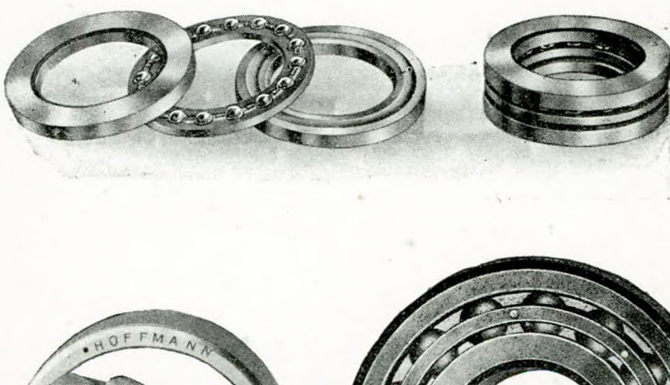
Visit to the Works of the Hoffmann Manufacturing Company, Limited, Chelmsford.

Our visit on June 28th to Chelmsford, where the "Hoffman" Ball and Roller Bearing Works are situated, was a pleasant and instructive one. Mr. Pryke met us at the entrance to the works with members of the staff and conducted us in sections through the departments, where we were shown the operations of manufacture from start to finish.

The quality of material used must of necessity be the highest, and great care is taken that the steel used is of uniform quality.

The steel bars are first turned down in sections of a breadth to correspond with the size of bearing required. Short lengths of bar are then placed in a vertical drilling machine of high power. The centres are bored out and the blanks thus left are then ready for the turning machines. There is a very complete plant for extracting the oil from the turnings, and large economies are effected by this means.

The shops in which the various parts are hardened were of especial interest. Various types of special hardening furnaces were seen; machines which have been developed to suit the particular requirements of this highly specialised work. After hardening, a certain proportion of parts from each batch are set apart for fracture and examination, and this constant supervision at every stage of manufacture was most noticeable throughout the works. Naturally, the grinding department, where the races are finished, was of great interest. In a very complete tocl and gauge department the party were shown a number of machines on which measurements to within 1/10,000th part of an inch can be made with perfect accuracy.



The works employ a total of 4,000 hands. There are three power-stations and both oil and gas engines are used. The shops are lofty, well ventilated and heated, with air ducts for changing the atmosphere so that the workers may carry on their duties under good conditions.

After being escorted through the works, we were invited to partake of tea, which was kindly provided for us in the staff's mess-room adjoining a large refreshment hall. Mr. J. Shanks then proposed, and Mr. George Adams seconded, a vote of thanks to the Company for their courtesy and to Mr. Pryke and the members of the staff for conducting us and explaining details. Mr. Pryke (commercial manager) replied and expressed his pleasure that he had met us on behalf of the Company.

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VISIT TO THE *Mississippi*.—By the courteous permission of the Chairman of the Atlantic Transport Company, we paid a visit on July 12th to the internal-combustioned-engined *Mississippi*, at the Royal Albert Docks, and had an opportunity of examining the machinery, the details of which were shown and explained, both in connection with the main engines and the deck machinery. For this educational value attaching to our visit we were indebted to Messrs. B. P. Fielden (Supt. Engineer), J. B. Harvey (Asst. Supt. Engineer), C. H. Hunter (Chief Engineer), and staff, who escorted the party in sections through the engine-room and other parts of the ship. By a coincidence, berthed alongside, was moored the sister ship *Maryland*, fitted with steam propelled machinery, and a comparison was instituted between the vessels to show the economic results in favour of the *Mississippi*. Broadly, there is a gain of 400 tons in carrying capacity, and in 12 tons of oil as against 42 tons of coal for $11\frac{1}{2}$ knot speed.

The *Mississippi* is 4,738 tons, $370 \times 50 \times 30{\cdot}8$. She is fitted with two sets of engines, each consisting of six cylinders, 670 m.m. dia. $\times$ 1,000 m.m. stroke, developing about 3,000 I.H.P. One cylinder of each set was opened up in course of overhaul and a piston with its packing rings was exposed. The inlet and exhaust valves, with the mechanism for working them, were pointed out and explained; also the locking device to prevent error in manipulating the gear from the platform.

The storage tanks for the compressed air are placed in the wings above the cylinder tops and from them are led the connections for the starting valves. The engines for generating electric current and air compression are of the internal combustion type. A stock of compressed air is kept for initial starting purposes, ready for use when required. The size of the electric switch board was commented upon and its importance realised when the deck machinery was examined, the winches, steering gear and windlass being electrically driven. The cooking arrangements also are dependent on electric supply for heat, the galley being consequently cleaner and neater, requiring much less labour from the assistants to keep it sweet. On the fore deck were two of the machines provided for service in waters containing mines and used for cutting away the connecting wires, by means of teeth set in strong jaws.

Tea was served in the saloon and partaken of with appreciation, and cordial thanks to our hosts for adding in many ways to the pleasure of our visit. A letter of thanks was conveyed to Mr. C. F. Torrey, Chairman of the Atlantic Transport Co. for granting his permission to inspect the vessel and machinery, and for the provision made to make the visit, which was of great interest, profitable to us.

We hope to publish in a future issue more details of the comparison between the sister vessels *Maryland* and *Mississippi*, showing what may be gained by fitting Diesel type engines.

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VISIT TO MESSRS. H. HUGHES & SON'S WORKS.—Our visit to these works at Hainault on July 26th was the means of revealing to us the minor details being made for many instruments used on ship-board. Mr. Hughes and his two sons kindly met us at the works and conducted us through the several departments, pointing out by the way the special features of interest.

The manufacture of drawing instruments with accuracy and despatch is realised as necessary considered from a users point of view, the specimens inspected indicated a neat and accurate finish, while the different stages in making and assembling of the parts illustrated that arrangements were organised for economic despatch. The machines and placing together of the details are manipulated by young women trained for the work.

The new works have been erected under war conditions, when special attention was demanded to instruments for ship work. As an instance, the compasses for night navigation had to be safeguarded so that the light might not be shown as a target. To deal with this, radium paint was used to place a horizontal and a vertical line on the glass face as guiding rays. An instance occurred where the compass light had indicated the position of a vessel, and a shot resulted.

The preparation of glass for the various purposes is extremely interesting, from the cutting to the polishing process, the different stages being shown and commented upon in the course of our examination, which included specimens of the finished products and a view of the surrounding country by the aid of the new marine binoculars now being manufactured.

Besides the machine and finishing stages, glass working department, testing shop, located apart and isolated, the works embrace a foundry and wood working shop in connection with which the enhanced cost of labour and material have brought up considerably the cost price of the standards for compasses, etc., and the reflection occurred to one what substitute can be used to militate against this, when so much need for economy is pressing upon all.

The surroundings added to the pleasure of the afternoon, as the works are placed in the open country with a clear atmosphere to the advantage of the workers; another addition to our pleasure was in meeting Mr. Hughes after his recent return from America in the *Aquitania*. Before leaving the thoughtfully provided tea-table our thanks were accorded to Messrs. Hughes and the staff, to whom we were indebted for the courtesy manifested towards us.

Awards.

The following awards have been given for papers prescribed for Session 1918/19:—

Sir Archibald Denny (P.P.) Award for Sea-going Members:—

Mr. H. Bullen (Member), instruments as chosen, value £3.

Mr. J. D. Boyle (Assoc.-Member), books, value £1.

John I. Jacobs Memorial:—

Mr. E. W. J. Fynn (Graduate), books as chosen, value £1.

The subjects for the current Session are undernoted, as previously announced:—

SIR ARCHIBALD DENNY (P.P) AWARD FOR SEA-GOING MEMBERS.

Subject: "Hints and Deductions from Practical Experience which may be useful towards improving Ship and Engine Design. Reports upon Consumption of Coal; Water per I.H.P. per hour."

STEPHEN MEMORIAL AWARD FOR ASSOCIATE-MEMBERS AND ASSOCIATES.

Subject: "The Sequence of Cranks in Multiple Expansion Engines and the Balancing of Powers."

Subject: "The Internal Combustion Engine for Marine Purposes; the various Fuels which may be used and their Combustive Merits."

JOHN I. JACOBS' MEMORIAL AWARD FOR GRADUATES AND OPEN COMPETITION.

Subject: "The Main Engine Shafting from and including the Crank Shaft; how lined off and fitted into a new Vessel from the Propeller; also the Stern Tube with detailed description of the latter."

Subject: "The Internal Combustion Engine; Historic Sketch and comparison with the Steam Engine."

GRADUATES AND ASSOCIATES: On a Visit to the Shipping, Engineering and Machinery Exhibition.

Mr. J. H. R. Kemnal, V.P., offers Awards for Papers on "The Water Tube Boiler," open to Members and Associate-Members.

Each Paper to be written under a *nom de plume*, enclosed in an envelope inscribed with the grade of membership, the *nom de plume*, to be in a sealed note giving the full name and designation of the writer for identification.

The Lloyd's Register Scholarship Examination was held on July 24th and 25th at Cardiff, Devonport, Hull and London, to suit the residence of candidates. The results are under consideration.

Correspondence.

MR. STEPHEN H. TERRY: I have read with great interest the masterly paper of Mr. J. H. Anderson on the winning of coal, and I note that he makes a point in criticising the wasteful usage of coal at collieries; this he may very well do, for it is quite a usual sight to observe a battery of say six large double-flued Lancashire boilers providing steam for the winding engines, pumps and fan engine, and underground haulage all blowing off steam as if it cost nothing, and when the winding engines starts, to see the sterterous efforts of the steam to escape to the atmosphere through one vertical exhaust pipe, placed midway between the two horizontal cylinders, each perhaps 42 inches in diameter by 6 ft. stroke, which when starting from rest carry their steam from $\frac{1}{3}$ to near half-stroke, the result of the single exhaust pipe, into the base of which the steam enters from exactly opposite directions, is the choking of the free exhaust of both cylinders, there is often condensed water present which is without other means of escape than to be blown upwards with the steam to the detriment of the buildings and roofs.

In Staffordshire I have seen during my residence in the colliery district many engines of large size working under these conditions, when all that was needed to effect perhaps 10 per cent. economy in steam would be the leading the exhaust from each cylinder separately to the atmosphere, providing also suitable pump and drainage from it at the foot of each exhaust pipe.

I notice also that Mr. Anderson describes the Koepe system of winding, the instance he cites is electric driven. He describes the single pulley drive dispensing with the drum, but I find no reference to the "tail-rope" without the balancing effect of which, surely would fail for want of adequate adhesion. Some thirty years ago I was given a very well written little treatise on the Koepe system of winding in which the tail rope played an essential part. I fear I have lent this book to someone who has not returned it or I should quote from it now.

Election of Members.

Members elected at a meeting of the Council held on July 1st, 1919:—

Members.

William Norman Barron, Dalmally, Wentworth Street, Randwick, Sydney, N.S.W.

Arthur Cheetham, 37, Park Road, Rugby, and Association of Engineers, Singapore.

George William Cope, 145, Boundary Road, East Ham, E.13.

Roger Cyril Fogg, 17, Glazebury Road, London, W.14.

Richard Wilbraham Randle Ford, East Cliff, Budleigh, Salterton, Devon.

Charles Rapley, No. 5 Residence, Royal Mint, E.1.

William Wallace, Schoolhouse, Livingstone, Nr. Mid Calder, Scotland.

Herbert Fleming White, 102, Henderson Road, Forest Gate, E.7.

Robert Tweedie Wilson, "Ninalea," Dalnottar Hill, Old Kilpatrick, Scotland.

Companions.

Albert Edward Earnsby, 19, Swan Street, Minories, E.1.

Alfred William Saint, 19, Swan Street, Minories, E.1.

Transfer from Associate-Member to Member.

Gilbert Ashton Plummer, 2, Kenwood Road, Stretford, Manchester.

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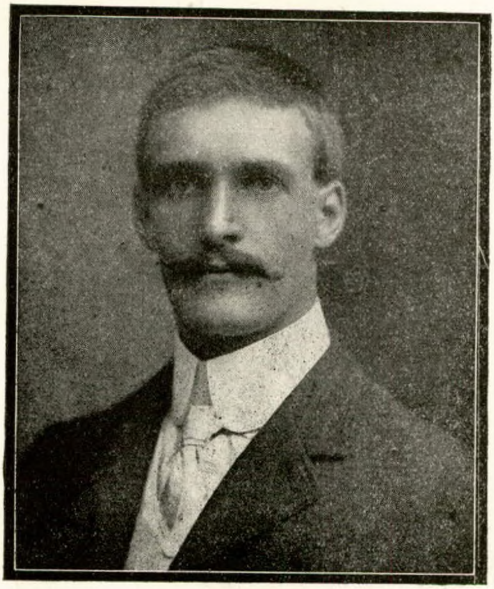

FREDERICK EGGINGTON.

With regret and sympathy for Mrs. Eggington and her four young children, the death of Mr. Fred. Eggington is recorded. He was born at Liverpool in 1882, educated at Rainhill Boarding School, and served his apprenticeship with Messrs. Crighton & Co. He went to sea in the *Indrawade*, and subsequently served in the *Teodoro de Larrinaga*, *St. Helena*, and *Mount Coniston*, obtaining his 2nd certificate in 1905, and his Chief's in 1907. He was promoted to Chief Engineer of the *St. Helena* in 1910. In May, 1916, he was appointed under the Admiralty for Government work as Chief Engineer, and in December, 1917, when serving in the *Eveline*, the vessel was torpedoed. In January, 1918, he joined the *British Viscount*, and on February 23rd he again suffered the experience of the torpedo, but with more serious results as he was in the sea for about two hours and picked up unconscious. He alone of the engineer officers survived. The ship was carrying crude oil to supply war vessels for the boilers, and when the *British Viscount* was sinking the oil spread over the sea. When the engineers came on deck from the engine room the boats were gone so that they had to swim or float on the water in the hope of being picked up; the oil fumes, however, were against them, and the survivor suffered very badly for weeks owing to the oil having entered his system. He was appointed to supervise the repair and overhaul of the *British Earl*, which had been torpedoed, but brought into Milford Haven; during this time his health was still a cause of anxiety to his friends. In August, 1918, he joined the *War Rajput* in Newcastle, and sailed to Texas, and about three weeks afterwards typhoid fever broke out on board attributed to bad water, the fourth engineer died, and on reaching port, on September 20th, the sufferers were taken to the hospital, where the Chief Engineer died on October 15th. Mr. Eggington was elected a member of the Institute of Marine Engineers in 1916.

Engr.-Comdr. JOHN MANN. R.N.R., D.S.O.

To our great regret we have to record the death, at Bombay on May 21st, of Engr.-Comdr. John Mann, and with deep sympathy towards his widow and family we place his name in our obituary column. He was a native of Stranraer, born in 1869, educated at Sheuchan School, Stranraer, he, on the completion of his school days, went to Glasgow and served his apprenticeship with the Fairfield Co. He then joined the service of the British India Steam Navigation Co. in 1890, his first steamer being the *Fazilka*, and subsequently served in various other ships trading on the Indian Coast, receiving promotion, step by step, after obtaining his certificates, second in 1891 and Chief's in 1896. The first steamer to which he was appointed Chief Engineer was the first *Nevassa*, subsequently serving in various others. He held an appointment on the shore staff of the company in India for some time, and shortly after the outbreak of war he brought home to London the twin-screw turbine steamer *Angora*, selected for special service work by the Admiralty. While the ship was being fitted out a photographic group of the engineers was taken, and this was reproduced in *The Marine Engineer*. Mr. Mann served in the *Angora* as chief engineer, while engaged on strenuous and important work. His keen and attentive appreciation of his duties with the consequent good results led to the bestowal by His Majesty the King of the D.S.O., a well deserved tribute to his valour. Owing to the severe strain after fully three years' service of an arduous and risky character, he was granted leave for a season, which he spent at Stranraer, in order to recruit his health, broken as a result of the service in which he had been engaged. On the expiry of his leave he returned to India for further service in the British India Co., and when in Bombay, he was seized with illness, removed to the hospital, where he died on May 21st. In addition to the D.S.O. he gained the medal with two bars for transport service during the South African war, and also the Boxer Rising in China. Mr. Mann was a member of the Institute of Marine Engineers, and took a warm personal interest in its operations.

A. Steers (Member).—Intimation has just been received from Dunedin, New Zealand, that Mr. A. Steers was lost at Sunday Islands in June, 1917, while attempting to escape from the German raider *Wolff*; we place this on record here with regret, and may have an opportunity of reproducing his portrait subsequently on receiving a reply to our letter of sympathy sent to his relatives in New Zealand.

E. T. TYLEE.

E. T. TYLEE, Engineer Sub-Lieut., R.N.R. Elected in 1916, as an Associate Member of the Institute of Marine Engineers, was born at Napier, new Zealand, in 1891, and served his apprenticeship with Messrs. Niven & Co., Napier. He left for Britain in 1912, and was employed in the drawing office of the Fairfield Co., Glasgow for about 16 months, after which he went to sea as 4th Engineer in the S.S. *Visigoth*, and later joined the Eagle Oil Co.'s S.S. *San Jeroninio*, being afterwards transferred to the *San Fraterno*. Having joined the R.N.R. he was appointed to the *City of Oxford*, and after serving for about 15 months was appointed to the *Avenger*, on which ship he was when torpedoed, he however escaped and was sent to Portsmouth. In August, 1917, he was appointed to H.M.S. *Nairano*, and sailed to the Murman Coast. While the vessel was laying in the Firth of Forth, he was seized with illness and removed to the City Hospital, Edinburgh, where he died on 26th January, 1919. He obtained his 1st class certificate in November, 1918. Great sympathy is felt for his father and relatives in New Zealand, who were looking forward to his return home to New Zealand when made free from duty.

WILLIAM WALTON.

We regret that no definite information has yet been received of William Walton, who was second engineer of the *Narragansett*, and a member of the Institute of Marine Engineers. Any information will be gratefully received by his relatives at 199, Alexandra Road, North Shields. He was born at North Shields and served his apprenticeship with Messrs. Beard Bros., engineers, North Shields, and afterwards was employed in the works of the Wallsend Slipway Co. He went to sea as a junior engineer in the *Bellona*, of the Thompson Line, and afterwards served in the *Whinfield*, *Aysgarth*, *Havre*, *Trocas*, *Murea*, *Castor*, *Patella*, and *Guyahogh*. He obtained his second certificate in 1912, and his chief's in 1914. He was appointed and sailed as second engineer of the *Narragansett* in 1916; in March of the following year the vessel left New York on her voyage to England, and was reported to be in a sinking condition, due to enemy action, when nearing her destination. Since then no further information has been received, but hope has been entertained that some had been rescued and possibly interned.