The Thornycroft Torpedo-Vessels; Their Construction, Armament, &c., and the Results of Certain Experiments That Have Been Made with Them

Mr. John Donaldson

To cite this article: Mr. John Donaldson (1877) The Thornycroft Torpedo-Vessels; Their Construction, Armament, &c., and the Results of Certain Experiments That Have Been Made with Them, Royal United Services Institution. Journal, 21:91, 611-632, DOI: [10.1080/03071847709415809](https://doi.org/10.1080/03071847709415809)

To link to this article: <http://dx.doi.org/10.1080/03071847709415809>

Published online: 11 Sep 2009.

Submit your article to this journal [↗](#)

Article views: 5

View related articles [↗](#)

The Journal
OF THE
Royal United Service Institution.

VOL. XXI.

1877.

No. XCI.

LECTURE.

Friday, May 11th, 1877.

VICE-ADMIRAL the RIGHT HON. SIR JOHN C. DALRYMPLE HAY,
Bart., C.B., M.P., &c., &c., Vice-President, in the Chair.

THE THORNYCROFT TORPEDO-VESSELS; THEIR CON-
STRUCTION, ARMAMENT, &c., AND THE RESULTS OF
CERTAIN EXPERIMENTS THAT HAVE BEEN MADE
WITH THEM.

By Mr. JOHN DONALDSON, Assoc. I.C.E., and Firm of Messrs. Thorny-
croft and Co.

SPEAKING generally, naval warfare heretofore has been conducted on the surface of the water, and a fighting ship has usually been constructed so as to carry her offensive and defensive equipment about and above her water-line, her guns and the bulk of her armour-plating being always above that line, and the remainder of her armour-plating only extending below it sufficiently far to protect the vessel from shot while rolling.

The thickness and strength of the bottom have been usually determined by structural considerations, and in modern ironclads it has been kept as light as possible in order to secure the buoyancy necessary for carrying the heavy guns, and the heavier plating of these huge vessels. The consequence is that the bottom of an ironclad is her most vulnerable part, and a vessel costing half a million of money, and carrying say 500 men, may be sent to the bottom at any moment by means of ramming or the successful explosion of a torpedo.

It may be urged that ramming is not always successful, and doubtless, the ram—being of necessity a heavy and ungainly vessel, not easily diverted from its path—may be eluded by skill and dexterity on the part of the Officers and crews of the intended victim.

From a well planned torpedo-attack however, in sufficient force, I believe there is no escape, and it is of vessels specially constructed for this purpose that I propose to address you this afternoon.

I think I am right in stating that the first attempt to use torpedo-boats systematically, was made during the American war, and as two

vessels at least—the United States' steamer "Housatonic" and the Confederate ram "Albemarle"—were actually sunk, and several others severely damaged by means of these weapons—besides the apprehension excited among all the vessels engaged—the attempt may be considered as having been decidedly successful.

The torpedo-boats used on these occasions were either submarine boats, specially designed and constructed for the purpose, or ordinary steam launches fitted with outrigger torpedoes. Neither of these types of boat is well suited for the work, as in the first case, independently of the difficulty of steering a boat under water, it would be almost certain to be destroyed when the torpedo exploded, and so sacrifice the crew engaged in the attack (as happened in the case of the sinking of the "Housatonic"), and in the second case the noise from the funnel, and the want of speed in ordinary steam launches, would effectually (except when the attack was made on a dark night) betray their position, and allow them to be made targets of, long before they came any way near their enemy.

Von Scheliha in reviewing the experience gained during the American war in the use of torpedo-boats, considers that submarine boats acting independently are quite unsuited for torpedo warfare, and that a swift jolly-boat, rowed with muffled oars, and provided with a self-acting contact torpedo, fastened to the socket of a movable torpedo spar 12 feet long, was preferable to any submarine boat. He further states that the general conclusions arrived at by American engineers were:—"That a torpedo-boat should have a speed of at least 11 knots, as the greater the speed, the less is the danger of being discovered, or struck by the enemy's missiles; that the engine must work without noise, and no smoke should be visible; that the boat must obey the rudder, and that the crew should be protected against musketry, and the fire of light artillery."

The majority of these requirements could be satisfied without much difficulty; but the problem as to speed remained—as far as small boats were concerned—unsolved till 1871, when Mr. Thornycroft brought out the far-famed "Miranda," a vessel under 50 feet in length, which, when experimented on by Mr. Bramwell in the spring of 1872, attained the astonishing speed of 18·65 statute miles, or nearly 16½ knots per hour.

These remarkable results did not remain long unnoticed by torpedoists, as about this time the Whitehead torpedo was being introduced; and the question of how best to use torpedoes in offensive warfare was beginning to receive that attention which I have no doubt will be well justified in the next great naval war.

The first Government to recognise the great advance made by Mr. Thornycroft in the speed of small boats was the Norwegian, which, in 1873, gave my firm an order for our first torpedo-boat.

This boat, represented by diagram A, was 57 feet in length by 7 feet 6 inches beam, drew 3 feet of water, and the stipulated speed was 16 English statute miles, or nearly 14 knots per hour; which speed was not to be ascertained by a mere measured mile trial, but was to be 16 miles through the water in a run of one hour's duration.

Diagram A.

Diagram B.

The hull of the vessel was constructed entirely of steel plates and angle bars, and as may be seen from the diagram, was divided into 6 water-tight compartments, A, B, C, D, E, F.

The compartments marked A and F in the stem and stern were for stores; those marked B and E were fitted with seats for the crew, and were provided with movable steel covers, so that on going into action, or during rough weather, they might be completely covered.

The compartments C and D are for the steersman and the machinery respectively, and were covered completely by steel plating $\frac{3}{16}$ of an inch in thickness—a thickness which has been found sufficient to withstand Snider or Martini-Henry bullets, fired from a distance of 20 paces, as illustrated by the specimens on the table.

The compartment D was furnished with a hood, having slits $\frac{1}{4}$ of an inch wide, all round, through which the steersman could see with sufficient distinctness to direct his course easily. Motion was communicated from the wheel to the tiller by means of steel-wire ropes, which it was originally intended should be encased in wrought-iron tubes.

The possibility however of these tubes being bent by a shot, and so jamming the wire ropes, led to this arrangement being abandoned, and the ropes were simply run through eyes at intervals along the side.

The engines were compound, of the usual inverted double cylinder-direct-acting type, capable of developing about 90 indicated horsepower, and were fitted with a surface condenser, so that the vessel could run in salt water, without danger of injuring her boiler.

A small tank contained a supply of fresh water, to make good deficiencies arising through leakage, and from steam escaping at the safety valves, &c.

The circulating, air, and feed pumps were driven by a separate engine, as we feared at that time, that it would be impossible to run them at the same speed as the main engines.

The boiler was of the locomotive type, the shell being made of Bessemer steel; the fire box, and its stays, of copper, and the tubes, of solid drawn brass.

The armament was not supplied by us, but I have reason to believe that it consisted of a cylindro-conical shaped torpedo towed from the top of the funnel, round which a ring was fitted with two pulleys for the towing ropes: the strain being taken off by means of two stays attached forward.

The length of this torpedo was 13 feet, and the diameter 9 inches, and with a speed of 11 knots, it has diverged to about 40 degrees from the direction of the boat's motion when running in smooth water.

The torpedo is worked by means of a small winch and brake fixed on the after part of the engine-room skylight, davits are provided for dropping the torpedo overboard.

The method by which the contract speed of the boat was to be ascertained was prescribed to us by the Norwegian Government, and consisted of running the vessel at full speed for one hour, and counting the number of revolutions made by the propeller during

that time. The vessel was afterwards to be run six times over the measured mile, and the number of revolutions necessary to do a mile in still water ascertained.

The number of miles actually done in the hour was then to be found by dividing the number of revolutions done in the hour by the number required to do one mile.

The problem of finding the number of revolutions required to do a mile in still water, presents no great difficulty if the mile trials are run in still water, and consists simply of finding the arithmetical mean of the number of revolutions done on the six runs.

If, however, the trials are run in a river like the Thames, where there is a considerable current, it is evident that the vessel will be under the influence of the current for a shorter time when going with it, than when going against it, and the result would be that if the arithmetical mean were taken, a larger number of revolutions would apparently be required to do a mile, than were actually required.

The number of revolutions required to do a mile in still water, when the mile trials are run in water having a current of which the velocity is constant, or nearly so, is found by adding together the product of the number of revolutions made by the boat when running with the current, by the time taken to run against the current, and the product of the number of revolutions made by the boat when running against the current, by the time taken to run with the current, and dividing the sum by the sum of the times.¹

On the preliminary trials, we found we could do our contract speed of sixteen miles per hour without much difficulty, but we believed the boat was capable of doing more, and as the Norwegian Government in impressing on us the high value they attached to speed, had put us in a position to try experiments, by offering a premium on every mile, or part of a mile, by which the speed exceeded sixteen miles per hour,

¹ This is shown more clearly by the following investigation, in which I assume that the velocity of the current is constant during each pair of runs,—an assumption which is not quite correct for tidal currents, but, in the case of boats having high speeds like ours, is very nearly so:—Let x = number of revolutions per knot in still water, n = velocity of tide, R = revolutions with the tide, t = time with the tide, R_1 = revolutions against the tide, t_1 = time against the tide. Then distance run by boat with the tide in knots = $1 - nt$, and distance against tide in knots = $1 + nt_1$. Number of revolutions made under the circumstances respectively:—

$$R = x(1 - nt) \dots (1) \quad R_1 = x(1 + nt_1) \quad (2)$$

$$\frac{R}{R_1} = \frac{1 - nt}{1 + nt_1}, \text{ or } R + Rnt_1 = R_1 - R_1nt$$

$$n(Rt_1 + R_1t) = R_1 - R \therefore n = \frac{R_1 - R}{Rt_1 + R_1t}$$

$$\text{but from (1) } \dots x = \frac{R}{1 - nt}$$

$$\therefore x = \frac{R}{1 - t \left(\frac{R_1 - R}{Rt_1 + R_1t} \right)} = \frac{Rt_1 + R_1t}{t_1 + t}$$

we reviewed carefully the whole design of the boat, with a view to find out what part was most susceptible of improvement.

The least efficient part seemed to us to be the propeller, so we cast about to find a propeller that would give us a little additional speed, but found none that we could depend on.

In the end, Mr. Thornycroft invented the propeller which now bears his name. This propeller, as may be seen from the specimen on the table, is a modification of the Dundonald propeller, the principal difference being, that in the Dundonald propeller the blades were inclined backward in straight lines, while in the Thornycroft propeller they are curved.

The object in both cases was to prevent the water from being driven out radially from the axis by the centrifugal force, and while the Earl of Dundonald tried to effect this by means of a straight blade, inclined backwards, Mr. Thornycroft considered that the blades should be curved, and that the curvature ought to vary in such a way, that the inclination of the blade to the axis should be greater near the boss than at the tip, on account of the greater amount of centrifugal force impressed on a particle of water near the boss as compared with a particle of water near the tip.

On the official trial, which took place on the Thames on the 17th October, 1873, the number of revolutions done in the hour was found to be 27,177, and the number required to do a mile in still water was 1,578. The distance run in the hour was, then, $\frac{27,177}{1,578} = 17.22$, or very nearly $17\frac{1}{4}$ miles.

The steam-pressure during the trial averaged 85 lbs. per square inch, and the vacuum $25\frac{1}{2}$ inches.

Boats of the same size, and similar in all particulars—excepting the engines which we improved by driving the air-pump, feed-pump, and circulating pumps off the main engines, and abolishing the auxiliary engine, which performed these duties in the case of the Norwegian boat—were made for the Swedish and Danish Governments. The result was an increase of speed to 17.27 miles, in the case of the Swedish boat, and to 18.06 miles, or $15\frac{1}{2}$ knots in the case of the Danish boat.

I have no information regarding the armament of the Swedish boat, but the Danish boat was armed with two spindle shaped torpedoes 12 feet long, and $11\frac{1}{2}$ inches diameter, somewhat like the Whitehead torpedo. They were placed on deck longitudinally, near the funnel, so as to facilitate launching, and were arranged to be towed from an upright pole 8 feet high, placed about 6 feet from the stem.

A small winch was fixed on either side aft, to pay out the towing line, and to bring back the torpedo. By these arrangements the torpedo could be projected at a large angle from the direction of the boat's motion, and at considerable velocity. The speed of the boat when towing one of these torpedoes, is about 10 knots.

With regard to the strength of boats of this type, I may mention that when the Norwegian boat was fixed on board the steamer for conveyance to Norway, that vessel in going out of dock came

into collision with a telegraph-cable-laying steamer, the bow of which penetrated the side of the torpedo-vessel, and pulled her off the chocks on which she rested, causing her to fall a distance of from 15 to 18 inches, and bending her bottom slightly, but otherwise doing so little damage that she started immediately on her arrival at Stockholm on a voyage of 150 nautical miles to her destination in Norway. With regard to their sea-worthiness, I think I cannot do better than read the following extract from a letter addressed to me by Captain Koren, of the Norwegian navy, in which he describes this very voyage :—

“ In reply to your letter of the 14th, I have the pleasure to give you the following account of my trip in November last, from Götheburg to Horten (a distance of about 150 nautical miles) in the launch built by your honoured firm for our torpedo service.

“ The season being far advanced, I was anxious to take the boat to Norway as soon as possible, so having patched up the hole in her larboard quarter, and made a short trial trip, to see if the engine was in good working order, we started from Götheburg at two in the afternoon on the 21st of November.

“ It had been blowing stiffly the whole day from south-west, and my friends asked me not to start that day, as there would be a heavy sea rolling into the fiord, which I had to cross to get to the new canal and inshore passage to Marstrand, where I intended to stop for the night. Time pressed, however, and I started. I had engaged a Swedish pilot for the whole voyage on the testimony of his having traded on this coast for twenty-five years, and not doubting that he knew every creek and passage. When we got out in the above-mentioned fiord, it was blowing a stiff double-reefed-topsail breeze, with a corresponding but confused sea, but still we had some shelter from the outlying rocks. I ordered the pilot to steer for the opening of the canal on the other side, a route which would let us have the sea about four points on our port quarter; but that fellow coolly told me that ‘ he never went that way; he only knew the circuitous outer route,’ which would take us out into the open sea to round the island on which Marstrand is built. I did not know what to do at the first; it was getting dark and the wind was freshening, and the boat certainly did not *look* like a sea-going craft; but we had come thus far, and I thought it best to push on. We had about fifteen minutes to run with the sea on the beam, and when we lost shelter from the rocks, her movements were quite extraordinary, alarmingly quick, and great. However, she shipped no water, and having observed her for some little time, I knew there was no danger, and it was with a sort of pleasure I heard that stupid fellow of a pilot ask, ‘ If I thought the boat would capsize?’ When we had rounded the last island, and began running before the wind, the boat went quite steady, and we got safely into the harbour. Two hours after we came in it was blowing a most violent gale. The next day we had to pass outside the rocks for a distance of 20 miles; the wind had gone down, but there was a heavy swell. We had a pressure in the boiler of about 50 lbs. only, and the only inconvenience we expe-

Diagram. C.

STEAM TORPEDO LAUNCH,
As constructed for the Dutch and Italian Governments

Dimensions
Length (extreme) 76 0
Beam 10 0
Draft 4 0
Speed 18 knots

Diagram. D.

H. M. STEAM TORPEDO LAUNCH "LIGHTNING"

Dimensions
Length (extreme) 84 6
Beam 10 0
Draft 5 0
Speed 18 knots

"rienced was the constant priming when the boat was rolling, and the impossibility of using the injector, so we were obliged to keep the donkey going all the time. We got to Horten in good time, and all safe, and after my opinion, the boat is much more sea-worthy than one could possibly think, judging from a hasty glance only."

In a subsequent letter, Captain Koren says:—"We ran on a flat rock with your launch last year, and with tolerable good speed too. In backing, the two-bladed screw knocked against the rock and got a very curious new twist. The blades did not break, and the boat came off without any sort of injury, as happily the rock was quite smooth but the test was rather severe."

I am particular in giving these facts, as at the time this vessel was tried on the Thames, many persons hearing of the thickness of the plates employed in her construction, feared that she would not be sufficiently strong for sea work; and even Mr. E. J. Reed stated in the House of Commons that "he was always afraid of putting his foot through the bottom, when he went on board any of our boats."

All the boats we have built are allowed to lie on the foreshore of the river opposite our works while they are being finished, and are left high and dry every tide, without taking the slightest harm, a want of care which I think would prove ruinous to any of our modern ironclads were they so treated.

Doubtless much of the misapprehension regarding the strength of these boats arises from people contemplating only a thin flat plate, which certainly does not appear to have much stiffness; but when that plate is of steel, and is hammered on an anvil to the shape of the boat's side, the case is widely different, the steel is to a certain extent tempered in the same way that a saw is, and the combination of the curved plates, and the strong framing which supports it, forms a structure which is well adapted to resist any ordinary detrusive forces which may be applied to it.

The next size of torpedo vessel is that supplied to the Austrian and French Governments, and is illustrated by diagram B. The dimensions are:—length, 67 feet; beam, 8 feet 6 inches; draught of water, 4 feet 3 inches. The guaranteed speed in the case of the Austrian boat was 15 knots in a run of one hour's duration, and in the case of the French boats 18 knots, in a run of two hours' duration. These boats were built of somewhat thicker plating than the 57 feet type, and the armour was extended, as shown by the blue shading on the diagram, down to the water-line on each side.

They were divided into six water-tight compartments, and they differed from the Scandinavian boats in having the spaces forward and aft of the machinery, permanently decked, instead of being covered with movable steel covers only.

The machinery was somewhat similar to that in the Scandinavian boats, excepting that the engines were capable of developing 200 indicated horse-power, and that the air was supplied to the furnace by being forced into an air-tight stoke-hole, instead of being forced directly under the fire-grate.

The armament of these vessels consisted of two torpedoes attached

to the end of wooden poles, $4\frac{1}{2}$ inches diameter and about 43 feet long, connected to the battery by insulated wires, and arranged to be fired either by coming in contact with the enemy's vessel or at any distance from it, at the will of the operator.

The torpedoes themselves were simply copper cases, like those on the table, and as illustrated by diagram G, of sufficient size, in the case of the Austrian boat, to contain 11,000 cubic centimetres of explosive, and in the case of the French boats, to contain 25 kilogrammes, of dynamite. At one end is the socket for the pole, and at the other, the contact arrangement, which consists of a metallic plate capable of being pressed against the ends of the studs to which the wires are attached. This plate and its connections are covered by an india-rubber cap, so as to render the cases water-tight.

In the middle of the case is the aperture for charging the torpedo. This is a hole $3\frac{1}{2}$ inches in diameter, into which, when the torpedo is filled, is screwed the cap F. The wires are introduced by the aperture C, fitted with a screw gland, so as to prevent the ingress of water.

The battery is a modification of Smee's well-known single acid battery and consists of six cells, fitted with platinized silver and zinc plates, which, in order to prevent unnecessary oxidation may be lifted and kept clear of the acid by means of the roller N.

The fuse (several specimens of which are on the table) consists of two strong copper wires, kept apart by means of a non-conducting composition, and connected by a very fine platinum wire, imbedded in fulminate of mercury, which is protected by a tinfoil casing. These fuses are used with a detonator—a long copper cap half filled with fulminate of mercury. The connecting wires are arranged in the neat and effective way patented by Captain McEvoy, of the London Ordnance Works, by means of which, with only three wires, the torpedo may be made to explode either on contact with the enemy's vessel or by means of a firing key, at the will of the operator. This arrangement is shown in diagram F. D and D₂ are the wires leading from the poles of the battery to the torpedo. The fuse is inserted in the wire D₂ at a point within the torpedo case, so that, when the case is charged, the fuse is entirely surrounded by the explosive. The connecting wire D₁ is attached to the wire D near the battery, and to the wire D₂ at a point between the fuse and the stud, to which that wire is attached in the torpedo case. A firing key is inserted in the wire D₁ at E₁, and a contact breaker in the wire D at E₂.

The firing key is simply an apparatus for connecting the two ends of the wire quickly. It is shown in diagram F, and consists of two pieces of vulcanite, through each of which the wire is led and fastened over the end. These pieces are kept together by means of a vulcanite nut, and a spring keeps the ends of the wire apart until pressure is applied.

The contact breaker is similar to the firing key, but there is no spring in it, and the two parts may be screwed backwards and forwards, so as to separate or connect the wires when required.

The object of having the contact breaker in the circuit is to prevent the torpedo from being exploded by contact with the enemy's vessel,

and so, to place the control of the explosive entirely in the hands of the operator. If it is in use, it will be seen that no current can pass through the wire D, and that it is only possible to fire the torpedo by pressing the firing key and sending a current through the wires D₁ D₂. Should it be desired to fire by contact, the contact breaker is screwed up, so that the wire D may be put in circuit; a current is then possible through the wires, and D and D₂ as soon as the circuit is completed by the contact plate being pressed against the studs.

However effected, whether by the firing key, or by contact with the enemy's vessel, as soon as a strong current passes through the fuse, the small platinum wire is heated to redness, and the fulminate of mercury exploded; this explodes the detonator, and with it the charge of the torpedo, the force of the explosion finding its way along the nearest path to the air, which path, if the torpedo is sufficiently close, is through the enemy's ship.

The arrangement for working the torpedo-poles is shewn on diagram H, and consists of two tubes riveted together at right angles so as to form something like the letter T. The torpedo-pole is put through the horizontal tube, which is free to move round the centre of the vertical tube, and the vertical tube is free to move through a quarter circle at right angles to the centre line of the vessel.

In attacking in front, the vertical tube is laid over, till it is parallel to the water surface, and the horizontal tube is allowed to incline sufficiently far to allow of the end of the pole, when run out, to be depressed from 8 to 10 feet below the water-line. It is held in this position by a pair of blocks attached to the top of the short mast A.

In attacking on the broad-side, the vertical tube is laid over till it assumes a position such as to allow of the pole when swung round, to touch an enemy's vessel at about 8 or 10 feet below the water-line.

The speed trials of the Austrian boat took place on the 11th September, 1875, when she did 24,700 revolutions on her hour's run on the Thames, and the number of revolutions required to do a knot in still water was found to be 1,357. This gives the distance run in the hour as 18.202 knots, or 3.202 knots over our contract speed. The steam pressure averaged 105 lbs. per square inch, and the vacuum 25½ inches during the run.

In the case of the French boats, the total number of revolutions done in the two hours' run in the roadstead off Cherbourg, was 49,818, and the number required to do a knot in still water was found to be 1,382, so that the distance run in the two hours, was 36.05 knots, or just over our contract speed. During the two hours, the average steam pressure was 108 lbs. per square inch, and the vacuum 25 inches.

The Austrian boat was sent to her destination on board a steamer, but the French boats, under the command of an experienced captain, steamed by themselves from Chiswick to Cherbourg, not crossing at the nearest points, and running along the shore, but going boldly from Dover, direct to Cherbourg.

Shortly after the arrival of the French boats in Cherbourg, they were altered so as to attack in front only, as the French authorities

found that these small vessels were better adapted for resisting the effects of an explosion at the bow, than at any other part.

The arrangement adopted is shown in diagram J, and consisted of a steel pole about 40 feet in length, having one end about 6 inches diameter, and solid, and the other about $1\frac{1}{2}$ inches diameter, and hollow; this pole was mounted at its solid end on small pulleys which ran upon two ropes stretched fore and aft of the vessel; the other end, to which the torpedo was attached, was led over a pulley fixed on the bow. Ropes passing over pulleys to a windlass in the after compartment were attached to the inboard end, and by turning the windlass, the pole was drawn backwards or forwards as required.

It will be observed that as the pole is drawn forward, the inboard end being constrained to move in a line parallel to the deck, the outer end is depressed in the water, and is so adjusted that when the pole is run out to its full extremity, the torpedo is depressed to about $8\frac{1}{2}$ feet below the water level.

The arrangements for firing were, I believe, similar to those described as having been fitted to the boats by us, but of this I have no definite information.

In February and March of this year some very remarkable experiments were made at Cherbourg with these boats, which not only shewed the terrible effect of an explosion on the vessel operated upon, but also the small effect that the explosion has on the torpedo-boat. The last of these experiments was made in the roadstead off Cherbourg on the 3rd March, in presence of Vice-Amiral Cloué, Contre-Amiral Jaurez, Contre-Amiral Lafont and many other officers of the French Navy. The vessel attacked was the "Bayonnaise," an old wooden frigate of about 2,000 tons displacement, which had been damaged in one of the earlier experiments, and was on this occasion kept afloat by means of empty casks. In order to realise as nearly as possible the actual conditions of warfare, the "Bayonnaise" was towed by the paddle-steamer "Coligny," at the rate of about 6 knots per hour. The attacking boat, under the command of M. Lemoine, came up at a speed of about 14 knots, which on nearing the "Bayonnaise," was reduced so as to prevent a collision between the two vessels at the moment of attack.

The torpedo charged with 15 kilogrammes of damp gun-cotton, submerged to a depth of $2\frac{1}{2}$ metres, or about $8\frac{1}{2}$ feet below the surface of the water, exploded immediately on striking, and the "Bayonnaise," with the hole in her bow, shown in the photograph on the table—large enough, I believe, to admit a full-sized omnibus—would at once have gone to the bottom, had it not been for the empty casks, with which she was filled.

At the moment of explosion, a slight shock was felt, and immediately afterwards a large wave was upheaved between the "Bayonnaise," and the torpedo-boat, which was driven backward a considerable distance, and completely covered with water, so much so that M. Lemoine and his brave companions for the moment could not say whether they had gone to the bottom or not.

VIEW OF FRENCH VESSEL "BAYONNAISE"
Showing Breach produced by the Explosion of 15 Kilograms of damp Gun-cotton.

PL. IX.

J. J. Atkins

This state of doubt was soon dispelled however, and M. Lemoine steamed slowly off to report himself on board the "Coligny."

The effect on the torpedo-boat in attacking a wooden vessel like the "Bayonnaise," half filled with water, with thick wooden planking, and still thicker ribs, is, I believe, greater than it would be in attacking an ironclad, with its bottom of thin iron or steel, and the result showed very clearly that no harm is likely to happen to boats of this class, either in the hulls, or the machinery from the explosion of this formidable weapon.

I may remark that the second Thornycroft boat was not stopped in time, and ran into the "Bayonnaise," at a speed of about 8 knots, the result being that the bow was doubled up, but so little real harm done, that on the following day she steamed out into the roadstead in rough weather, and returned without shipping more water than could be easily disposed of by her bilge pumps. None of the machinery was displaced, and no joints broken.

One important result of the experiments made by the French Government, was the finding that only 90 per cent. of the weight of explosive that might be safely fired at the bow could be fired at the stern, and only 35 per cent. on the side.

The third size of boat built by us is that we are now supplying to the Dutch and Italian Governments; these vessels are 76 feet long by 10 feet beam, and are guaranteed to do a speed of 18 knots.

They are similar in design to the French boats, and differ from them in having engines of 250 indicated horse-power, and in having more freeboard forward, so as to make them better sea-boats.

The Dutch type will be armed with the outrigger torpedo, as supplied to the French Government, and the Italian type with the Whitehead or fish torpedo.

The exact details of the construction of this torpedo are kept carefully concealed from manufacturers, but generally it consists of a cigar-shaped vessel, varying from 14 to 19 feet in length, and from 14 to 16 inches in diameter. It is made of specially prepared steel, and is divided into three parts; the head containing the gun-cotton, and the exploding apparatus; the central part containing the machinery; and the third, or tail part, containing the supply of compressed air for the engines. The motive power is supplied by a small engine of the Brotherhood 3 cylinder type,—a type which lends itself readily for packing in a cylindrical chamber, and so compact, that I believe I am right in stating that an engine capable of developing 40 indicated horse-power can be made to weigh only 35 lbs. weight. The working pressure of air in the tail is usually about 1,000 lbs. per square inch, and the quantity carried is sufficient to propel the largest sized torpedoes a distance of 220 yards, at a speed of 24 knots, or 1,000 yards, at a reduced speed of 16 knots. By an arrangement connected with horizontal rudders, the torpedo can be made to run below the surface of the water at any required depth, and to keep at that depth till the end of its run. Such is the skill already acquired in the use of this torpedo, that I understand it would be almost im-

possible to miss an ironclad at a distance of 1,000 yards, even when the ship from which it is fired is moving at the rate of from 10 to 12 knots per hour.

We now come to the "Lightning" type of vessel, which is illustrated by diagram D, and the photographs on the table. This vessel is 84 feet long over-all, by 10 feet 10 inches beam, draws about 5 feet of water, and is guaranteed to do a speed of 18 knots on her trial. The machinery on board the "Lightning" is similar in design to that already described, and is capable of indicating 350 horse-power. The hull of the "Lightning" is made of heavier plating than we usually employ, and her lines are fuller, as she is intended for use in a tolerably rough sea if necessary; and in order that she may be able to remain at sea for some time, cabin accommodation on a scale larger than in any of the other boats is provided for the Officers and crew. The steering gear is arranged so that the vessel may be steered from the deck, or from the conning-tower, and the usual telegraph gear is fitted to communicate from the deck, or from the conning-tower, to the engine-room.

The top of the conning-tower is supported on three screws, so arranged that it may be raised or lowered, and the space for sight adjusted according to the range of vision required, or the risk to be run from the enemy's missiles.

The "Lightning" is to be armed with the Whitehead torpedo, which will be discharged from her forward deck by means of a discharging apparatus, the details of which I am not sufficiently familiar with to be able to give a description.

The torpedoes will be charged with air, by means of one of Mr. Brotherhood's air-compressing pumps.

The "Lightning" has not yet been officially tried, but on her preliminary runs in the Thames, she attained a speed on the measured mile of 19.4 knots per hour, a speed which will be somewhat reduced when she has her torpedoes and their gear on board, but which will leave us an ample margin on our guaranteed speed of 18 knots per hour.

The next size of boat is the 87 feet type, as illustrated in diagram E, of which type we have six in hand at present for the French Government.

These vessels are 10 feet 6 inches beam, and are built of heavier plating than the "Lightning," and we have undertaken that they shall maintain a speed of 18 knots in a run of three hours' duration.

The propellers, contrary to our usual practice, will be placed in front of the rudders, so as to give increased readiness in steering.

In order to prevent oxidation of the hulls as far as possible, we have arranged to galvanise the plates and frames below the water-line; and a spark-catching apparatus will be fitted to the base of the chimney, so as to prevent the position of the vessel being betrayed to the enemy during the night.

The armament of these vessels will be fitted by the French Government, and will, I believe, consist of an outrigger arrangement similar

to that now in the boats we formerly supplied to them. They are equally well adapted, however, for the Whitehead torpedo, and they may be fitted with the apparatus for discharging that weapon. They will also be provided with an apparatus for deadening the shock, in the event of their coming in contact with an enemy's vessel at too high a rate of speed, as happened to one of our boats during the experiments at Cherbourg.

I have now described the principal features of those boats we have built for torpedo service, and although the results in the matter of speed are high, they are not so high as we have obtained in some of our other boats,—as for instance, in that built by us last year for the Baroness Rothschild, and tried on the Lake of Geneva. This vessel, 90 feet long by 13 feet beam, maintained a speed of nearly 21 knots in a run, the whole length of the lake from Geneva to Villeneuve.

I may further add, that although this is the fastest boat in a long run we have built as yet, we have designed, and are prepared to build boats capable of maintaining a speed of 25 knots.

These vessels would be larger and more expensive than any I have described, but would, I think, be invaluable in war, either for actual torpedo work or for use as dispatch vessels.

High speed, although so thoroughly appreciated by foreign torpedoists, has not hitherto received that attention which it merits from our own people. I have reason, however, to believe that this will be remedied as soon as the official trials of the "Lightning" are concluded, but in the meantime—it may be on the eve of a great war—the fact remains, that we have only one fast steam torpedo launch in Her Majesty's navy, while other nations are providing them by the dozen, for the defence of their principal ports.

In advocating the value of high speed, I have sometimes been told that although very useful in its way, it is not required for torpedo work, and that an ordinary ship's launch, if directed to move slowly and silently against an enemy's ship, would be quite as efficient as a fast vessel; and as these launches are always required on board ship for other purposes, and are besides much cheaper in first cost, it is better to buy a large number of them than to have a few fast vessels for a special purpose. Doubtless this would be true, if the enemy's vessel were at anchor, and if an inefficient watch were kept on board; but this is a conjunction which I apprehend would be very rare in modern warfare.

I think it may be very safely asserted that numbers are only useful in war when their force can be brought to bear on the enemy; and I am quite certain that any number of ordinary 8 knot steam launches, fitted with outrigger torpedoes, might just as well be away on the China station as any way in the neighbourhood of an enemy's ironclad, capable of doing 12 knots, for all the harm they would do her.

All the ironclad would have to do would be to keep running at a little slower speed than her Lilliputian foes, and sink them in detail as they came within range.

On the other hand, take the case of the same ironclad appearing off one of our ports defended by a fleet of 18 knot torpedo-boats.

Nothing would require to be done till she came in sufficiently close to use her guns—say three miles at the outside—when, if half-a-dozen or a dozen 18 knot torpedo-vessels were launched against her, they would be alongside in half an hour from the time of their starting, even if the ironclad got away at once, and used her utmost speed in escaping.

If the torpedo-vessels were armed with the Whitehead torpedo, it would not be necessary for them to go close alongside, and so they would be less easily hit; but the danger of hitting objects running at even the slow speed of six knots per hour, or ten feet per second, relatively to the ironclad is very slight indeed.

Last year at Wimbledon there were 5,000 shots fired at the running-deer—a target moving at the rate of six feet per second, and out of these shots, fired from a fixed platform, by men who almost make a business of shooting—only one in ten hit the bull's-eye at 110 yards; while if the target was stationary, nine shots out of ten could always be depended upon as being bull's-eyes. Add to all these difficulties, men comparatively unaccustomed to shooting, firing at an uncertain distance from a moving platform, at a target moving twice as fast as the running-deer, when the torpedo boat is in chase of an ironclad, or five times as fast if the ironclad is caught napping, and some idea may be formed of the difficulty of hitting these boats.

Then if they were hit, no small-arm bullet would penetrate any part of them at even comparatively close ranges, on account of the obliquity of the surfaces exposed, while it is calculated that large guns firing Shrapnel, if the aiming were accurate, and the distance correctly ascertained, could only send $1\frac{1}{2}$ bullets for each round into the area exposed by a vessel as large as the "Lightning" at 1,000 yards.

In considering the question of the safety of the attacking boats, I do not think that sufficient value is given to the demoralizing effect of the stealthy approach of a vessel carrying so tremendous a weapon as a torpedo.

The French officers on board the "Coligny" during the experiments at Cherbourg said they experienced a decidedly uneasy feeling when they saw the two small grey-coloured boats gliding silently up, a feeling somewhat akin to that experienced on the approach of a deadly snake.

The most valuable experience however was acquired during the American War, and Lieutenant Cushing thus describes the dangers he ran from bullets while sinking the Confederate ram "Albemarle," and the small effect they had on him and his party:—

"The rebels sprung their rattles, rang the bell, and commenced firing, at the same time repeating their hail, and seemed much concerned."

And again:—

"Three bullets struck my clothing, and the air seemed full of them."

The result of all this firing was—"the most of our party were captured, some drowned, and only one escaped besides myself, and he in a different direction." But he makes no mention of any having been shot.

The question is often asked, what is the best kind of torpedo for these boats? and it is a difficult question to answer. For the 57 feet sizes, such as supplied to the Scandinavian Governments, and the 67 feet boats, such as supplied to the French Government, I should say that either the outrigger, or a modification of the Harvey torpedo, is the best, as these boats could not carry the Whitehead torpedo, with its launching and air-compressing gear.

The Harvey torpedo might be used for the larger class of vessels, but I think the outrigger and the Whitehead torpedo are the preferable weapons.

The Whitehead is generally considered the safest torpedo to use, but if the men have to expose themselves on deck, even at 500 yards distance from their enemy while discharging it, I almost fancy it would be better to have them all under cover, and run the extra risk from the larger missiles, and to go close alongside, with the outrigger torpedo. The operation would, I think, be more certain in its result.

As an illustration of what may be done safely in going alongside and attacking large vessels, I may instance the daring attempt to sink the United States' steamer "Minnesota," by Captain Hunter Davidson, of the Confederate Navy. This officer proceeded from Richmond to Hampton Roads, in a small steam launch, armed with a torpedo containing 60 lbs. of gunpowder. Leaving Richmond in the evening, he travelled all night, and during the day hid himself and his vessel in a creek. He arrived in Hampton Roads the next night, and in going alongside the "Minnesota" he was hailed, and ultimately fired at; but such was the confusion, that he not only succeeded in exploding his torpedo, but in escaping safely back to Richmond, although firing and signalling were going on in all directions, and his engineer could not get his engine (a single cylinder one, which would hang on the dead centre) to start for some considerable time after the explosion of the torpedo.

I believe the best defence against attack from these torpedo-boats is to have other and similar boats steaming round the vessel to be protected, ready to ram or otherwise destroy the attacking boats.

Possibly some modification of the hand grenade might be used for this purpose.

Such guard-boats should have as much speed as the attacking boats, and arrangements should be made for hoisting them on deck, when they are not required for guard duties. We have designed some small-sized boats for this purpose, but I think the 57 feet type is quite small enough for sea work, and her weight of 7 tons is not a difficult problem to grapple in the way of hoisting.

The principal danger run by our boats is, undoubtedly, that of being sunk, and I have thought, for some time past, that it would be better to abolish the thick bullet-proof plating in their construction—excepting that immediately over the engine-room—and to use ordinary plating instead. The weight saved could then be used in the bottom, in the form of half bulkheads, sufficiently high to reach above the water-line at every third or fourth frame along the bottom; these half bulkheads are shown in red, for the sake of illustration, on the

hull of the French boat in diagram E. If a shot penetrates the boat, it does not follow that any of the crew will be struck by that particular shot ; but it does follow that if the shot goes through the bottom, water will enter, and, unless the quantity is limited, the boat will sink. The half bulkhead protection limits the quantity of water that will enter, and, I should say, there would be no difficulty whatever in plugging up the hole made, and afterwards pumping the water out by means of the bilge-pumps.

Doubtless, some of my audience may see some other ways in which these boats may be improved, and I shall feel grateful for any suggestions in this way.

The adoption of these suggestions, however, would depend on the responsible officers of the Governments ordering the boats ; but I may say that, so far as my partner and myself are concerned, we are always willing to adopt any improvements, and we never knowingly allow any bad design, bad materials, or bad workmanship to pass from our works.

In conclusion, I beg to tender my thanks to the Council of this Institution for the opportunity they have afforded me of describing our boats, and to you, Gentlemen, for the patience with which you have listened to what I have had to say.

Mr. LEWIS OLDRICK, C.E. : In August, 1875, I was honoured by being appointed by the Danish Government to inspect one of the steam launches made by Messrs. Thornycroft for that Government. I cannot, therefore, be considered as an impartial observer, for, on the contrary, it was my duty to be very partial in favour of the Government that employed me. It may, therefore, be interesting to hear a report that is based upon facts which it was my duty to ascertain and to look into in the most careful manner. Having been brought up among such machinery as is made by Messrs. Maudslay, Sons, and Field, I have been used to first-class machinery, and am therefore not easy to satisfy. The boat built for the Danish Government had compound engines, with an intermediate receiver. The contract number of miles she had to make was 17 per hour ; instead of which she made upwards of 18 miles on a careful trial trip. The indicated horse-power ought to have been 90, but I believe it was over 100 ; so that the boat in every respect came far above the contract figures stipulated. The boiler was of the locomotive type, worked by a centrifugal fan ; and at full speed (18 miles an hour) there was no noise whatever perceptible, and there were no sparks coming out from the fire, so that she would not be seen by the enemy she was attacking. To enable us to take indicator diagrams, it was necessary to use a scale of 100 pounds pressure to the inch. Ordinary indicators could not have been used, and to take indicator diagrams at 500 revolutions per minute is somewhat novel ; but, however, it was accomplished without the slightest trouble. There was also a feature in the machinery, at that time novel to most engineers ; that was—to drive an air-pump at 500 revolutions per minute. I omitted to state that in calculating the indicator diagrams, which were no larger than could fairly be put inside the palm of my hand, I was obliged to use the ingenious instrument known as Amstler's planimeter. The revolutions on the measured half-mile were 514 per minute, and the true mean speed 18·31 miles per hour. The result of one hour's trial was 1,695 mean revolutions per mile, giving an average speed of 18·06 miles per hour, or more than a mile in excess of the contract number of miles it ought to have made. The design was wonderfully light. That was obtained by no unnecessary material being used. I had an opportunity to closely examine the engines and the boats in all the stages of their manufacture, and I have no hesitation in saying the design was excellent throughout, and the workmanship could not be surpassed. The torpedo launch, as a whole, reflects the greatest credit on the firm of Messrs. John I. Thornycroft and Co.

Captain COLOMB, R.M.A.: I should like to ask one question, and that is as to the coal-carrying capacity of the several vessels described by the lecturer; and also the amount of fuel consumed per hour.

Captain SMITH: I should wish to ask Mr. Donaldson the distance which these torpedo vessels would require to turn in at full speed; and also the distance they would run in slowing down from, say, a speed of 18 knots to a speed of 10 knots, as they would be longer under fire in going at a slower rate of speed. If you were pursuing a vessel going nine knots an hour you could not come up alongside her at full speed.

Commander LAW: I should like to ask whether that vessel can turn the helm hard over—the torpedo being lowered in its position for striking—without doing any damage to any of the machinery connected with the torpedo?

Captain SCOTT, R.N.: It is extremely difficult to speak on such a paper as we have just heard, unless one makes some comparison between our present war ships and the relative position and capabilities of the Thornycroft torpedo boats.

The value of our ironclads depends first upon their gun power, and secondly upon the strength of the armour which protects them; but if the gun power be small, the guns not very accurate, or the aiming of the gunners be imperfect, then the large amount of fighting efficiency which we might anticipate from ironclads is neutralised.

The lecturer told us of the difficulty experienced by marksmen in hitting the running deer target at the Wimbledon competition; but, notwithstanding this, I feel sure that by carefully selecting and training special men, a far greater result might be obtained in firing at sea than is now reached.

As regards naval guns, we have continued the use of studs up to this time, and consequently have only obtained a very low velocity of projectile, combined with inferiority in accuracy of fire; and now, at the last moment, we are hastily changing from studs to wads, a means of rotation which will not admit of a sufficiently sharp spiral of rifling to give steadiness of rotation to the projectile.

The result must be a want of that precision of fire which has become so necessary to repel boat and torpedo attacks with small guns, and to pierce the cuirass of an ironclad with the heavier ordnance.

The increase in the range and speed of the fish-torpedo is in some measure due to its being fired under water from an air chamber, from which it issues with some velocity, and is then projected onwards by its own engines, driven by compressed air.

Whitworth's fluid steel, from which the torpedo has been recently made, enables the very high pressure of 1,000 lbs. or more to the square inch to be obtained; the result being that instead of the original comparatively poor weapon running at about 12 knots per hour, which is below the speed of some of our ironclads, the missile starting from the air tube is now propelled with so high a velocity as to enable it to outstrip a swift Thornycroft boat for a short distance.

Another important improvement consists in the power of discharging the fish-torpedo from some distance above the water level without impairing the straightness of its run, and hence the missile can now be used by small vessels with far greater advantage than it can be launched from an ironclad.

The operator on board the Thornycroft would have a clear view all round the horizon, and hence would be enabled to discharge the fish in any direction, taking care there was no chance of a friendly ship's crossing its line of advance during more than 1½ minutes occupied by this torpedo in running 900 yards.

The operator between the decks of an ironclad or other heavy war vessel would have a very limited view, and be only able to train the torpedo on its carriage 15° or 20° each way, and hence would have far less opportunity than the operator on board the Thornycroft of discharging the "fish" at the right moment.

The carriage and use of so delicate a weapon on board an ironclad, and costing half a million, with a crew of 400 or 600 men, is of doubtful advantage, for should its air chamber or the 60 or 120 lbs. of gun-cotton carried in its head be struck by an enemy's shell, the blowing up of its deck, or even still more serious damage might ensue.

There is a further danger attendant upon the use of a torpedo in a squadron,

resulting from the awkward tendency of this missile to take a curved course before it has reached its extreme range of about 1,000 yards; but should the tail or the machinery become damaged, the torpedo might return like a boomerang, and even blow up the vessel which fired it. I am pointing out the great care and the very skilful handling required, with the view of indicating that the fish-torpedo can be more advantageously handled by the picked crew of a Thornycroft than on board one of our larger war vessels, where an accidental blow might cause an explosion.

On the other hand, in addition to heavy ordnance projecting explosive shells with high velocity, the ironclad should carry some perfectly accurate and quick working light guns so as to destroy an enemy's gun and torpedo boats, two or three thousand yards beyond the *extreme range* of the fish torpedo.

There is, however, another weapon, which, from its long range and high velocity, seems likely to play an important part hereafter. I allude to the almost forgotten Hale rocket, which is a comparatively safe missile, and which, if its powers were developed with half the care and skill which has been bestowed upon the fish, would soon become a flying-fish torpedo through air and water. This rocket could be discharged at least 5,000 yards through the air (carrying a large bursting charge) with a rapidity little less than that of the rifle projectile. The cost of the Hale rocket would be far less than that of the fish-torpedo. The reason Mr. Hale did not proceed further appears to have been owing to the difficulties he experienced in the manufacture of the small rocket; these difficulties have now passed away, and had Mr. Hale lived he might now have been able to give proof of the value of the war rocket as compared with the gun as a means for destroying life.

We are no longer satisfied with killing one man at a time, but we want to blow up 500 at once, and instead of rejecting, as our fathers did, the employment of explosive bullets, we now seek to obtain the most fearful destructive agents with which modern research can supply us.

Another point I wish to bring before the many gentlemen present who have given attention to the subject is, that Mr. Thornycroft's boats work with a mean pressure of about 80 lbs. to the square inch; but I can see no reason why a boiler pressure of 500 or even 1,000 lbs. to the square inch should not be used in suitable boilers. The present boilers of our war ships are large steam reservoirs, which the bursting of an enemy's shell inside, would convert into a mine; but if, instead of bringing together such vast quantities of water and steam, the boilers consisted of a large number of encased tubes, on Mr. Perkins' plan, you might safely work at a very high pressure without incurring the risk of a fearful explosion.

High pressure not only affords the means of increasing the speed, but it is also very economical as to consumption of fuel, and this is a very important consideration, seeing that our ironclads can now only carry coals for five or six days' full steaming.

Experiments with the Perkins boiler have been long since officially recommended, but no trials have as yet taken place. Had such trials been carried out, I think Mr. Donaldson would have been able to have brought before you a higher result as to speed, and have answered the question as to the coal supply carried by his boats more satisfactorily than he can now do. Full speed is only needed in the act of attacking an enemy, and naval men know that these swift boats need sail to supplement their coals, and, like larger vessels, will need floating or other depôts from which to replenish their fuel when employed at a distance from their own ports.

Commander W. DAWSON, R.N.: We are engaged in discussing the most important naval question of the day, and not a single officer on the active list has got up to speak upon it, and draw attention to that fact as one which frequently occurs in the United Service Institution, and is a sad contrast to what occurs whenever any professional subject connected with the Army is brought forward, for then we have distinguished generals on the active list, able colonels, majors, and captains rising with one another in discussing professional subjects boldly and intelligently, without fear or affection. I venture in the name of the active officers of the Navy, who cannot or dare not speak on professional themes, being myself on the ineffective list, to return the thanks that are due on the part of naval officers to Mr. Thornycroft, for the very wonderful way in which he has developed the speed of these very small vessels, and I may also venture in their name to return thanks to Mr. Donaldson for the very exhaustive and instructive paper he has given us. I came into this room

expecting to criticise the tactics suggested for use with these vessels; but as the paper progressed, I found the wind taken out of my sails, and that many of the things I had heard in connection with the tactics suggested for adoption by these torpedo boats had certainly not appeared in the paper. My own feeling is that the safest way for boats to approach armed ships is stealing up under the stern, or down under the bows, or getting alongside from any arc of the horizon, except the broadside of the enemy, and exploding the charge whilst alongside. The point we have to bear in mind is, that if the torpedo be held at a given distance of safety from your own boat, and be brought within destructive range of the enemy, the boat may lay alongside the enemy's ship whilst blowing her up. But in order to enable you to do so with the greatest destructive range, the charge appears to me to be insufficient. The charge is quite sufficient, it is true, to penetrate the bottoms of any ship, if it be exploded in actual contact; but the point I am contending for is, that it ought not to be necessary that the charge should be in actual contact, for the difficulty of getting into contact is so great, that you are obliged to run the great risk of approaching from under the stern, or from under the bows, or exploding whilst lying alongside. If the dimensions of that spar-torpedo were to be increased by a very small diameter, one inch or two inches, you might double the amount of charge, and the effect of doubling the amount of charge would be, that the effective destructive range would be increased. We know the effective destructive range of dynamite, and those powerful rapid explosives, is much less in proportion to their explosive effect than corresponding charges of slow gunpowder—that is to say, if 25 pounds of dynamite will, when in contact, do the same work as 100 pounds of gunpowder, then it would not do equal work to the equivalent charge when removed to the same distance from the object. When they are not in contact, equivalent charges have not the same effective distinctive range. There would be very little difficulty in the spar carrying double or treble; the charge and the result of that addition would be that you could operate against the bottom of an enemy's ship at a greater distance than at present. That is a very important point, because the destructive range involves a great deal of the tactics of spar-torpedo boats. Mr. Donaldson spoke of this nation being rather slow in adopting special vessels. The British Navy has a very wise prejudice against special vessels that can only be used for one special purpose, because such vessels are quite sure to be at the wrong end of the world when they are wanted. Just now it is not at Portsmouth, but at Gibraltar or the Grecian Archipelago that such vessels are likely to be wanted. Is there any difficulty in adapting these vessels for the ordinary purposes of war? For once that the British Navy is able to use a torpedo for blowing up a vessel, it is able to use a gun a hundred times. Is there, then, any reason why the decks should not be so strengthened in one part that a gun could be mounted on the other deck, and thus these boats might be made use of for river service and for the service for which small gunboats and steam launches are now employed? If we could use the Thornycroft vessels for such purposes, then there would not be the same objection to the British Navy receiving them for the use of torpedoes. That objection will stand a good deal in the way of their adoption in the British Navy, and if you can overcome it, then the difficulty in the Navy in receiving special vessels of very limited utility would be very much diminished.* Allusion was made to the experience of the American war. Well, we have profited a good deal by that experience. They were labouring under great difficulties in the matter of ignition on the Confederate side. They had only one mode of igniting spar-torpedoes, and that mode demanded contact being made nearly at right angles to the side struck, which necessitated the torpedo vessel approaching the enemy on the very worst possible position for her own safety—namely, against his broadside. The consequence was that when the "Housatonic" was destroyed, the torpedo boat ran at right angles to the broadside, and ran into her own explosion, and the boat disappeared, as well as the corvette. Nobody ever heard of her afterwards, and it was believed that the effect of her own explosion was the cause of her disappearance.

* It was subsequently stated that the Thornycroft boats could only carry coal for two or three hours' steaming at full speed. This obviously limits their utility much more than I was aware of when making the above remarks.—W.D.

ance. Then on the occasion on which Captain Davidson performed his remarkable feat, he failed to destroy his enemy entirely, because the charge was too small. That is a lesson that cannot be pressed home upon us too strongly. It is no use a boat running the great risk of bringing a torpedo near to an enemy's ship, unless the boat carries such a weapon as will be sure to do its destructive work without any doubt. Over-refinements in weapons of war are very objectionable. A great number of the Confederate ships were fitted with spar-torpedoes, but the reason why so little use was made of them was the difficulty arising out of the mode of ignition which required an approach to the enemy's vessel in a very exposed situation. With reference to the destruction of the Confederate ironclad "Albatross," it will be remembered that the Federal mode of ignition was different, it was by trigger line. At the conclusion of Mr. Donaldson's paper he alluded to the experimental results of accuracy of fire with the Whitehead torpedo in the open sea, but he acknowledged that his knowledge of the accuracy of range of the Whitehead torpedo in the open sea was by hearsay. The danger connected with the Whitehead torpedo is that the path is invisible to friends as well as foes, and during the time which elapses between the torpedo leaving the ship that forces it, and reaching its intended destination, when squadrons are intermingled in the fray, some friendly vessel may very easily but unknowingly intercept the invisible torpedo, and you may then blow up your friends instead of your enemies. When several moving vessels are rapidly launching successive fish torpedoes against moving vessels the danger is greatly multiplied. That seems to me a very formidable objection to turning adrift a number of invisible weapons like the Whitehead fish torpedoes in squadron actions at sea.

The CHAIRMAN: With the permission of Mr. Donaldson and of the meeting, as I was on board the "Lightning" I may be allowed to mention two practical points which occurred to me, and which are not contained in the lecture. In the first place, I do not think Mr. Donaldson has pointed out that the very high rate of speed attained in these boats is due to the fact that the screw shaft is level with the keel, and that the semi-diameter of the screw propeller is in addition to the draught of the vessel; that by that means she develops a larger power through a very much larger screw propeller than any other vessel has yet obtained, and obtains immersion in that way which is of great value. There is another point—namely, the curious fact that the additional speed is obtained by the vessel herself being forced out of the water; and that after she begins to go at the great rates of speed, after 14 knots, she is drawing something like three inches less water. I think it would be interesting to the meeting to have some information upon that point. Up to the 12-knot speed the "Lightning" was followed by a wave higher than herself at a very short distance astern; but when the speed increased to 16 knots there was no wave at all, the vessel herself was forced out of the water—like a skimming dish on the top of the water. And, in addition to that, the vibration which at 12 knots was considerable, entirely disappeared at 18 knots. I believe it will be interesting to have some more perfect information upon those two points. There is another point it would be desirable to know, and that is—what number of torpedoes can a vessel of that sort—such as the "Lightning"—carry for service. There is also another very interesting point, I do not wish Mr. Donaldson to go into the items of the firm, but the cost is an element with which approximately, perhaps, he will be kind enough to favour us.

LORD OTMO FITZGERALD: One matter that has been overlooked is with reference to the fouling of the screw; that is the only objection that occurs to me to these torpedo boats. For instance, if a few old herring-nets were hung round with buoys in the water at half a fathom deep, I do not think any torpedo vessel could pass them; any such matters as old herring-nets or old ropes held in the water would so foul the screw that her progress would be entirely stopped. Perhaps Mr. Donaldson will say whether he contemplates any means for avoiding such a casualty.

MR. DONALDSON, in reply, said: Mr. Olrick mentioned that no sparks came from the funnel in the case of the Scandinavian boats. That is so; but in the French boats we had some sparks, and that is the reason why in the new French boats provision is made to prevent them escaping. Captain Colomb asks about coal-carrying,

and I think I am right in saying the Scandinavian boats used about six or seven hundredweight in the hour's run, and the French boats about a ton in the two hours; but in running for a long time a great deal of the coal is thrown up the chimney, so that you can scarcely get an idea of the efficiency of the machinery of these boats from the amount of coal used. In ordering their boat, the Norwegian Government stipulated we should carry coal for above a two hours' run; the French Government stipulated for three hours, and in the new French boats there is three hours' supply. The "Lightning" carries five tons of coal in her bunkers, and two and a half tons was found quite sufficient to take her round from Chiswick to Portsmouth. We have no very accurate information about the coal-consumption in our boats. Captain Smith asks the distance in which the boat could turn at full speed with the screw aft the rudder. This distance is greater than in ordinary boats, as we cannot put the rudder hard over suddenly, because the rudder on being put over makes a vacuum, and the engines get away too fast. It requires to be done carefully, but I should think that at Cherbourg, on running round the breakwater, we did it in about a quarter of a mile radius going at full speed. As to stopping we can stop dead from 18 knots in about the length of the boat in any of them. Commander Law inquired if we could turn the helm hard over with the torpedo lowered into position without doing any damage: I cannot say, as we have never made the experiment. Captain Scott asked about the safest torpedo: when I said the Whitehead torpedo was considered the safest I spoke of the opinion I have heard officers express regarding it. They seem to think the Whitehead is a safer torpedo to use than the other, on account of their not requiring to go alongside with it.

Captain SCOTT: Safe as respects the officers using them not being obliged to come under fire.

Mr. DONALDSON: Yes. The Hale rocket I should think would be well adapted for our boats, because there would be very little recoil on the rocket leaving the boat. We use 120 lbs. pressure in our boilers, and if Mr. Perkins' engines and boilers could be made as light as ours I do not know why we should not use them; but I think they are heavier than we make them, as a rule, and we have always the carrying consideration to look to. With regard to the sails in those boats, there were some sails reported as having been used on the French boats, lateen sails, and some French newspapers went the length of giving the dimensions of those sails. These, however, were only newspaper reports. There were no sails at all; I suppose the torpedo spars were taken for sails. Captain Dawson spoke of coming alongside, and the effect of distance on the explosion. I believe there was an experiment made in Sweden with 32 lbs. of dynamite fired three feet from the side of a section of a vessel representing our "Hercules." The explosion sent a hole nine feet by three through both bottoms, the inner bottom being three feet distant from the other, and the torpedo being three or four feet off. I cannot say much about this question, however, as we only build the vessels. We never made experiments with the torpedoes. About the difficulty of adapting our vessels for carrying guns, we have fitted some of our small boats for 9-pounder guns, and I should think small guns of that kind could be carried easily; but in mounting heavy guns of course you require heavy carriages, and I think my partner would object to putting such heavy weights in our small boats. With regard to the submarine vessel that sunk the "Housatonic," I think I have heard it said that that vessel was recovered and is now in the Museum at Washington.

Captain McEVOR: She was recovered about three years after the war. The divers went down and found her lying alongside the hull, with the remains of the nine men that were in her.

Mr. DONALDSON: I should say the vessel would certainly be destroyed by the effect of the explosion, because it would be all round her. I do not think there would be much chance of it escaping.

Captain McEVOR: It was a sort of submarine boat, so constructed as to be able to come to the surface and to go down at pleasure, and to stop down a certain length of time under water. But, however, she had drowned several men in experiments before she went out that last time. She had drowned a crew of nine men just previously, but notwithstanding that they found a crew very readily to take her out the last time.

Mr. DONALDSON: With regard to the Whitehead torpedo experiment, the only ones I have seen are those in the canal, at Woolwich and at Fiume, where they seemed to go very straight. Sir John Hay asks what is the high rate of speed due to. It is due to everything—a carefully designed light hull, carefully designed powerful engines, and to a certain extent to the large screw area. With regard to the boat being lifted out of the water, there was a very interesting paper read by Mr. Thornycroft at the British Association in 1875 on this subject. The experiments were made on the 67-foot Austrian boat, and she certainly was lifted.

Mr. THORNYCROFT: At 11 or 12 knots the boat was depressed in the water five inches below its ordinary line of floating; but on the speed being increased to 13 knots, the boat floated at about three inches above the ordinary level. I might further be allowed to add, in the experiments made on the "Lightning," I expected a similar rise above the ordinary floating level; but so nearly as I have been able to make out from the experiments made, the boat did not rise perceptibly above the ordinary floating level, although there was a corresponding depression of the centre of gravity of the boat at the lower speed, which corresponded to the 12 knots in the smaller vessels. This discrepancy may be due to imperfect observation, but the experiments on the Austrian boat were made in shallower water; and the different conditions in which the experiments were made, due to depth of water, may account for the apparent discrepancy.

Mr. DONALDSON: The number of torpedoes that can be carried is simply a question of weight. The French boats were fitted with two each, and the Norwegian boat with one torpedo, and the Danish boat with two torpedoes. I think the "Lightning" will be fitted with four, but I am not quite certain. With regard to the cost of the boats: the cost of the Scandinavian boats, without torpedoes, was £1,800 each. If I remember rightly, the cost of the 67-foot French boats was £3,400 each; the cost of the Dutch type of 76 feet length was £4,750; the cost of the "Lightning" £5,250; and the cost of the new French boats is £5,500. These prices are, however, complicated by the fittings on board, the torpedoes, delivery, and such like questions. Lord Otho Fitzgerald asks if herring nets would stop the torpedo boats. I think I have heard Mr. Thornycroft say he has gone through a bed of osiers with his weed cutter, so that probably the weed cutter would cut the nets as well as the osiers.

The CHAIRMAN: It only remains for me to convey the thanks of this meeting to Mr. Donaldson for the very valuable lecture he has given us. The next information we ought to have, as sailors, is how we are to defend ourselves from these vessels.

NOTE BY MR. LOFTUS PERKINS.—The Perkins engines and boilers need not be heavier than those used by Messrs. Thornycroft in their torpedo vessels, if specially designed (as Messrs. Thornycroft's engines are) for the special purpose; and, for heavy war ships, Perkins' engines and boilers would be lighter for the same power than those now used in ships of war.