ONE HUNDRED AND TWENTY-FIRST PAPER
(OF TRANSACTIONS).

THE DEVELOPMENT OF THE TORPEDO-BOAT DESTROYER.

BY

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CHAIRMAN:
MR. D. HULME (MEMBER OF COUNCIL).

(ILLUSTRATED BY CINEMATOGRAPH.)

I AM very much honoured by being permitted to submit a paper to this world-known institution, though I must confess that in the subject chosen—namely, "The Development of the Torpedo-Boat Destroyer"—I only regard myself as an amateur, for it is a subject of which I venture to express an opinion that, stately and imposing as a battleship is, there is nearly as much brains worked into a destroyer as in the battleship, the details of both being myriads. But in the case of the battleship, as compared with the destroyer, weight is of very much less moment; and it will be thus seen that the problem of how to give a maximum of strength with a minimum of weight, with a maximum of speed with a minimum of coal consumption, must of necessity be the greater task in the destroyer.

Being an amateur, I have gathered a great deal of information very kindly placed at my disposal by firms of very high repute, among whom I may mention, in alphabetical order, Messrs. John I. Thornycroft & Co., Messrs. John Samuel White & Co., Messrs. Yarrow & Co.

These firms have placed their knowledge freely at my disposal. And so, having the material for an instructive mental repast, should the repast not be to your liking I would remind you many sea-going gentlemen who are here present that there is an old blue-water proverb, "Providence sends grub, and the devil sends cooks."

I think it may be claimed that in building destroyers our nation is pre-eminent, and though shipbuilders and engineers often meet on cosmopolitan ground and compare and freely impart ideas, I think our national egotism may fairly claim that in the matter of construction of torpedo-boat destroyers we lead the world.

I would remind you that the River Thames and the Solent first gave us what is called a "torpedo-boat," and though the area of production has been very much enlarged it can certainly be claimed that the productions of those localities are still in the front rank.

From very early times the glamour of the torpedo—or the "infernal machine," as it has been called—has occupied people's attentions and prompted its usage; for the idea is that you may, by a sort of "hitting below the belt," destroy your enemy with but little risk to yourself; and, further, when there is risk involved, it would only be borne by a very small number of assailants, and that in fact, as represented by novelists and others, risks to each individual may be less than that of the players in a football scrimmage.

I need scarcely say that torpedoes may be classed as fixed and moving. Of the fixed ones our experience as a nation was gained during the Russian war of the fifties, when at least one of our ships was slightly injured in the Baltic by the explosion of a torpedo under her, and some officers and men were injured by the explosion of captured torpedoes whilst they were being taken apart. During that war also was used what may be described as a moving torpedo, one of our sailor-men being credited with swimming into the harbour of Sebastopol and fixing an infernal machine under the counter of a line-of-battle ship, for which bravery he was rewarded; but I believe the ship was not blown up.

In 1858 our Navy had experience of a moving torpedo, a Chinese invention. H.M.S. *Niger*, while lying in Fatee Creek ready for the bombardment of Canton, was torpedoed by a moving junk filled with gunpowder, etc., towed from each bank of the stream and cleverly placed under the bow of the *Niger* and exploded. The damage inflicted was more moral and intellectual than physical.

And of other fixed and moving torpedoes we have lately had knowledge in the operations in the Far Eastern seas.

I may also remind you that the moving torpedo, carried on the end of a spar, was used during the civil war in North America, notably when Commander Cushing blew up the Confederate warship *Albemarle*. Another attack by the Confederates, in 1864, with the spar torpedo was successful in sinking the Federal man-of-war *Housatonic*, the attacking boat being sucked into the breach made by the explosion and also foundering with all hands. Also during that war there were several cases of ships being destroyed by anchored mines.

After that we had the Harvey towing torpedo, which was an adaptation of the canal barge towed from the bank, or of what is known as the salmon poacher's "otter" with baited hooks, the poacher walking along the river's bank and towing his "otter," which keeps mid-stream, and so catching his salmon. These "otters" can also be made to alter the direction of their motion by a strong pull on the towing line, which enables the poacher to retrace his steps, still towing his "otter" mid-stream.

After that we had the Whitehead invention, which has necessitated alterations and additions both of tactics and of shipbuilding.

Not always has perfection been obtained without early fatalities. We had in our Navy a very promising officer, Lieutenant the Hon. Meade, brother of the present Earl Clanwilliam, blown up when manipulating a torpedo of his own invention in the sixties. And later on in the seventies we had an engineer officer killed and another maimed in working the Whitehead apparatus, due to escape of compressed air. There have been other incidents giving maiming of limbs, which is a toll learners have had to pay in manipulating these and other deadly weapons; and happily the history of our Navy shows that whether boiler explosions, machinery disasters, or other incidents giving mortality, there are always many living volunteers to take a dead man's place.

The Whitehead torpedo is fairly well known. This is the invention of a marine engineer, and is a weapon which marine engineers are most aptly fitted to manipulate.

Its original propelling apparatus was by compressed air working compound oscillating engines and driving a single propeller, giving rather a low speed.

The first vessel in the British Navy for using this torpedo was the *Vesuvius*. This was a vessel low in the water, having a peace funnel of the ordinary type pointing to the sky and a war funnel horizontally along her deck to discharge smoke right aft. She was fitted with induced draught. She had a submerged torpedo tube pointing right ahead, from which the torpedo was ejected by a telescopic apparatus actuated by compressed air. It was early seen in this vessel that the speed of the torpedo should be increased, for it is one of the legends of the Navy that when she did fire an actual live torpedo from her tube at a hulk, she being under way, those looking over the bows of the vessel saw that the *Vesuvius* would soon overtake the torpedo, and perhaps be blown up herself. Higher speeds of torpedo were afterwards obtained by adopting the Brotherhood three-cylinder engine, and this has been continued.

The development of the torpedo boat and destroyer is due primarily to the fact that it was found that these Whitehead torpedoes could be discharged from above water.

The first experiment being made from the deck of an old sailing vessel, the torpedo launched, and the regulating valve for the engine being tripped as it passed over the side, when it was seen that the torpedo dived and soon regulated itself to the depth required and propelled itself in a straight line. From this was evolved the ordinary deck torpedo tube now used in torpedo boats and destroyers.

The torpedo "drop gear" fitted to vedette boats, etc., was an adaptation invented by Engineer Rear-Admiral J. T. Corner, and is an arrangement of tongs which is lowered from the boat's side, submerges the torpedo, and on tripping its regulating valve, thus setting the propeller in motion, releasing the tongs at the same time, the torpedo starts and soon finds its depth. These vedette boats of wood, sometimes called "torpedo-boats wood," in 1878 were 48 ft. long and 12 knots speed, have been developed to 56 ft. long. Special boats of this class, by J. Samuel White, of Cowes, have obtained 19 knots on trial.

About 1873 some very fast vessels began to be constructed on the Thames. These vessels were marvellous in their low weight and high power. They completely upset the theories which are written in some books on naval architecture, in which it was laid down that speed at sea could only be obtained by enormous increase of dimensions of the vessel, and it was inferred that the speed of small vessels could only be put to a certain limit, dependent on length.

In 1875 Messrs. Yarrow constructed a torpedo launch of the then high speed of 13 knots, fitted with a spar torpedo, and made a war test by blowing up a barge on the Thames prior to shipment and delivery to a South American Power.

Sir John Thornycroft was the builder of the *Miranda*, in 1872. This vessel was 45 ft. 6 in. long, and obtained a speed of 16·2 knots per hour. This firm constructed the first large torpedo boat for H.M. Navy. She was the *Lightning*, completed in 1877, her length 87 ft., speed 18½ knots, and she did many years of constant service at Portsmouth.

Also in 1877 the Russian Government obtained from home and two foreign firms 100 torpedo boats. A large number of these were built by, or to the design of, Messrs. Yarrow, celerity being required. They were 75 ft. long by 10 ft. beam, were required as small as possible for keeping the seas for a few days, and also adapted for transmission by rail. The first boat tried on the Neva in 1877 obtained 18 knots speed.

Following the *Lightning*, various batches of boats for our Navy were constructed at various times up till 1889. These were by Messrs. Thornycroft, White of Cowes, and Yarrow. Their lengths were from 113 ft. to 130 ft. long, giving horse-powers from 730 to 1,100 and speeds from 20 to 23 knots. Some of the earlier and shorter of these were dispatched to various stations—China, Cape of Good Hope, Australia, North America, India, etc. Most of these voyages were under their own steam. The longest voyages, from England to Vancouver Island via Sandy Point, were performed by two Yarrow boats. There were no incidents during these voyages engendering mistrust as to strength of hull. As to the crews, their normal states may be described as "Dirty, but Happy." In connection with this matter of strength of hull, of the destroyer class especially, it is much to be regretted that alarm was some few years ago created by irresponsible and untechnical writers—some of them neither naval or expert, though called naval experts—who argued from wrong premises and preached ideas which, if followed, would cause a most useless and wasteful expenditure of public money.

In the Chilian-Peruvian war, 1879-1881, spar torpedo boats were employed by both combatants. The blockade of Callao was commenced at about 5 a.m. on April 10th, 1880, by the Chilian Thornycroft torpedo boat *Guacolda*, an 11-knot craft, attacking the Peruvian man-of-war *Union*, which was surrounded by timber booms. The boom was shattered, but the small-arm fire drove off the torpedo boat.

The gallant but unready Peruvians only had makeshift craft, which did good work, in that they caused the Chilian blockading fleet to proceed to sea daily at sundown and spend the night in a safe offing, the entrance to Callao Bay being patrolled by Chilian torpedo boats. In the middle watch of

May 25th of that year a Peruvian spar torpedo launch, some distance from the shore, was surprised by the *Guacolda*, which chased her. The 18-knot Yarrow boat, the Chilian *Janeques*, also chased and overtook the Peruvian, the result being that the Chilian was torpedoed and sunk, and the Peruvian foundered when returning. Gallant Peruvian Lieutenant Galves badly wounded and seven of his crew of sixteen were rescued by the *Guacolda*; his surgeon, Uriarte, and eight men were killed. The surgeon was given an impressive public funeral in Lima. The Chilian loss was two men, the remainder escaping in boats seized from a vessel lying in the out-of-fire zone.

It will be remembered that this war was remarkable for the destruction of two vessels by torpedoes. In one case the transport *Loa* captured a coasting barge adrift full of vegetables, fruit, poultry, and other good things, which were heartily welcomed by the crew, who had a long diet of sun-dried beef and biscuit. On examination of the barge it did not show any explosives; but as the welcomed cargo was unloaded from the barge alongside the *Loa*, mechanical arrangements were such that when the weight in the barge had been very much reduced an explosion ensued, which blew in the side of the *Loa* and sank her with loss of life of 145 men of a crew of 200.

Another case was the *Covadonga*. She had been captured from the Spaniards by the Chilenos many years before by a deception, and another deception was her doom. This vessel captured a little skiff which was adrift, and, in hoisting her on board, the *Covadonga* also was dynamited and sunk. There were moving torpedoes supplied for that war, but they did no destruction. They were of the "Awash" principle,controlled from a station by wire. They were not regarded as satisfactory by the Peruvians. In one case it is said that one got out of control and returned towards the Peruvian ship *Huascar*, from which it was being operated,and only the gallantry of Lieut. Diez Canseco of that ship saved her, he jumping overboard and diverting the torpedo. The Peruvian Admiral Gran was so disgusted by these weapons that he landed them and buried them in the public cemetery at Iquique.

Later, in 1891, in those South Pacific waters the Whitehead was used. In one case a Whitehead was fired from a picket boat at a large Chilian mail ship, but did no damage, being found next morning minus its head, no explosion happening. But the ironclad *Blanco Encalada* fared worse. Some six Whiteheads were fired at her, of which one only seems to have struck, and its charge of 58 lb. of guncotton knocked a hole in her side 15 ft. fore and aft by about 7 ft. high. She sank in less than five minutes, losing 150 officers and men. Of the eleven officers missing six were engineers. The only engineer who was saved was washed up one of the ventilators. Later on in that war a spar-torpedo picket boat was destroyed by the explosion of her own torpedo, and five men were blown up or drowned.

In 1893 torpedo warfare was conducted on the Brazilian coast. The ironclad *Aquidaban* was struck forward by a fish torpedo having 125 lbs. of guncotton, which caused the two forward compartments to fill but did not sink her. In this case one hit in four discharges was given.

The precursor of the destroyer class was evolved about 1884. Hitherto the plan had been to give torpedo boats an alternative armament, so that half of the boats might be employed for firing torpedoes, the others acting as torpedo-boat destroyers, the boats armed by the small guns resisting attacks of torpedo boats. But as the speeds would be about the same in each, it is evident that neither could decrease the range of the other when attacking or escaping. Perhaps the first approach to the destroyer was the production of Messrs. John Samuel White, of Cowes. This was a vessel added to the British Navy in 1885. She was 150 ft. long, and so larger than boats hitherto in use, which were single-screw boats. She was fitted with twin screws and with more power—a larger vessel and better sea boat and of higher sea-speed than they. In the British Navy she did good work as the commodore of the flotilla.

Another vessel, 200 ft. long, 2,900 h.p., named the *Sea Serpent*, was also laid down by that firm in 1885, and obtained a speed of 23·8 knots with a load of 20 tons, and 21·5 knots with a load of 90 tons. The curt term "destroyer" not then being in use, she was termed an "exaggerated torpedo boat." At that time "Rattlesnakes" were in fashion, but the "Exaggerations" are now a survival of the fittest.

Her speed was a little disappointing, the shallow water of Stokes Bay not favouring speed. Also, if subsequent knowledge as to material of propellers had been available, she might have obtained 25 knots, and so fulfilled most of the conditions which were afterwards required in torpedo-boat destroyers. She was eventually acquired by the Chinese.

Messrs. Yarrow & Co. constructed the *Kotaka* in 1885 for the Japanese Government. She was 170 ft. long and fitted with twin screws, and practically an armoured destroyer, being fitted with armour 1 in. thick round the machinery and boiler compartments sufficient to resist the fire from the torpedo boats as then armed. This vessel led the attack, with other torpedo boats, on the Chinese ships at Port Arthur. It is not generally known that in that Japanese attack that the weather was so bitterly cold that it actually froze the sea-sprayed torpedoes in their carriages, and that of eight torpedoes which were attempted to be fired against the Chinese men-of-war only two were actually fired, the others being frozen in their tubes, and could not be ejected till thawed out. Perhaps in reference to this incident I may suggest that the recent operations in China seas have also been very much influenced by the freezing weather, for engineers well know that compressed air in escaping is frozen, and that where compressed air is used for operating machinery the exhaust pipe must be very short, and to carry a Whitehead charged with compressed air which will rapidly assume the temperature of the surrounding atmosphere, which may be initially several degrees below freezing point, this expanded air exhausting from the Brotherhood engine through a long hollow propeller shaft, may cause such freezing in that shaft as will decrease the speed and range of the torpedo, and perhaps render it inoperative.

About 1893 the British Navy gave orders for torpedo boats which were to be of higher speed than hitherto; and not only of higher speed, but to obtain this speed carrying a greater load than hitherto. These boats were Nos. 88 to 97 of our Navy, constructed by Yarrow, Thornycroft, and White, of Cowes, and one of them by Laird, of Birkenhead.

Some were fitted with locomotive boilers; those by Thornycroft with water-tube boilers; one by Yarrow also with water-tube boilers. Trials of these vessels showed that certainly for this service the water-tube boiler was far preferable to the locomotive boiler.

About this time also the "torpedo-boat destroyer" was evolved. Practically these destroyers were given just double the power of the latest torpedo boats in being. The hulls were built round them with due regard to the armament to be carried and the weight to be carried on trial, and also, of course, with due regard to the fact that they would be expected to be more sea-going. The draught was restricted to 5ft., giving immunity from destruction by Whitehead torpedoes, which are erratic and inclined to "porpoising" if set to run at 5 ft. depth or thereabout. They were armed with guns and Whiteheads, and so were calculated not only to destroy torpedo boats, but battleships.

This batch of destroyers, originally confined to Yarrow, Thornycroft, and White, was afterwards spread all over the country. They are fairly well known to most engineers. These expanded an industry which required high technical knowledge and superior handicraft.

Observers of the building of these hulls will note that with the very thin plates as used it is absolutely necessary to manipulate those plates to give the requisite strength to resist any alteration of form. A 5-lb. plate—that is, $\frac{1}{8}$ in. thick—is a very limp object when received from the cogging mills, but after it has passed the levelling slab and been levelled it becomes very stiff; and its actual tensile strength is not in any way altered, while its strength to resist bending is very much increased, the levelling or "planishing" rendering the plate extremely stiff; and it is this knowledge of building among the workmen employed which is noticeable in various vessels, those built by longer experience certainly being stiffer and better vessels than those not having that experience.

This paper is not intended to enter into the dimensions of scantlings employed, but perhaps it would be interesting to note that the 27-knot destroyers built of galvanised mild steel plates, with tensile strength 30 tons, the thickness of garboard strake is $6\frac{1}{2}$ lb.; sheer strake, 9 lb.; deck-plating, $6\frac{1}{2}$ and $8\frac{1}{2}$ lb. per square ft.

Afterwards a harder and stronger steel was used, which was more difficult to manipulate. This increased the cost of building but permitted lighter scantlings, comparatively. This latter steel was 40 tons tensile strength. Its riveting was much more difficult with the hard rivets used; they required more knocking down, and the riveting was not so comely and smooth.

These 27-knot destroyers were of various lengths from 180 to 190 ft. and horse-power varying from 3,700 to 4,800. It may be mentioned that there was great public interest aroused not only by ordering of these boats, but some men who seemed to have knowledge actually expressed their views as to the speed being unobtainable; and in one case simultaneously with such assertions that the speed was not obtainable there came the actual news that the *Havock*, by Yarrow & Co., the first of the destroyers, had obtained a speed of 26·2 knots. This vessel (length 180 ft., beam 18 ft. 6 in., depth 10 ft. 6 in., and displacement 240 tons) showed what could be done with least displacement, with least power, and with the least coal consumption towards carrying the armament required at the speed required. The larger vessels carrying the same armament with greater power and with a much greater coal consumption also gave the same speed of 27 knots with the same armament; and though it may be advocated that the large vessel has advantages over the smaller one, primarily in the matter of habitability, I would put it that the vessel doing the work on the least displacement and with least coal consumption is certainly a triumph of brains if nothing else. I also think that such a vessel should initially cost less than a larger one—certainly she should cost less for maintenance.

One important improvement introduced by Mr. John Samuel White, of Cowes, prior to the year 1883 is a feature in all subsequent torpedo boats and all destroyers. This is the cutting away of the "dead wood" at the stern, thereby securing a manœuvring power that would otherwise be scarcely possible, coupled with a more efficient feeding of the propellers so essential to high speed.

It is well known how that from 1891 to 1896 the trials of the 27-knot destroyers were chronicled in the newspapers, and each seemed to go one better than the other.

In the matter of speed the highest on the measured mile was given by the *Boxer*, by Thornycroft, the speed obtained being 29·1 knots with 4,490 h.p. In the matter of coal consumption the lowest was the *Hornet*, by Yarrow & Co.; she burned 9,322 lb. per hour, giving 27·6 knots, the highest burning 17,122 lb. per hour, giving 27·4 knots.

All these trials were full of very interesting incidents, and one thing they taught was that the very best material, and certainly the very best workmanship, was indispensable, coupled, of course, with the most talented brains in the drawing office. For the "spoke-shaving" was such that between success and failure was almost at times just the thickness of a sheet of paper.

In the matter of machinery trials numerous incidents might be mentioned. I should like to say this, having observed some of the trials—and I am not alone in my opinion—that the way in which youngsters, apprentices and young journeymen, tackled the duties which were placed upon them, and tackled them with a knowledge that occasionally there were accidents which might produce maiming, was certainly good to observe from a national point of view.

Better pens than mine have told of the fair-haired public school boys and others doing their duties among the machinery in a most laudable manner, including the son of a belted knight in the stokehold oiling the fan engines, and certainly covered at the end of the trial with a coating of oil and coal dust perhaps weighing 2 lb. to the square foot of flesh and clothing; and I might also mention one case of several apprentices, including a "premium," did the coal trimming in the bunkers for a long trial rather than forego the trial by waiting for coal trimmers who did not turn up. So much for the personal element.

It was my very great honour to take Mr. Rudyard Kipling into the engine-room of a Thornycroft destroyer on trial. He seemed to be much impressed by seeing engines with 18 in. stroke doing their 400 revolutions in an apparently small space, the eight connecting rods each making their 800 swings a minute, faster than the eye could follow. He said that he had come to the conclusion that the youth who wished to become an engineer was prompted not so much by love of pelf, but from seeing the creations of engineers do such work as this and to be identified with it. He also compared the engine-room with the 500 bewilderments of ill-livers deceased, as preached in some tenets.

I might mention many incidents which occurred during these trials, showing that high-grade workmanship was required, and also showing how negligent workmanship cost many golden sovereigns to the shipbuilders.

Boilers, engines, condensers, shafting, and screw propellers, all gave little troubles, and all gave valuable pointers for improvement in the future.

As regards the boilers, it was proved that the locomotive boilers gave excellent results up to a certain grade of coal burning, and at slow burning they were very economical, but the tube ends could not be depended on to remain tight. These troubles were not experienced in water-tube boilers, which were of various systems, some with straight and some with curved tubes. Practically all showed their superiority over any type of locomotive boiler which had hitherto been used when forced to the utmost extent of their coal-burning capacities.

Nevertheless the locomotive boiler gave 1 h.p. for 1·33 sq. ft. of heating surface, as against a maximum of 2·58 sq. ft. in a water-tube boiler.

Principally incidents in the engine room were due to inefficient lubrication.

It is generally well known that the oiling was supplemented by men with syringes, and there was no stint of oil. So large a quantity was used, which, if named, might cause a great deal of horror to those who are wont to be economical in the engine-room. I can only, perhaps, mention that in a foreign destroyer, modelled something after the English pattern, the engine-room department is credited with having used 450 gallons of oil in three hours, so that at least they must have been pretty attentive to the oiling. Our records do not chronicle such a high consumption.

If the white metal of the crank-head at any time ran, it was very advisable to stop the engine dead, as otherwise unpleasant consequence ensued.

Generally it may be said that all oiling arrangements were made with a view of keeping the oil in the journal. That is to say, the oil channels were stopped short at the ends of the bearings, and the liners between the brasses were in some cases made to fit close, if not touching the crank-pins or journals, so that the oil could all be retained between the rubbing surfaces, and only weep away at the ends.

Some trouble was experienced with surface condensers, principally in the matter of split tubes, some splitting before, some splitting during, and some splitting after a trial—as a consequence producing boiler trouble from brackish feed.

I think it may be said that the troubles of water-tube boilers arise primarily from faulty surface condensers, and had satisfactory surface condensers been in vogue when water-tube boilers were first adopted there is no doubt that much public discussion on the great water-tube boiler question would have been avoided.

The form of surface condenser used in destroyers is well known, a few having double flow of circulating water and the majority having a single flow. My opinion is that those having the double flow—that is, having short tubes—have given less trouble than those having the single flow with long tubes. Even the most hypercritical inspections and testings of condenser tubes before building the condenser failed to obviate all trouble.

There is such a little difference between those tubes which act well and those which act badly that it can hardly be detected. Toughness, combined with requisite hardness, is what was aimed at, and in some cases hardness verged on to brittleness, and brittle tubes became split.

The quality of the material may be fairly well tested by taking a short piece and cracking it in a vice. Those which compress to a certain limit and only crack in two places give better working than those that compress and crack in three places. A good tough tube of the required hardness should be capable of being flattened with water-pressure test of 300 lb. inside of them without fracture, and pieces flattened in the vice should bear a certain amount of flattening without fracture, and the alteration in dimensions at fracture should point as to the quality of the tubes.

It is well known that in the larger ships of His Majesty's Navy it has become a practice to fit two condensers to each engine, so that if one becomes defective and gives salt feed it be may shut off and rectified, the remaining condenser giving a fair amount of power, though reduced.

I look forward to the time when our present Hall's surface condensers will be abolished, and I have had an opportunity of seeing an invention towards this end. By the kindness of Messrs. Caird & Rayner, I have viewed a new type of condenser, which will enable condensers being built in groups each of 1,000 h.p., and each and every one of these may be disconnected any time for examination and repair, whereas with the present surface condensers examination of the thousands of square feet of internal and external surfaces of the tubes is almost an impossible operation. With the condenser at Caird & Rayner I note that such may be taken apart in a few minutes, and the whole of the internal and external surfaces of the cooling surface examined, corrosion noted (if any), and the surfaces cleaned and rendered efficient.

As well as split tubes in the torpedo-boat destroyers' condensers, we have had occasionally ferrule slackening, due, no doubt, to vibration. This was overcome in some cases by the invention of the Thornycroft ferrule. Of all the systems, however, I prefer the Yarrow system, in which the tube goes right through the ferrule and has a small wire guard to prevent slackening of ferrule, and it has the great advantage of giving an unimpeded flow of a full bore of water through the tube. The ordinary ferrule now in use would not give this, as there must be some eddying at the entrance of the tube.

Occasionally there were twisted shafts, about which there were many opinions, some holding that the shafts were not strong enough, and some holding that the longitudinal vibration of the vessel tended to seize the shafting in the bearings, and so produced twisting.

Most valuable lessons in fatigue of metal were learned. Stresses which, if once applied, would give no indication of ultimate fracture were found to produce fracture after thousands of such stresses. These were principally by bending.

I may mention that in bolts with reduced shanks, which were supposed to stretch a lot before breaking, I never saw any such stretching, the bolts generally fracturing near the end of the screw thread. Had there been such stretch of material, some disasters might have been averted.

But above all those trials gave most valuable lessons in screw propellers. It had been customary in torpedo boats and prior boats that propellers should be of forged steel, and the substitution of manganese bronze gave the then marvellous result of an increase of speed of about two knots an hour, this increase being obtained by using a manganese bronze propeller of practically the same dimensions as those of forged steel, the figures being that at 384 revolutions per minute a forged steel propeller gave $24\frac{3}{4}$ knots. The manganese bronze one at the same revolutions gave 27 knots in the same vessel at the same draught.

Other items as to the various ratios to be used—namely, the ratio of pitch to diameter, and the area of the blade as compared with the area of the propeller disc—also became apparent, showing the direction in which improvement might be effected, as well as of other suitable dimensions.

Generally the knowledge gained was that each time the propeller was fined there was a gain, and each time the propeller was decreased in diameter, retaining the same pitch, there was a loss. To a certain ratio the area of the blade could be increased with advantage, provided the engine would turn the propeller round. Practically, whenever the slip was decreased by fining the propeller, or perhaps by fining and increasing its diameter, or perhaps by fining, increasing its diameter, and putting more area of blade, there was a gain not only in the speed, but in the coal bill.

Vibration was found to be modified by the propeller used, by the position of the blades with respect to the cranks, and by pitch deviations in each blade. The speed of "No Slip" was important.

These experiments showed that if only the indicated horse-power were required, the propeller could be fitted which would give perhaps 20 per cent. more horse-power than an ordinary propeller. If the speed were required, a very different propeller would be adopted; but if speed coupled with a small coal bill were required, the propeller between these two would give the best results. Also that the proportions of the propeller influenced the coal per i.h.p., the coal per i.h.p. propeller lacking in propulsive effect. The least immersion of the propellers gave the best results both in speed and coal bill; and the distance apart of twin-screw propellers was of moment.

I may give comparative instances of propellers showing how improvement was given: (*a*) Diameter increased 4 per cent., area increased 19 per cent., pitch not altered, the coal bill was decreased 27 per cent. at equal high speeds; (*b*) Pitch fined 6 per cent., no other alterations, gave the same high speed with 10 per cent. less indicated horse-power and $17\frac{3}{4}$ per cent. less coal bill; (*c*) Diameter increased 2 per cent., pitch fined 9 per cent., gave $\frac{3}{4}$ knot more speed, and coal bill decreased 40 per cent. at the same high speed obtained by the first propeller.

I suggest that the torpedo-boat destroyer experiments might be regarded as model experiments on a very large scale, of which the expense was borne by the contractors, and the result is that many larger ships, both naval and mercantile, are now having much more efficient propellers fitted—perhaps from this experience.

The words of Sir W. H. White uttered twenty-one years ago were prophetic: "In these torpedo vessels we have no doubt the pioneers of future navigation at higher speeds than have ever been attained."

The load carried on these 27-knot destroyers was 30 tons. This was a task heavier than had hitherto been the practice in any navies.

In this matter of propellers it will be thus seen that when 27-knot destroyers are loaded down to their war-service draught their trial trip propellers are practically unsuited for that draught, and the loss of speed which ensued, consequent on the choking of the propellers due to increased draught and displacement, was noticeable, and gave some disappointment.

I am of opinion, however, that all 27-knot destroyers could even now obtain better sea-speeds if they could be fitted with propellers different to their original ones. But this is a very complicated question, as it will be seen that a propeller which may enable the engines to do their speed, we will say, of 400 revolutions a minute with a fully loaded destroyer, may let those engines run away in an undesirable manner if she be lightened to nearly empty bunkers and magazines. New deep-draught propellers provided by the original constructors of the vessels would doubtless give increased speed with lessened coal bills, which would soon pay for this small outlay.

Those 27-knot boats gave an indication that the depth of water in which measured mile trials were run was of very great moment in results obtained. Practically in the same vessel run on two different measured miles, one locality would require fewer revolutions per knot, and the engine not so much loaded as the other. In this respect there is no doubt the measured mile at Wemyss Bay is the best. Those destroyers which obtained their speed in shallow water have generally given better sea results than those which obtained their speed in deep water.

Experience gained in the 27-knot destroyers was of great use when faster ones of 30-knot speed were required.

During the construction of the 27-knot destroyers Messrs. Yarrow & Co. produced the *Sokol*, a destroyer for the Russian navy. This vessel, 190 ft. long by 18 ft. 6 in. beam, obtained a speed of $29\frac{3}{4}$ knots in the shallow water of the Maplin Sand measured mile, and so proved herself superior to all British destroyers. Probably if she had run at Wemyss Bay she would have approached 31 knots. She was the precursor and pattern of a large number constructed in Russian yards.

The terms of the trials for the 30-knot destroyers were very much amplified, for whereas in the former 27-knot destroyers there were no reserves of coal consumption, in these it was intended that $2\frac{1}{2}$ lb. per i.h.p. per hour should be a standard. This was much less than the average of the former 27-knot destroyers. Messrs. Thornycroft & Co. obtained the first record for 30 knots in a British naval vessel at the Maplin Sands in the *Desperate* in April, 1896. The vessel was loaded as per contract and ran this trial in a stiff gale with all wind resistances, boats, etc., in place.

Various contractors throughout the kingdom followed on, and in most cases fulfilled the contract without very much exertion.

There were, as before, a few incidents arising from unforeseen circumstances, but take it all round the 30-knot destroyer gave less trouble than prior ones.

Two other destroyers of higher speeds were also produced, the *Albatross* by Thornycroft, and the *Express* by Laird. The former obtained a speed of $31\frac{1}{2}$ knots with indicated horse power of 7,700. This was at the Maplin Sands, where the drag of water, due to shallowness, became very apparent. The latter was tried at Wemyss Bay.

The 30-knot destroyers were followed by a reaction in favour of stronger vessels, now known as the "River" class. These vessels are of about 550 tons displacement, 200 to 230 ft. long, and horse-power 7,500. They are much more costly than the 30-knot destroyers, and though their speed of $25\frac{1}{2}$

knots was obtained in deep water, I am of opinion that, as before mentioned in my remarks, if the 30-knot destroyers had different propellers fitted they would outrace all the "Rivers" at war-service lading with a smaller coal bill.

The following table from a Parliamentary return gives information of the "River" class.

I should mention that the latest torpedo boats, Nos. 89 to 117, were tried at their deep-sea draught, and obtained speeds of 25 knots, with an average power of about 3,000 h.p. These vessels are superior to earlier torpedo boats, and being 165½ ft. long and about 9 beams long, are good sea-boats.

The newspapers tell us that a destroyer of 33 knots is again contemplated, and it will be apparent that very high power would be required. The following table will show you that in the 20-knot boats of the eighties it required 10½ h.p. per ton of displacement, and so on through each batch of vessels as they became larger.

In conclusion, I may be permitted, perhaps, to express a few opinions on the utility of these vessels. As I have said, they appeal to marine engineers, because the Whitehead is a marine engineer's invention and is a weapon which all marine engineers can well manipulate. I think that if a coast volunteer corps could be established, largely composed of young mercantile marine officers, both deck and engine departments, for service in these vessels as coast defenders, not only the manipulation of the machinery and of the Whitehead, but also the firing of the guns, could be entrusted to such volunteers, and the pure navigation of the ships and boat-work done by men of whom there are so many round our coasts as the deck officers of coasting steamers, trawlers, and fishing-boats, who not only know the coast thoroughly, but whose inner framework of body has been habituated to the motion of the seas of the Channel.

I suggest that the whole of our coasts could be defended by torpedo-boats and destroyers, leaving the battleships to do their work for the high seas.

It has been said that the war in the Far East has proved the utility of the battleship, and that only. But it must be remembered that Admiral Togo had to nurse his destroyers and do the greatest injury with the smallest risk, so that had he had more destroyers, and so been enabled to risk more, we might have heard a different account of the deadly weapon the Whitehead.

At all events, I think that, say, 1,200 men should be better utilised in craft of the destroyer and torpedo-boat description than putting the same number in a large battleship, which might be sunk by even one of these craft; and we have very high authority stating that four such craft, costing a fourth the price, and manned by a fourth of the crew of a battleship, would doubtless sink that battleship. And surely they would prevent her approach to our shores near enough for her guns to range us. Moreover, torpedo-boats and destroyers remain war-worthy longer than battleships.

In these days, when conscription is being preached, it is well to consider alternatives. Our thickly-inhabited islands have 3,740 knots of coast line. Allowing one destroyer or sea-going torpedo boat to each ten knots, we find that 200 destroyers and 174 torpedo boats, manned by twenty-one thousand sea-stomached young mechanical engineers and small-craft men, would give national mental repose at a cost of twenty millions sterling as a preliminary outlay and about two millions a year for wages and maintenance.

Is this as good as conscription? Would not young Britons prefer to serve in and be slaughtered in a destroyer rather than a battleship? Indirectly, our nation should gain by the technical education imbibed, both in constructing this Ban Dog fleet and also in service therein. "'Ware the Ban Dog," so long potent in our island life, would suggest a motto for such a corps—W. T. B. D. I think that such a corps raised and managed with tact, with pecuniary inducements sufficient to tempt the best of our young mechanical engineers, and with the view that they are the ready-made sea-fighters, which latest accounts tell us it is now desired the mass of the seamen of the fleet should become, would much attract the youth of these islands. For we cannot blink the fact that wars of the future must depend more on mechanism than on individuals.

At all events, we know that the wolf prefers lamb to porcupine, and the oldtime behest should ever be before us: "It is the Navy whereon, under the good providence of God, the safety, honour, and welfare of this kingdom most chiefly do depend."

DESTROYERS "RIVER" CLASS.
Contract speed $25\frac{1}{2}$ knots.

Destroyer	By whom built	Speed obtained on full speed trials Knots	Coal per I.H.P. on the high speed consumption trial Pounds	Air pressure on full speed trial Inches
Welland ...	Yarrow & Co. ...	26·2	1·65	1·8
Usk	,, ...	26·1	1·77	1·6
Teviot ...	,, ...	25·9	2·07	2·0
Ribble ...	,, ...	25·8	1·57	1·6
Exe	Palmer's Co. ...	25·6	2·11	2·4
Waveney ...	Hawthorn Leslie ...	25·6	2·19	3·2
Derwent ...	,, ...	25·7	2·24	2·8
Erne ...	Palmer's Co. ...	25·6	2·25	2·5
Dee	,, ...	25·5	2·28	2·6
Ettrick ...	,, ...	25·6	2·33	2·6
Cherwell ...	,, ...	25·6	2·34	2·7
Kennet ...	Thornycroft & Co. ...	26·0	2·39	3·8
Jed	,, ...	25·7	2·46	4·0
Itchen ...	Laird Bros. ...	25·6	2·46	4·3
Blackwater ...	,, ...	25·7	2·62	5·3
Arun ...	,, ...	25·7	2·68	4·4
Foyle ...	,, ...	25·6	2·79	4·4
Eden (turbine)	Hawthorn Leslie ...	26·2	tons. cwt. 7 9 per hour	3·3

LENGTHS, WEIGHTS, AND SPEEDS.

Vessel	Length Feet	Speed Knots	I.H.P. per ton of displacement	Propellers
Miranda	$45\frac{1}{2}$	16	14·7	Forged steel
Torpedo boat ...	113	20	10·6	,,
,, ...	125	21	10·6	,,
,, ...	130	22	12·9	,,
,, ...	140	23	15·6	,,
,, ...	140	23	13·0	Manganese bronze
,, ...	$165\frac{1}{2}$	25	15·0	,,
"River" class ...	220	$25\frac{1}{2}$	12·6	,,
Destroyer ...	185	27	15·7	,,
,, ...	215	30	20·0	,,
,, ...	228	$31\frac{1}{2}$	21·1	,,

At the conclusion of the paper a large number of views were shown, and, by means of the cinematograph, battleships, torpedoes, submarines, and other craft, in progress through the water, were exhibited, including a fleet in action.

A cordial vote of thanks was given to Mr. Harding, and discussion on the paper was adjourned.

DISCUSSION

AT

58 ROMFORD ROAD, STRATFORD, E.,

ON

MONDAY, MARCH 20th, 1905.

CHAIRMAN :

MR. W. LAWRIE (MEMBER OF COUNCIL).

The CHAIRMAN : Those who were present last Monday evening will have a clear recollection of the very admirable paper which we had from Mr. Harding. The eager interest with which our members followed that showed, I think, that they fully appreciated Mr. Harding's labours in putting such a paper before us. We have met for the purpose of discussing the paper, and I hope the members will rise without being called upon. If they cannot altogether criticise the paper, they can ask questions, and I have no doubt Mr. Harding will be pleased to reply.

Mr. W. McLAREN (Vice-President) said their members were not torpedo experts, yet they might be able to elicit further information by asking questions. He hoped Mr. Harding would not take it amiss if they asked him some rather pertinent questions. The author seemed to be rather in favour of the torpedo boat for coast-defence purposes. In that respect he was at one with him. It had been argued over and over again by all conditions of experts whether we should adopt such a light, small ship in place of the enormously weighty ironclad. No doubt the ironclad had its place as well as the torpedo boat. One difficulty with the torpedo boat was that she could not travel so far from her coaling port except at slow speed. They had an example of that disability before them at the present time in the case of the Russian and Japanese fleets. So far as he was able to judge, these two fleets were about 3,000 miles apart, and they seemed to be staring at each other across that stretch of sea. He would like to call Mr. Harding's attention to the paragraph on page 6 which referred to the upsetting of the theories contained in some text-books regarding the size and weight of vessels and their dimensions. He thought it was generally recognised that our merchant ships, if they were to pay, could not be placed in the same way, as regards lightness, as torpedo boats, unless they were to carry passengers alone. To carry cargo, stiffness was necessary to get speed out of the vessels. That was illustrated very forcibly by the torpedo-boat engines compared with the merchant-service engines, showing the enormous weight of the latter by comparison. In merchant steamers the engines weighed from 260 to 280 lb. per i.h.p., whereas torpedo-boat engines only weighed 35 lb. per i.h.p. The author had also referred to the Brazilian ironclad *Aquidaban*. The episode which took place in 1893 or 1894 was only playing at warfare. He was on the Brazilian coast at the time, and had stayed up until early morning in order to see the *Aquidaban* go before the forts, which were about a quarter of a mile apart. She cleared from there with sixteen men on deck, and the captain was on the bridge surrounded by bales of cotton. He went on board twenty-four hours after her escape. They made more noise in heaving up the anchor than one would expect in real warfare, as they could be heard all over the harbour. The *Esperanza* came through with her speed safely. The escape valve of her low-pressure cylinder, however, was knocked off. He would like to thank Mr. Harding personally for his contribution to the Institute. It was something new for them, and he hoped some of the other members would be able to draw further information on the subject from him.

Mr. JOHN MCLAREN (Member of Council) said Mr. Harding had treated the subject so exhaustively as to leave very little to ask. With regard to the steering of torpedo boats, the author had remarked that it was a point in naval architecture that the boat should not list when put hard over, turning in her own length. It would be of some value if he could further enlighten them on that point. Although the paper did not touch upon the submarine, he would like to refer to the manholes of those craft. Supposing something went wrong with a submarine, and she floated, was it possible for her crew to get out? How long would it take the men to get through that hole? It had often struck him that there should be some method of releasing the whole hatchway. Were there any means of doing that?

Mr. Alfred Cooke (Member) said he would like to ask Mr. Harding a question with regard to the modern torpedo boat. Were they all fitted with water-tube boilers, and had the locomotive boiler been entirely superseded? Also, what temperature did they get in the engine-room and stokehold when going with full power?

The Chairman said that after looking over the paper he noticed that the cases they had of torpedoes taking men-of-war were mostly in the Chilian-Peruvian war. He was wondering whether they could not have some of the results of what had been done in some more recent war. That was to say, whether the torpedo, when fired by a Western nation, or manipulated by a Western nation, had really been effective or not. He did not know, but, like most of the members, he was under the impression that the torpedo had not come quite up to expectation. Was it a fact that the torpedo nets round about the vessels offered too much obstruction to the torpedo to get at the ship, or was it that those on board the man-of-war were too much alive to be caught napping? In the case of the *Niger*, to which the author had referred, they could not have been keeping a very good watch, when they allowed the Chinese to tow a junk down the river and explode it right under the war-vessel's bows. They would think that with the torpedo, in its present state of perfection, they would have a fairly good chance of striking a battleship. One thing that had struck him in the pictures that had been shown on the screen was the tremendous amount of smoke coming out of the funnels. It did not occur to him that it was Welsh coal that was being used, and he was surprised to see that. It seemed almost impossible to get so much smoke from some of the craft. In regard to the question of condensers, Mr. Harding had told them that if Hall's condensers were brought to better perfection they would have less trouble with water-tube boilers. It seemed to him that Hall's condenser was good enough for any purpose. They had been informed that men-of-war were supplied with separate sets of condensers, so that if one went wrong they could still go on at reduced speed. The conditions on a man-of-war could hardly be as trying as on a torpedo boat. The question was whether in getting a knot or two more speed out of the torpedo boats they had not reduced the standard beyond what might be necessary. They knew that with a torpedo boat it was necessary to deliver an attack and then clear off, but if they went to the extreme of having the shaft bending he thought it would be better to do away with a little bit of speed and have more reliability. In the torpedo-boat trials reference had been made to the difference in speed when the trials were run on the Maplin Sands or at Wemyss Bay. He did not think that the draught of torpedo boats would have been sufficient to afford an explanation of that difference. They knew that with vessels of considerable draught there might be an appreciable difference in speed, and no doubt it made a little difference in torpedo boats, and he would like to know how much. With regard to propeller trials, he thought the results of torpedo-boat trials coincided very much with what had been found in merchant vessels. Many years ago it was customary to make propellers too coarse in pitch. He knew one superintendent who had made his name by fining down the pitch, and thereby he obtained much better results. It seemed to him that when they designed a propeller for a torpedo boat it would be much like that in the merchant service. He had no doubt those propeller trials must prove very useful in settling the dimensions of propellers generally, although, considering the speed of the engines, he did not think it quite applied to what would be used in the mercantile marine. He remembered hearing of some trials of Japanese torpedo boats, and it was then stated that they got more speed in Japan than was obtained on the trials. He was wondering whether Mr. Harding had heard of any such cases, and, if so, what was the cause? He had heard it put down to the fact that the fuel was better. Then, in regard to trials for war and for ordinary service, he had heard that two different propellers were required for the two different trials. Why was a different propeller needed for light draught? When the torpedo boat had got her full load on board she would have a greater draught than on ordinary service, but it seemed to him that she ought to be run in the conditions on which she was to work when in action. Thus one propeller would be enough for the work she was supposed to do. Mr. Harding, at the close of his paper, had referred to the guarding of our coasts by torpedo boats. That, he thought, was a good idea, but he was of opinion that those light craft ought to be able to travel a little further away from the coast. If any of our neighbours on the other side of the Channel wanted to steal a march on us, he thought it would be a very good thing if some of those light torpedo boats could get over and try and have a look at them before they sailed away from their own port. We might not give them all the "jumps," but it might upset their nerve a little bit. Then came the question whether the torpedo boats or the mines were the best. Our foes would only attack certain ports on our coasts if they wanted to land, and that would reduce the necessity for watching the coast to a certain radius. What was the range of action of the torpedo boats, and how far could they go away?

Mr. G. SHEARER (Member) said he agreed with the views expressed by Mr. Harding in his paper. His proposed system of defence for the coast in general was, he thought, one of the best methods he had ever heard of. It was both effective and economical. From the experience that the Japanese had had, the torpedo, apparently, was not quite so effective as the mine. He did not think there was an incident of putting either a cruiser or a battleship out of action by a single torpedo, but he thought they had all read that the mine had proved most effective; in fact, it had, on occasions, entirely collapsed the ship. That, of course, both as regards torpedo or mine, would entirely depend on the portion of the ship that was affected. For example, take the case of a big battleship or cruiser. If she were punctured near the boilers, there were watertight compartments there in all fighting ships. If one boiler-room were disabled, the other, as a rule, was quite good enough. But it would be a very serious matter if she were struck in the engine-room, or, worse still, if in the magazines. Of course, they required battleships, cruisers, and scouts for deep-sea work, but for the protection of the coasts he did not think there was the slightest doubt but that the torpedo-boat destroyer was the engine of destruction for that service. Mr. Lawrie had referred to the smoke emitted from the funnels of the torpedo boats. In the pictures which had been shown the boats were not in action, and, so far as his experience of torpedo boats went, it was not Welsh coal that was used in many cases. For instance, on the Clyde it was always Scotch coal that was used on the trial runs, and, of course, they all knew the amount of smoke that the Scotch or Newcastle coal gave off, and that, he thought, accounted for some of the smoke shown in the pictures. Regarding condensers, he did not see why there should be any more trouble with the condensers of a torpedo boat or destroyer than with the condensers in an ordinary merchantman, battleship, or cruiser. There was less pressure on condensers in torpedo boats than on other classes of ship. The circulation of the water in the torpedo-boat destroyer condenser was purely automatic. The inlet had a small scoop, which inclined forward, and another in the discharge, which looked aft. Consequently the speed of the vessel drove the circulating water right through the tubes without any mechanical action, and without the aid of any engine. There was a circulating engine, but it was only used whilst the boat was lying at anchor. Personally, he had not had any trouble with the condenser tubes in torpedo boats. He had been on board some of those craft when they were running their trials, and a tube might give way here and there; but that was simply a case of a defective tube, which they might find in any condenser, and he did not think it was simply because it was a tube in a torpedo-boat condenser. The vibration at full speed was something enormous in the torpedo boats which were fitted with reciprocating engines. He had not had experience of the turbine-propelled boats, but, so far as they could gather from the reports, the vibration in those turbine boats was comparatively slight He thought it was a good idea, in case of accident, to have two or more condensers in small sections. That would certainly facilitate matters during action, which would be a very important point if the condenser were to get out of working order then. But it was always entailing more labour, more wor , and more expense to put in condensers of that kind, and the question was, was it worth it? Was it better to go to that expense with the ship, or to risk the ship under ordinary circumstances? Regarding the load-line, he thought the ordinary destroyer was run with something like thirty tons deadweight on the trial trips. He quite agreed with Mr. Lawrie in every way when he had observed that on the trial trip the boat ought to be loaded down to her fighting trim. He thought it was absolutely necessary for those boats—or, indeed, any warship—to run their trial trips in fighting condition with everything on board. With regard to the lines of a fast torpedo-boat destroyer, he had found that when a torpedo-boat destroyer was running at full speed her lines were entirely changed from what they were in her normal condition. In one instance which he might mention he got into very heavy weather with a destroyer. That vessel was, in fact, the largest destroyer afloat at that time. She was larger than the British torpedo-boat destroyers then were, and more strongly built in every way. She was decked and planked the same as a cruiser. In the heavy weather a little damage was done to her scantlings in the fore-peak. The stringers and gusset-plates were carried away, but as that portion of the ship was bulkheaded off they did not know of the damage at the time. They got into smooth water after crossing the Bay of Biscay, and came into port. After going out of port into smooth water a peculiar noise was heard in the fore-peak. He had the manhole opened, and got inside to examine the interior. He then found that the thwartship stays were buckled and the gusset-plates all carried away, the rivets being shorn off. So far as he could remember, to give them a rough idea, he might say that the pitch of the beam of the vessel in the fore-peak was 3 ft. 4 in. or 3 ft. 6 in. Within that 3 ft. 6 in. the sides of the boat had "come in" 12 in. He did not see that action taking place, as it was during the heavy weather, but on examination he could see where the gusset-plates had crossed each other to that extent on the panting beams. After everything was put right again, he took quite an interest in the lines of that destroyer, and in both calm and rough water he watched her very closely. Everything was set up after the damage, so that they might say it was perfectly rigid. But in that same portion of the vessel he could notice, when plunging, that the sides would come in about $1\frac{1}{4}$ to $1\frac{1}{2}$ in. between the frames. The distance between the frames he could not quite remember, but he thought it would be about 18 in. Everything was so rigid after repair that the frames themselves were not perceptibly moved.

Mr. HARDING: Did she vibrate sideways or vertically at any speeds?

Mr. SHEARER said the vessel had a vertical and horizontal motion. When standing at the stern it was necessary to get off the heels; the vibration was so great that it shook one up. At full speed the only relief right aft was by easing one's heels off the deck.

Mr. HIGGS (Visitor) remarked that there seemed to be a remarkable difference between the speed obtained with a manganese bronze propeller and that obtained by a forged steel propeller.

Mr. JOHN CLARK (Companion) said that although Mr. Harding had referred to himself as an amateur, he had proved exceedingly interesting not only to naval people, but also to land people. Speaking generally, he thought as a nation we were all interested in the development of torpedo boats and warships. But in the development of the torpedo-boat destroyer there was a vast amount of knowledge of what might be called side issues. The propeller data on page 14 was exceedingly concise and of great value, but he thought the propeller was a subject which still required a great deal more light thrown upon it, judging from the article in the current number of the *Engineer*. With regard to the treatment of steel, our knowledge on that subject had now been very much extended. The accident to the *Bullfinch* had perhaps, he thought, been the means of opening up the question not only of stresses in connecting rods, but also the shape and thickness most suitable for the purpose. Also in connection with that the question of the annealing of steel cropped up. He thought it was Mr. Andrews who took up the question, and who had expressed the opinion that the annealing was not carried out properly in the first instance. The annealing of steel had only within recent years become a scientific subject. About a year ago there was published in the *Engineer* a temperature chart, which had been prepared by eminent people, but the point was not so distinctly shown as in some recent tests. The accident to the *Bullfinch* had also brought out the value of impact tests, which was a method giving more reliable indications of the nature of the material and the "fatigue" it would stand than the ordinary tensile tests so frequently adopted. Mr. Harding had referred to the stiffening of plates. They were greatly indebted to the torpedo-boat experts for their knowledge of resistance curves. One would think that resistance in a boat would increase directly as the cube of speed, but they generally found, by special curves, that it went up in a series of jumps at different speeds. Mr. Shearer had referred to the subject of vibration. He could not say that he had ever been on a torpedo boat, but the vibration was a well-known fact, and it was one of the most uncomfortable facts that the men on board those boats had to deal with. Possibly the effect of trying to remove that vibration had had a great deal of influence in increasing the speed by the adoption of the Parsons or other turbine. Mr. Harding had referred to the fact that White, of Cowes, the well-known builder, had started the idea of cutting away the dead-wood aft. He thought he had done that not in torpedo boats first of all, but in the steam launch. They might have been Admiralty boats. The cutting away of that dead-wood had also been found to reduce vibration. Then Yarrow's experiments, published in *Engineering* in 1890, together with full-plate photographs of a torpedo boat in the West India Dock, gave interesting information in respect to the ripple of water alongside the boat. He thought that Mr. Harding might have dealt a little more fully with the subject of vibration. In regard to the question of speed in shallow and deep water, in the current number of the *Engineer* there was an article giving particulars of the trials of the German scout *Bremen*. When running in fourteen fathoms of water, the indicated horse-power being 10,920, the number of revolutions 140·2, the speed was 22·50 knots. When running in water of a depth of 35½ fathoms, with 9,750 indicated horse-power and 135·9 revolutions, the speed was 22·47 knots. He would like to ask Mr. Harding if the character of the bed of a river had anything to do with the difference in speed obtained, or was it due to the depth of water alone? It appeared to him that there might be a great deal more difficulty in obtaining speed over a sandy bed than over a bed, say, of boulders. The Clyde was a well-known place for trying torpedo boats and other vessels, as well as Stokes Bay. It was deeper, and in addition to that, except for a small sandy bit at Skelmorlie, it was a well-known rocky river. Had that anything to do with the speed of the boat? Then Mr. Harding had touched upon the quantity of oil that was used. He did not think it was necessary to go to marine work to note the losses by the excessive amount of oil used for lubrication, but it was really wonderful how the proper application of oil reduced the amount required for lubrication. It was customary to test all stores, but he did not know whether it was customary to test oils under working conditions so as to obtain the reduction in friction during the number of hours run. In electric lighting stations the reduction of the consumption of oil was one of the most important points; it was decided under conditions that gave working results. Then Mr. Harding had referred to the fact of destroyers not being known as destroyers. He could remember in 1885-6 Thompson's built a boat for the Spanish Government called *El Destructeur*. She was a very beautiful boat. Mr. Harding had also referred to the *Express*, built by Laird's. He believed she was fitted with locomotive boilers.

Mr. Harding: The *Express* had modified Normand boilers.

Mr. Clark, continuing, said he would also like to ask if there had not been reason to question some of the work undertaken by our naval constructors. It was a well-known fact that the Admiralty had taken a destroyer into harbour and tested it to destruction, to find the force necessary to buckle the plates. The accident to the destroyer to which he had referred had caused the Press to take up the matter, and instead of condemning the Press he thought it would be a good thing to give them all the information they could. He thought, in reason, they ought to be afforded facilities for finding out weak points, because when the destroyers were called upon to work for the country they would have to work under war conditions, and if they knew the weak points before, then they might be able to put them right. He would like to thank Mr. Harding for his very excellent paper. It was on a subject he had always taken a great interest in.

Mr. SHARP thought the subject of the paper was not one that lent itself to much discussion, but nevertheless it will be welcomed by a large section of the members, especially those on the sea, on account of the interesting and racy manner in which it is written. There are portions of it which cannot fail to arrest the attention of the thoughtful reader, and the part that has attracted his attention most is at the top of page 14, where we find the substitution of one material for another gave an increase in the speed of $2\frac{1}{4}$ knots. This statement is not satisfactory; undoubtedly there was some cause and effect which ought to be inquired into. One might be led to think, from the extent of the alterations and experiments that have been carried out from time to time with propellers, some light would have been let into some of the obscurities—that there would be a common agreement on some of the fundamental parts. But at the present day there was just as much groping as ever. Even with the best of builders none of them seem to be very certain of their ground, when conditions have to be fulfilled involving much of a departure from what they have done before; and it is principally in the matter of pitch and surface where the greatest diversity occurs. The author had mentioned the immersion of the propeller in a specific case to the effect that it should be small, then he had qualified that by giving the various conditions of ship for war service. Could they take it as a general rule the more it was immersed or the less the propeller was immersed the better? He had always thought the more the propeller was immersed, within reasonable limits, the better; in other words, that it was an advantage if no air got down at the sides of the blades. He was sorry he could not endorse what the author had said of mercantile marine vessels having more efficient propellers.

Experiments had been made on destroyers and cruisers, but he had never heard of the results of those experiments having been given to builders from which to form any opinion or make any deductions in the designing of their propellers. He did know, however, that some time ago a quantity of blades of different design were made for ships of the "County" class, and as far as he could gather these blades were a decided improvement, but he had never heard what the extent of the alterations was. Regarding what Mr. J. Clark had said on the impact testing of steel, so far as he had seen, it was a very good thing, but when one ordered forgings from a maker who had not previously made forgings which had to undergo the test, at first the tests showed the material to be inferior, but when the maker got to understand the nature of the test the forgings usually came up to requirements. The conclusion he had come to in the matter was that the impact testing was mainly a question of the amount of hammering done to the shaft. If they hammered the forging well, and put a lot of work on it, the impact test generally showed better results than one poorly hammered. Impact testing, although a splendid thing in itself, was not a test on which one could absolutely rely.

Mr. A. H. MATHER (Hon. Financial Secretary) said he was glad to see so much interest being taken in the lines and strength of those high-speed craft. He would like to have an expression of opinion from Mr. Harding in regard to the development of a new class of boat which had come to the front during the last year or two. The general trend of design for boats of the torpedo class was to get more into the lines of the cruiser, so evolving a ship which could keep at sea for a considerable time and have a good radius of action. That left the ground open for high-speed craft in which speed would be the greatest consideration, and followed on what the author had said in regard to safety even being sacrificed through cutting down weights. But the speed could be obtained by adopting the design of the racing motor craft. Such a design could be adopted for very high-speed craft intended for torpedo-boat work only. One such racing craft was shown at Olympia, fitted with a petrol motor. The design was similar to the small racing craft, but the lines of these boats were altogether different from what they had been in the habit of seeing before. The draught was kept down as low as possible, and the bottom was getting flatter and flatter to counteract the drawing down of the stern when running at high speeds. The boat was constructed to practically skim over the water, the propeller being set down to get proper immersion. Such craft were very useful for smooth-water inshore work, and for very high speeds. The question arose, Was such a design adaptable for war purposes? With regard to condensers, he thought Mr. Shearer had expressed the opinion that there was not much difference between the condensers in battleships and those in merchant vessels. During the last year or two the condensers used in naval and merchant vessels seemed to be approaching each other in design, but the condenser on the battleship or cruiser was a very light structure as compared with what they had in the merchant service. Slackening of the joints and tube ends due to vibration appeared to be a more common failing in the Navy than in merchant vessels, although, from what he had seen of testing the feed-water with the nitrate of silver test as it came from the condenser, very few condensers appeared to be absolutely tight. This became a serious matter with the water-tube boiler, as with those boilers, if they got a cloudy indication in the feed-water under the nitrate test it was sufficient to condemn the water right away. With regard to the question of weight, he was pleased to see that Mr. Harding had referred to the advances which it was possible to make. They had had the Lungstrom condenser in small boats, and now they had a new condenser following the same lines. With regard to the smoke shown in the pictures, he might say that when photographing locomotives going at high speed he had found that half a crown given to the driver previous to starting would generally get them a good cloud of smoke and steam when they wanted to get that into the photograph for the sake of effect. Something similar may have happened when taking these pictures.

Mr. ALFRED COOKE, in referring to the great difference in speed obtained by substituting a bronze for a steel propeller, said he had seen the same thing carried out in merchant ships with practically the same results. In two exactly similar merchant ships, one fitted with cast-iron propeller and the other with solid bronze propeller, they got much better results from the bronze propeller.

Mr. HARDING, in reply, said that the discussion had been very valuable to him to see the different aspects in which the points had been viewed and the very practical questions that had been raised. Mr. W. McLaren was quite right when he said that one view of those destroyers was that they should have a long radius of action, or a long tether. He might answer that question by saying that in recent boats built on the north-east coast it was the intention to develop a large sea-going destroyer. Some boats of that description were now being built—boats of the *Sentinel* class—whilst the smaller boats would be retained for coast-defence purposes. The larger boats were 3,000 tons. Their engines were of something like 17,500 h.p., their speed being 25 knots loaded down to war-service draught. Practically they were nothing more nor less than destroyers grown big. They were armed with light guns, and kept the sea, and if any torpedo boat came out against the fleet their function was to make mincemeat of them. Of course, there was no doubt about the machinery in the mercantile marine differing from that in men-of-war. It was, of course, a fact that the very much heavier machinery would have a longer life. No doubt they did more millions of revolutions in the mercantile marine than they did tens of thousands in the Navy. The question of weight must always come in—it meant durability. He had with him a few figures by Sir John Durston, in which he gave the weights of various types of machinery per horse-power. In the *Magnificent* class, vessels of 12,400 h.p., and having eight large Scotch boilers, the machinery weighed 242 lb. per i.h.p. In the *Pelorus*, third-class cruiser, the machinery was 118 lb. per i.h.p. In the destroyer, where the weights included the water in the boiler, it stood at from 43 lb. to 58 lb. per i.h.p. In the *Sentinel* class—the "Scouts"—he believed the weight per i.h.p. was approximately 90 lb.; whilst in the *Amethyst*, cruiser type, it it was 114 lb. per i.h.p. The weight of machinery was the test of its durability—the heavier it was the longer it would last. In battleships, however, the question of weight had to be considered, as there were only so many cubic feet of water to be displaced, and if that was displaced by the weight of the machinery they did not have much for the hull and armament. With regard to the *Aquidaban* episode, he read of the fighting at the time, and did not see any of it. He felt convinced, however, that had there been Britishers on the *Aquidaban* she would have beaten the torpedo boats off, and also if there had been Britishers on board the torpedo boats he felt sure they would have sunk the *Aquidaban*. That was his opinion. Mr. J. McLaren had raised a question regarding the stability of the torpedo-boat destroyer when circle-turning. It was well known that when they put the helm hard over they were trying to capsize the ship by centrifugal force. If they had a weight of twelve or thirteen tons on the masthead, and the helm was put over, over the ship would go. If the ship were going round, the centre of gravity of the ship being above the centre of lateral resistance tended to topple her over. The weight was pressing one way, and she was kept upright by the rudder, which was tending to put a brake on her and make her heel inward. That was a very great question which had cropped up—the question of stability when turning round with the helm put suddenly over, as in war service. He would ask Mr. Mather to consider how the flat-bottomed motor boat would act, referring to the question of stability, under war-service conditions. In regard to those craft, he thought the question of stability would come in, and that the boats would be inclined to heel over in a very uncomfortable manner. The submarine he considered to be an invention of the devil, and he agreed with Mr. John McLaren that engineers would be able to provide some means whereby the whole hatch could be released, and so give the poor wretches a chance of coming above the water. He would almost say that submarines were useless and dangerous. He thought they would welcome very much any means of abolishing them if they came against us as enemies. The submarine was not an engineer's weapon, and it was far from perfect. It was like going to sea in a ship with wet coal and no ventilation to the bunkers. That was his opinion of the submarine. Mr. Cooke had asked if the modern destroyer was fitted with locomotive boilers. That boiler had gone out. It was a good-tempered boiler, and in some trials they burnt more coal with the locomotive boiler than with the water-tube boiler. They had burnt 114 lb. of coal per square foot of grate surface with the locomotive boiler as compared with, at the most, 80 to 84 lb. of coal per square foot of grate surface with the water-tube boiler. The locomotive boiler was a good-tempered boiler, but the water-tube type avoided a lot of trouble. With the fans going, the temperature in the stokehold would be about normal. Sometimes, however, when the fans were delivering over the boilers it made it very uncomfortable for those in the stokehold. That could not be well overcome except by arranging that air should not be delivered over the hot surfaces of the boiler. With the fans going, the temperature would be practically the same as the temperature of the outer air. Each ton of coal that was burnt took fifteen tons of air, and the temperature of the stokehold was practically the same as the outer air when the fans were blowing air. When the fans were stopped it was just a little sweat-box! He had tried to get some idea as to how the Japanese torpedoes had acted during the present war. Although they were very great friends of his—and he knew them fairly well—he had found them like oysters. They would not speak on the point. The case of the *Niger* had also been touched upon. He had it from an old officer that they had put booms round the ship each night to keep junks off, but on that particular night they did not put their booms out. The junk came down with one Chinaman on board; he exploded it, and then jumped overboard. There was a very nasty upset, and it led to many black eyes! That would show that vigilance was always necessary. The actual evolutions that were made yearly with our squadrons showed that our young officers did get their torpedoes in; the crushed heads of the torpedoes showed that they did get there. The smoke from the funnel was a subject which had had a lot of attention paid to it. In some cases there was an air pump pumping a jet of air across the furnace, and that, in some cases, decreased the smoke. He had come to the conclusion that with Welsh or any other coal they could only burn so much coal per square foot of grate without smoke. When they exceeded that quantity they must have smoke. But he was not quite sure that it was a disadvantage. It was terrifying to see a big volume of smoke bearing down on you, and possibly it might decrease the vessel as a target. They could aim much better at a ship than at smoke. Water-tube boiler troubles were due to the least tinge of salt water in the feed. With salt water they got priming, and things went wrong. The water-tube boiler would not go so well with salt water as the "dear old Scotch boiler." That latter-mentioned boiler could go even with salt feed up to a certain limit. He did not care to give information with regard to the reduction of scantlings. He was just willing to rest and say, "If shipbuilders say they are strong enough, I am willing to go all over the seas in these boats." The depth of water on the trial runs was an anomaly, for some of the best speeds were obtained in shallow water. The vessel seemed to create a wave of her own, and she ran along on that wave. There was no doubt, however, that depth of water on trial was the thing to have. The Admiralty now had a measured mile on the Cornish coast. Mention had also been made as to the fining of propellers and the adoption of manganese bronze for propellers. With regard to the trials of Japanese destroyers in

Japanese waters, he was not so sure that they could beat us in the matter of speed. They claimed to do so, and he would be willing to say that they might have done as well as we had. Their coal was nothing approaching Welsh coal. It burned with a white ash that looked like burnt flagstone. Japanese coal was no good, and they always imported the coal they needed for their war-ships. When our boats were designed we went one better than all the foreigners. The foreigners carried a load on the trial trip which represented the torpedo boat half-way between full and empty bunkers. We went one better, and put on full load, and got our speed. So the boats built then beat anything brought against us. The coal capacity of a destroyer of 80 tons was practically from 13 to 15 hours' supply for a full 30-knot speed. He was glad Mr. Shearer agreed with him that his idea of coast defence was an economical way of spending our millions. That gentleman had also raised certain questions as to what the effect of a torpedo would be. Each time they read of torpedoes being used they saw the variety of damage they could do. It was almost useless to try and foresee what the effect would be. He thought the condenser in the mercantile marine had more surface per horse-power than they allowed for in the Navy. It was simply a question of cutting down weights. Mr. Shearer's experiences in a destroyer were certainly interesting. With regard to the damage sustained by the destroyer to which Mr. Shearer had referred, he was inclined to think that the vessel vibrated and shook herself, and that the "panting" forward was due to the fact that she was not strong enough. The frames were too wide apart, or the plates were not stiff enough. Planishing could make them as stiff as a board. Mr. Shearer was not alone in his experience. Vibration and plunging pulled the vessel a little too much down by the bows. He could assure Mr. Higgs that with the revolutions mentioned they got the different speeds. At 384 revolutions the steel propeller gave $24\frac{3}{4}$ knots speed, whilst the bronze propeller, with the same number of revolutions, gave 27 knots. The forged steel propeller ran away, and would give a considerably higher percentage of revolutions at the same power. They got 6,000 horse-power out of the forged steel propeller at 400 revolutions, whilst the bronze propeller gave 6,000 horse-power at, perhaps, 385 revolutions. The forged steel seemed to let the propeller run away more, and it was inclined to cavitation, losing its tread. He had spent hours and hours on propellers, and it was a very interesting subject. Sometimes he approached engineers and asked what was the diameter of the boss. He firmly believed that the boss was the first thing to talk about, and that it should be very much bigger; but they had cut it down to decrease the weight. The boss should be a quarter to one-third of the diameter of the screw. There was no doubt about that. Having got the boss—the diameter of which he did not think any engineer could foretell—there was the pitch and area to consider. The propeller was a subject which demanded a lot of time. The questions regarding steel which had been raised were very interesting, and he agreed that we still had something to learn about steel, especially when they cut down scantlings too much. He would hardly like to express an opinion with regard to the *Bullfinch* affair. It was considered unwise to make the connecting rods of the same scantlings as before, and since they had increased them in size they had avoided all trouble. That, he thought, was an example of "fatigue" of metal, the scantlings not being big enough. In regard to propellers, the slip of the propeller at 28 knots should be less than the slip at 27 knots. When the slip was increasing there was something wrong with the propeller. Vibration had also been touched upon. The experiences of Messrs. Yarrow in that respect were well known. They led to the endeavour to avoid vibration by suitable balance-weights and by balancing the propellers, and also by other means. He thought many engineers were of opinion that the vibration was due to the ship not being strong enough, and he was also sure that the shipbuilders were certain that the unpleasant vibration is due to some fault in the engines. He did not know that he could give an opinion as to what effect the bed of a river over which a trial trip was run would have upon the speed of the vessel. He could only state that Wemyss Bay was the best measured mile going, and the genial hostess at the Tontine Hotel hoped it would remain the best mile. *El Destructeur* was an advance in the right direction, but that boat was not a British ship. The *Express* was built by Laird. She had Normand boilers. The Press had raised objections after a lamentable event, which, however, was an accident. The shipbuilders had turned out the job strong enough for service. Mr. Sharp was quite right—no one could tell what the proper diameter of a propeller should be. For high-speed ships it would be necessary to have three or four sets of propellers made and tried in order to see which was the best by the coal bill. It was not fair to ask any designer to spot the right propeller right off. With regard to the turbine, he had been speaking to the Hon. C. A. Parsons, and that gentleman got his high speeds as the result of trials of several propellers. Little things pointed out improvements in different directions, but it was all the result of successive trials. Concluding, he said he was very pleased to meet the members of the Institute, and it was a great pleasure to him to know that his efforts had met with their approbation, and had resulted in so successful a discussion.

The CHAIRMAN said he thought they would all agree that the paper had proved to be a very instructive and interesting one, and the discussion that night had been no less instructive. Not many questions had been asked, and he would have been pleased to have heard a few more, but Mr. Harding had gone into those questions so fully, and his replies must have been satisfactory. So far as it was possible he believed Mr. Harding had answered all the questions that had been put to him. At the previous meeting they had passed a vote of thanks to Mr. Harding, but he thought they ought to accord him another vote of thanks for the trouble he had taken in coming such a distance to answer their queries.

The proposed vote of thanks to Mr. Harding was cordially agreed to.

The CHAIRMAN then announced that on the following Monday (March 27th) Mr. D. Hulme would read a paper on "The Work of the Standards Committee." He hoped they would have a good muster of members, who would give Mr. Hulme a few questions to answer. April 3rd was one of the lecture nights, and he would draw special attention to the fact that ladies were invited to that night's lecture.

Mr. W. McLAREN proposed a vote of thanks to the Chairman for presiding, and the proposition, having been seconded by Mr. G. Shearer, was carried unanimously.