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IN

MARINE ENGINEERING.

BY

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PREFACE.

THE Marine Engine of the present day must certainly be regarded as far more the outcome of lengthened practical experience than the result of theoretical investigations and scientific research. The conditions to be satisfied on shipboard are so numerous, and many of them are of so special a character, that it has only been by watching the results of actual working and by taking to heart the teachings of sometimes bitter experience, that Marine Engine Builders have been able to produce the magnificent specimens of Mechanical Engineering now to be found on our large ocean steamers. Bearing these facts in mind, there is reason for believing that to those engaged in the design and construction of Marine Engines, a study of work already executed will afford information which can be gained in no other way. It is in this belief that the present Volumes have been prepared. No attempt has been made to render the work a complete treatise on Marine Engine Construction and the theoretical questions involved in the design of such engines have been scarcely touched upon, but it has been endeavoured to place clearly on record the productions of a number of our leading Marine Engineers during the past few years, and to do this in a manner which will afford data for future developments. Most of the illustrations in the present work, and much of the matter, have already appeared in the pages of ENGINEERING, but the text has been thoroughly revised, and in many cases greatly extended. It remains only to heartily thank the numerous firms who have by their co-operation in freely furnishing information and drawings rendered the production of the present volumes possible.

W. H. M.

LONDON, *December*, 1883.

THE HERRESHOFF TORPEDO BOATS.

WE give in Figs. 263, annexed, and Figs. 264 and 265, on page 281, views of the torpedo boat built in 1878 for the British Government by the Herreshoff Manufacturing Company, of Bristol, Rhode Island, U.S.A., the vessel being one marked by some very interesting peculiarities. The boat is 59 ft. 6 in. long with 7 ft. 6 in. beam, and it has a composite hull with timber planking below the water line, and a steel skin above, while there is also a steel superstructure of the form shown, covering the machinery and men. The form of this superstructure is explained by Figs. 263 and 264, the former figure

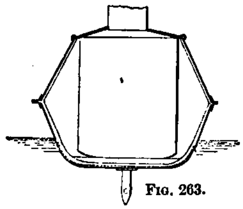

FIG. 263.

also showing the manner in which the junction is made between the steel upper skin and timber planking. The planking of the lower hull is of white pine $\frac{3}{4}$ in. thick, and the skin of the upper part is of the best homogeneous steel plates $\frac{1}{16}$ in. thick.

The composite system of construction we have described was adopted because a wooden covering below water can be made and kept more smooth than a steel one, while it is at the same time regarded by the builders as more durable on account of the very small thickness of steel which would be admissible in order to keep down the weight. It was proposed subsequently to cover the bottom with copper or Muntz metal when desirable. The lines of the hull are nearly alike at the bow and stern.

The boat is propelled by a compound engine of the intermediate receiver type, and having a 6 in. and a $10\frac{1}{2}$ in. cylinder, each with 10 in. stroke. The air pump is 3 in. in diameter and the feed pump $1\frac{1}{2}$ in. in diameter, both having 5 in. stroke and both being double-acting. These pumps are driven by a small independent horizontal engine, not shown in our engravings. There is also another independent engine for driving the fan blower, this engine being a small vertical of $2\frac{1}{2}$ horse-power, placed as shown in Fig. 264. The fan supplies air at a pressure of about $1\frac{1}{2}$ in. of water to the closed compartment in which the boiler is placed.

The boiler is, like many other details of the boat, of a special type patented by Messrs. Herreshoff, and it is illustrated in detail by Fig. 266, on page 283. It consists of a coil of wrought-iron pipe 2 in. in diameter and about 300 ft. long, this coil forming a kind of combustion chamber above the grate, which is 4 ft. in diameter. The feed is supplied to the upper end of the coil, and the mixed steam and water escaping from the lower end passes into a separator where the water is deposited, the steam being then led through a short superheating coil on its way to the engine. The separating chamber of the boiler is placed in the engine-room, where the blowing-off valve can be managed by the man who attends to the feed-pump and fan engine. We shall have more to say concerning this boiler presently.

As will be seen from Fig. 264, the engine is placed well forward in the vessel, and the shaft runs at an inclination through the bottom of the boat. In order, however, to counteract the effect of running a screw with a steeply inclined shaft, the latter is curved throughout its length, so that the after end is brought nearly horizontal. The shaft is of steel, and is kept to the curve shown by being run in a brass tube which is bent to the desired curve, and which forms a kind of continuous bearing from end to end. The tube just mentioned extends to within about a foot of the engine, and the stuffing-box is fitted to its inner end. This plan of employing a "sprung" shaft to communicate the motion to the screw is a bold departure from ordinary practice—as, indeed are many features of the boat—but it appears to answer well, and the friction involved by the arrangement is stated not to be in any way excessive.

The curved tube forming the shaft bearing is securely fixed inside a double-walled copper chamber, which projects below the bottom of the boat, and serves the triple purpose of a support to the shaft, a fixed centre board or false keel, and last, but not least, a surface condenser. The keel formed by the condenser being at the centre of the length of the vessel, forms a kind of pivot on which the boat may

THE HERRESHOFF TORPEDO LAUNCH.

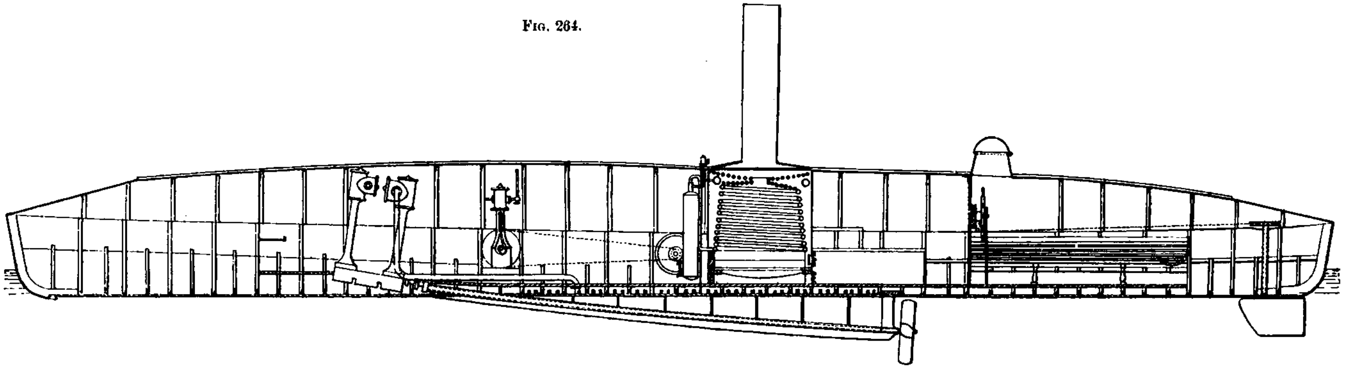

Fig. 264.

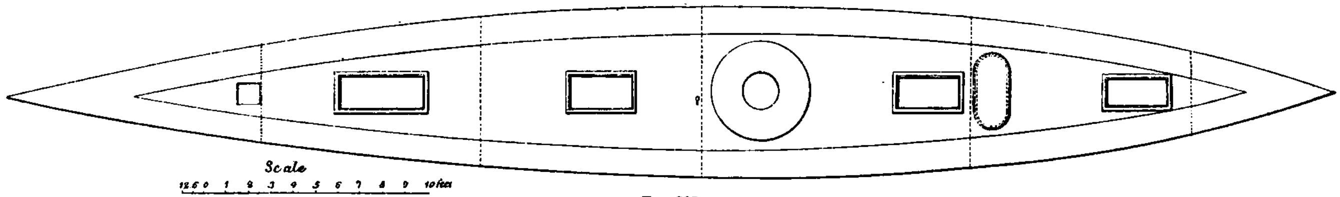

Fig. 265.

be turned. The exhaust steam from the engine enters the condenser near the forward end, and the suction pipe to the air pump draws from the after end.

The screw is 38 in. in diameter, with 5 ft. pitch, and as will be seen from Fig. 264, it is situated more than one-third the length of the vessel from the stern. Owing to its position, the screw is of course always working in solid water, and its power of suddenly starting or stopping the boat is thus greatly increased. By reversing the engine the boat can be stopped in three-quarters of its own length.

The rudder, like the screw, is placed in an unusual position, it being below the bottom of the boat, but close to the stern, as shown in Fig. 264. The rudder is partly balanced, and it is so mounted that it is free to turn in any direction, either forward or backward. The steering wheel is situated below a small conning tower, as shown, and the motion is communicated from it to the rudder head by means of a chain and rag-wheel. When the boat is going ahead, the preponderating side of the rudder is towards the stern as usual; but when going astern the rudder is allowed to swing completely round, so as to bring the preponderating part towards the bow. Under these circumstances the steering when going astern is as easy as when going ahead. The boat, when going either backwards or forwards, can be turned in a circle, the diameter of which is about three times her own length or about 180 ft.

The weight of the boat, with fixtures, is 6 tons, or with torpedoes and stores, 8 tons. The strength required for hoisting is given by the steel skin and the steel superstructure, while when running at full speed the boat is remarkably free from vibration, owing partly to the screw running in solid water, and partly to the curved form of the superstructure, which gives great stiffness to the ends of the vessel.

We have already referred briefly to the boiler with which the boat is fitted, and we may now describe it more in detail. The Herreshoff boiler—or rather steam generator, as it is called—consists of a continuous coil of wrought-iron steam pipe arranged in the form of a frustum of a cone, as shown in Fig. 266, this coil being placed above a firegrate, which is encircled by a dwarf wall of firebrick inclosed within a suitable casing, this brick-lined casing with the space within the coil itself, forming a combustion chamber. The whole is inclosed in a double or treble shell or smoke jacket, with an air space or spaces between for insulation.

There are two forms of the Herreshoff generator—viz., those of the double and single coil. In situations where it is desirable to combine economy of fuel, and to have the generator in as small a vertical space as possible, the double coil is used. In situations where it is an object to economise height a single coil is used. Our engraving, Fig. 266, represents a double coil.

In operating this generator water is delivered by the pump into the outside part of the flat coil A, which coil serves as a feed water heater, its inner end being connected to the top of the main coil B, through which the water descends. As the water approaches the bottom, it becomes partly vaporised, and at the bottom of the inner coil the pipe merges continuously into the outer coil C, through which the ascending steam and water pass to be finally delivered into the separator D. On its arrival at the separator the water is almost steam, only 15 to 20 per cent. remaining in a liquid state. The amount of water here collected should be proportioned to its purity. Where sea-water, or muddy or impure fresh water is used, 20 per cent. of the water that is forced into the generator is sufficient to carry with it all sediment which collects in the bottom of the separator, from whence it may be blown off at intervals. The rapidity of the circulation of the steam and water in the coils prevents lodgments or obstructions.

The end of the discharge pipe E entering the separator, is deflected in such a manner that the steam and water are projected against the sides of the separator, and a whirling motion imparted to them. By this operation the water is more quickly and perfectly separated from the steam. The water being heavier, it is thrown outward by centrifugal force against the sides of the separator, when it readily falls to the bottom. The steam occupying the upper and central portions of the separator escapes through the passage F to the coil G, in which it is more thoroughly dried and superheated. It is then conveyed by the supply pipe to the engine or other usea

The height of the water which collects at the bottom of the separator is always indicated by the glass water gauge H, and the surface blow-off I is provided with an adjustable valve or steam trap, through which the excess of feed water passes. The blow-off J is for the removal of sediment. If the boiler be used in connexion with a surface condensing engine, the excess of water which is blown off at the pipe I is returned again at the top of the coil, with the feed water arising from the condensation of the steam used by the engine. By this means no heat is lost by the escape of the excess feed water.

An important feature of the Herreshoff steam generator is its safety, the amount of water contained in it being so small that were it instantly liberated it could do little damage. But instant liberation is out of the question; the most that could occur would be a forcing open of the pipe which forms the coil, and this would only be followed by a harmless blowing off of the steam. The separator is the only part of the boiler possessing anything like a large diameter, and its entire removal from the fire precludes anything like possibility of explosion. It can also be made of a strength far exceeding the practicable limit of steam pressure.

It will be seen by Fig. 266 that the whole space surrounded by the coils on the sides, and from the grate below to the coil above, is a clear unobstructed chamber for combustion. The importance of so large a space is particularly of value in the burning of bituminous coal. The flames and heated gases are not allowed to escape through the top of the coils, which are purposely made tight. All the products of combustion are forced to escape through the narrow spaces between the pipes which form the main body of the coils. These spaces are graduated, being larger at the bottom and decreasing as they approach the top. The heated gases, being lighter, rise in the chamber and are held there, their escape being only permitted by the spaces of the smaller size. The heated gases from within are thus finely divided, and the several streams are brought well into contact with the heating surfaces of the generator.

The improvements made in steam launches during the past few years, have been almost always developments in the same direction, whereas the Herreshoff boat we have been describing constituted at the time it was brought out an improvement from a new departure, and its performance was therefore a matter of special interest. On January 20, 1879, the boat we have been describing was examined by the First Lord of the Admiralty, who was accompanied by Admirals Hood, Wellesley, and Sir Houston Stewart, and Mr. Barnaby, the Chief Constructor, who witnessed some experiments made with it at the Royal Victualling Yard. On this occasion the boat was hoisted by a crane with all stores and the crew on board, and without showing signs of springing, and it was then lowered into the river, and steam got up to blow off at the safety valves in five minutes after lighting the fire. The great handiness of the boat, and her powers of rapid stopping, starting, and turning, were then shown, and Mr. Herreshoff was complimented on the highly successful results by the Admiralty authorities. The speed attained at the Admiralty trial was 16 knots. The boat was also tested for stability by placing a

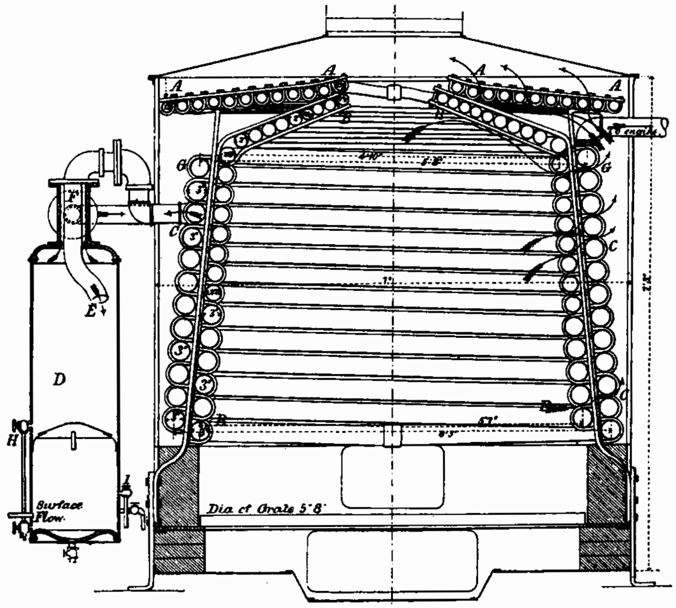

FIG. 266. THE HERRESHOFF STEAM GENERATOR, CONSTRUCTED BY THE HERRESHOFF MANUFACTURING COMPANY, BRISTOL, RHODE ISLAND, U.S.A.

load of 1700 lb. on the gunwale, the results being highly satisfactory.

After the products of combustion have sifted themselves through the main coils, they arise on the outside of the latter, between the coils and the jacket. Near the top of the coils and directly in the path of the ascending gases the superheating coil is placed, and this extracts still further any valuable heat which the gases contain. Even after this the products of combustion have to pass through the flat coil or feed water heater, the spaces between the pipes of which are larger than those of the main coil, so as to allow a free passage of the gases, which, by this time, are effectively cooled.

The reasons have already been given why the combustion of fuel in the furnace of the generator is so free under natural conditions. The heated gases are brought so quickly and directly into contact with the heating surfaces, and the coil itself contains such a small amount of water, that steam is generated almost immediately after lighting the fire. Sixty pounds pressure can be obtained in four or five minutes, and in six minutes 100 lb. can be indicated.

Of course, an important question to be considered in connexion with a generator of the type we are describing is its durability. In the case of the Herreshoff generator the sides of the furnace are lined with firebricks, and the fire is thus not allowed to come into actual contact with the coils, which are supported by the bricks at a distance of one-fifth of the diameter of the grate above it. The coils themselves also are so constructed that no injury can come to them through expansion and contraction, while it is now a recognised fact that the passage of steam over hot iron forms a protecting scale of black magnetic oxide of iron, which prevents injury of the metal beneath it from rust or corrosion. Messrs. Herreshoff affirm that the quality of the iron of which the coils are made improves by alternate heating and cooling, the iron composing the coil of an old generator being found to be tougher and stronger than when new. When it is desirable to stop the working of the generator for a longer or a shorter period, the water contained by the coils is entirely blown out; the generator then remains perfectly dry, and cannot be damaged by the action of frost.

The quality of the steam supplied by the Herreshoff generator is, we understand, very good, it being delivered from the superheating coil perfectly dry. The degree to which the steam may be superheated is proportioned to the length of the superheating coil, which can be made shorter or longer according to the purposes for which the steam is used. The superheating coil is so situated that the steam passing through it cannot be heated to a degree which would be injurious to the engine.

Bearing in mind the facts above recorded it may be worth while to trace briefly the history of the torpedo boat supplied to the British Admiralty in 1878, and to explain what has since been done in utilising the Herreshoff system in our Navy. After the boat above described had been running for a week on the Thames with considerable success, it was sent by train to Portsmouth, where the difference between English and American ideas upon the construction of torpedo boat machinery soon became manifest. The New England craft was continually developing fresh places of weakness in the construction and design of her engines, which, as soon as they were discovered by the dockyard engineers, were remedied, and, as far as possible, eradicated. In course of time the engines had been so far remade as to enable the Portsmouth officials to pronounce the boat complete, and an order was sent down from the Admiralty to have her put through a searching trial. In execution of this order she was run four hours a day at full speed for fourteen consecutive days, Sundays excepted. We were informed at the time that this was the most severe trial that any torpedo boat had ever been put to, and the strain on the engineering staff must have been such as is not often experienced even by torpedo boat crews, who undoubtedly have the most arduous duties of any class of men in the service. The boat passed through this ordeal with perfect success. An improved arrangement of the Herreshoff boiler was subsequently introduced, and a new boiler, made in England of best lap-welded tube, was fitted in the boat. Since that time this boat may be said to have had no history, as she has been principally used for the purpose of instructing the engineers, artificers, and stokers of the Steam Reserve in the working of the Herreshoff system.

Some time after the boat above referred to had been supplied, the Admiralty gave instructions to the Herreshoff Company to build two boats of a new type, plans for which were laid before the Board. These boats were constructed in America, and duly brought across the Atlantic on the deck of a Monarch line steamer. They were taken to Portsmouth, where they were subjected to a series of trials by the dockyard and naval authorities. Each boat is 48 ft. in length on deck, and 46 ft. over all; breadth 9 ft.; depth of hull amidships from lower edge of rabbet of keel to top of deck beams, 5 ft.; depth of hull amidships from load-water line to lower edge of rabbet of keel, 1 ft. 10 in.; depth of keel amidship, 8 in.; siding of keel, 4 in.; area of load water section, 217.76 square feet; displacement at load draught 7.44 tons; aggregate wetted surface, 365.5 square feet; co-efficient of fineness:

$$\frac{\text{Displacement}}{\text{Length} \times \text{breadth} \times \text{draught}} = 0.396.$$

The engines are compound surface condensing, with inverted cylinders of 8 in. and 14 in. diameter and 9 in. stroke. The large cylinder works the air and feed pumps by means of a lever. Both pumps are vertical and single-acting. The air pump has no foot valve; it has a receiving valve in its piston and a valve discharging into a closed reservoir, or hot-well, from which the feed pump draws. The engine frames consist of wrought-iron standards bolted to a cast-iron bedplate, and the leading peculiarity in the engine lies in this bedplate, the plummer-blocks and shaft bearings being placed underneath it, instead of above, in the ordinary way, so that the crankshaft is actually below the bedplate. Many advantages are claimed by the manufacturers for this arrangement. It is stated that by means of it the standards can be placed immediately over the position of the bearings, so that the vertical strain will be in direct line with their axes, and in this way a lighter soleplate may be used, and weight thereby saved. It would seem to us, however, that a little extra weight would be preferable to placing the main bearings of the engine in so inaccessible a position as beneath the bedplate, to say nothing of the impossibility of removing the crankshaft without lifting the engine, as would appear to be necessary with the design in question. The surface condenser is formed by two bent copper pipes placed outside the boat level with the garboards, one on each side. The pipes commence at a point 8 ft. forward of the position of the large cylinder; they extend nearly to the stern-post, and thence return to abreast the engines. As these boats are in many respects so different to any that had ever before been supplied to the Royal Navy, and as a remarkable result was obtained by them on trial, we append further particulars of the engines.

Diameter of piston rods	1¼ in.	
Port and clearance at one end of high-pressure cylinder...	0.0278 cub. ft.	
Length of steam port in high-pressure cylinder	7 in.	
Breadth of steam port in high-pressure cylinder	15/16 ,,	
Length of exhaust port in high-pressure cylinder	7 ,,	
Breadth of exhaust port in high-pressure cylinder	2 ,,	
Clearance in both cylinders	⅛ ,,	
Port and clearance of low-pressure cylinder	0.0675 cub. ft.	
	ft.	in.
Length of steam port of low-pressure cylinder	1	0
Breadth of steam port of low-pressure cylinder	0	1¼
Length of exhaust port of low-pressure cylinder	1	0
Breadth of exhaust port of low-pressure cylinder	0	2½

	ft.	in.
Diameter of air-pump (single-acting) ...	0	4½
Stroke	0	3⅝
Diameter of feed pump plunger (single-acting)	0	1¼
Stroke	0	5¼
Length of connecting rods between centres	2	8½
Diameter of crosshead journals	0	1¾
Length ,, ,, ...	0	3
Diameter of crankshaft journals (4 in number)	0	2½
Length of crankshaft journals (4 in number)	0	4½
Diameter of crank-pin journals	0	2½
Length ,, ,, ...	0	3½
Width of cranks	0	1½
Diameter of line shaft (steel)	0	2¾
Length of vessel occupied by engine ...	4	0
Breadth ,, ,, ,, ...	2	6
Height of engine above axis of crankshaft	4	0

Propeller of gun-metal 3 ft. in diameter and 4 ft. 1 in. pitch, four blades.

The fan, which is 42 in. in diameter, is driven by a separate single vertical engine with a cylinder 2½ in. in diameter by 5 in. stroke. This engine also works a donkey feed pump.

The boilers fitted to these boats are of the usual type of Herreshoff coil boiler, and are of the same dimensions and arranged generally in the same manner as the one first fitted to the torpedo boat before described, excepting that they have an outer coil, which is placed immediately inside the outer casing. This arrangement has been found to possess many advantages, the principal being that it affords a very effective means of insulating the boiler, and so preventing loss from radiation. The following are the leading details of the boilers fitted to the boats in question:

Diameter of the boiler outside casing ...	56 in.
Height from bottom of ash-pit to base of funnel	65 ,,
Diameter of furnace	48 ,,
Area of grate surface	12½ sq. ft.
,, heating surface	174 ,,
Diameter of chimney	16½ in.
Height of chimney above firebars ...	13 ft.
Square feet of heating surface per square foot of grate	13.8
Weight of boiler and water, including firebars, chimney and all fittings ready for steaming	3892 lb.

The following details of the performance of these boats are extracted from the Admiralty official report:

Vessel's name	Pinnace No. 150.		
Air pressure	1.66 in.	1.17	nil
Where tried	Stokes Bay	Round Isle of Wight	Stokes Bay
Draught forward ...	2 ft. 1½ in.	2 ft. 4 in.	2 ft. 1½ in.
Draught aft	3 ft. 8½ in.	3 ft. 9½ in.	3 ft. 9 in.
Boiler pressure (average)...	145 lb.	93.18 lb.	52.35 lb.*
Average vacuum	20.29	21.77 in.	22 in.
Barometer, inches of mercury	30.16	30.37 in.	30.35 in.
Mean pressure in cylinders, high p.	no cards	53.12 lb.	34.22 lb.
Mean pressure in cylinders, low p.		12.01 lb.	8.02 lb.
Mean revolutions... ...	453.07	333	273.03
Indicated horse-power ...	...	68.4	36.7
Speed in knots per hour...	15.124	10.18†	8.635
Force of wind	1	1	4 to 5
Sea...	Smooth	Smooth	Rough

* Engines linked up. † Speed taken by log.

The first of the trials above recorded was made in Stokes Bay, and was an ordinary six-knot run on the mile. The other two runs were made to test the continuous steaming properties of the machinery, no regard being paid to speed.

Subsequently to the date of the above trials two smaller boats were purchased from the Herreshoff Company by the Board of Admiralty. These boats being also of an unusual description, we will give a few details of them. Their chief dimensions are: Length over all, 33 ft.; breadth, 8 ft. 9 in.; mean draught, 1 ft. 7 in. The boats are decked in forward and after parts and narrow water ways fore and aft at sides, leaving a long open space for the machinery, a compartment forward, and an open cockpit aft. The engines are compound surface condensing with cylinders 4½ in. and 7 in. in diameter by 7 in. stroke. The condenser is of the outboard pipe description. The boiler is of the ordinary Herreshoff type. The screw is of brass, four-bladed, 31 in. in diameter and 44 in. pitch. The speed obtained on the official trial made at Sheerness with one of these boats was, we are informed, at the rate of 9¼ knots per hour, a remarkable performance considering the dimensions of the boat.

The Herreshoff Company have built a few vessels of different descriptions for various foreign Governments. The first they constructed was a gunboat which was built to the order of the Spanish naval authorities. This vessel was 135 ft. long, and, according to the certificate of her trial, steamed at the rate of 16 knots per hour for six hours. Half a dozen second-class torpedo boats were also ordered by the Peruvian Government during the late war, but only two were delivered before the collapse of the Peruvians put an end to the necessity for the boats, and any prospect of getting paid for them at the same time.

A second-class torpedo boat was afterwards constructed for the Russian Government and was duly sent to St. Petersburg. The hull was of composite construction, being of wood planking on steel frames. The engines and boiler were of the same description as those already detailed in describing the 48 ft. boats for the British Admiralty. On her trial trip in America over a three-knot course (making two consecutive runs over the base, or six knots in all), the speed of the Russian boat was officially returned to be at the rate of 19.87 knots per hour. The boat carried no extra weight on the trial, in this respect having an immense advantage over torpedo boats when officially tried in this country. This boat was afterwards run on the Thames, but showed a considerable diminution in speed, not much above 17 knots being attained.

The next vessels built for a foreign Government by this company were two boats constructed to the order of the French naval authorities. These were exactly similar in all respects to the two 48 ft. boats supplied to the English Government. They were officially tried in America by a Commission of French naval officers sent over for the purpose. Mr. Isherwood, U.S.N., watched the trials on behalf of his Government, and has issued a somewhat elaborate official report of the proceedings, from which we extract the following record of the principal trial. The time occupied on the run was exactly three hours, the boat steaming four times over a given base.

Means of the Four Runs.

Boiler pressure	129.5 lb.
Revolutions per minute	466.2
Slip of screw per cent. of speed	24
Air pressure in stokehold	2.35 in.
Revolutions of fan per minute	722.54
Speed in knots per hour	14.26

The second vessel realised a speed of 14.08 knots per hour.

Mr. Isherwood's report states that it was not found possible to take indicator diagrams on the full speed trials, but a considerable number of trials were run at lower speeds progressing up to 11.74 knots per hour. On the results obtained "a calculation has been made," so the official report says, "for the mean speed of the two trials, and the result is shown below. The indicated horse-power given agrees substantially with that furnished by an ideal indicator diagram constructed from the boiler pressure, condenser vacuum, and point of cutting off known to exist in the case." The aggregate indicated horse-power so obtained is 169.47. The following calculations as to the distribution of the power developed may be of interest, coming as they do from Mr. Isherwood, the extent of whose researches into such subjects is well known:

Indicated horse-power developed	169.47
Horse-power in working the engines... ...	21.31
Net horse-power applied to the crank-pins ...	156.65
Horse-power absorbed by friction of the load	11.74
Horse-power absorbed by resistance of the water to the surface of the screw blades ...	12.18
Horse-power expended in slip of the screw ...	31.85
Horse-power expended in the propulsion of the vessel	100.86

The fuel burnt on these trials was briquettes, such as are supplied to the French war steamers, the consumption being 4.13 lb. per indicated horse-power per hour, which may be regarded as a fairly economical result considering that, within a trifle, one indicated horse-power was being obtained from every square foot of heating surface, and rather more than 4 lb. of fuel were burnt per square foot of heating surface per hour.

The report further states that these vessels "can make fourteen geographical miles per hour for 6.43

hours with their bunkers filled with best steam coal. This is equivalent to a distance of ninety geographical miles. Of course, by carrying more coal in bags, this distance can be proportionately increased;" and we may add that equally, of course by steaming at a more economical speed, the distance can also be increased. The records of these four sister vessels, built for the English and French navies, are well worth attention. That 169 indicated horse-power could be got from the engines of a boat 48 ft. long over all would have appeared nothing less than impossible a few years ago, and even now we believe the highest power ever obtained in terms of displacement of a given vessel is that reached in the boats in question. The total weight of all machinery, including water in boiler, and also 720 lb. of water in a tank, was 7020 lb., so that by calculation made as before detailed, when the boat was running at the rate of 14.17 knots, the total weight of machinery per indicated horse-power developed would be 41.42 lb., or, deducting the water in the tank, but leaving the weight of the tank in the calculation, the total weight of the machinery per indicated horse-power would be 37.17 lb., while for each ton displacement of the vessel there would be given forth by the engines over 22 indicated horse-power. These figures well illustrate the enormous power that must be expended in order to drive a short broad boat at an excessively high speed. The following are the records of other trials made with these vessels at lower speeds:

Knots per Hour.	Indicated Horse-Power.	Revolutions.	Boiler Pressure. lb.
11.74	95.24	415	95
9.15	28.73	306.7	38
6.68	12.31	220	19.5

The screws used on the three last-quoted trials were of 6 in. less pitch than those used on the other trials, this being the only difference throughout in the boats and their equipment.