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LECTURE.

Friday, March 21, 1879.

ADMIRAL SIR R. SPENCER ROBINSON, K.C.B., in the Chair.

ON THE LATEST IMPROVEMENTS IN MARINE ENGINES AND BOILERS.

By JOHN R. RAVENHILL, Esq., M.I.C.E.

IN a paper read by me before the Institution of Naval Architects at an autumnal session, held at Glasgow in 1877, I drew attention, amongst other subjects, to the great strides that had taken place in ocean steam navigation since the "Great Western" steamship commenced her passages to and fro to New York in 1839. Having compared her performances with some of the fastest transatlantic steamers then running, and having alluded to the rapid increase in the use of the compound engine, I conclusively proved from results obtained the great advantages in the saving of fuel that were being derived from its adoption, pointing out that the consumption of coal was reduced, say, from 8 lbs. per indicated horse-power per hour to 2 lbs. I also showed that the average length of the voyage had been practically reduced one-half, and in a lengthy appendix I added a list of the then compounded commercial fleet belonging to seventeen of our principal steamship companies.

The "City of New York," belonging to the Inman Line, at that time fitting for sea with compound engines, by the Sunderland Engine Works Company, has been running on her station for some fifteen months, and her average consumption of coals per hour is stated to be 1.9 lbs. per indicated horse-power under favourable circumstances, with sails set, the speed of the vessel being 14 knots per hour. Her engines are of the compound vertical type, with four cylinders; the high pressure ones, each 40 inches in diameter, standing above the low pressure ones, which are 71 inches in diameter, having thus a proportion of 3.15 to 1; they have a stroke of 5 feet, and are fitted with expansion valves arranged to cut off the steam at from one-quarter to three-quarters the length of the stroke in the high pressure cylinders. The surface condensers contain an aggregate tube surface of 5,000 square feet. The steam is supplied by 4 boilers, double-ended, having 6 furnaces, in all 24, each with its own separate fire-box; they carry a working pressure of 75 lbs. on the square inch, and contain a total

heating surface of 10,000 square feet. After twelve months' working her consumption of coal is given me as 62·75 tons per day, and it is claimed for the engines that every part of them is very easily overhauled in the event of need.

The service, however, which had just then been commenced by the Orient Line between London and Sydney, with vessels originally belonging to the Pacific Steam Navigation Company, is perhaps the one above all others that has been the most *keenly* watched by all interested in steam navigation; and having regard to the distances run, and the speed maintained, it deserves special notice. The outward voyages are made round the Cape of Good Hope, the homeward through the Red Sea and the Suez Canal; and the following table may prove interesting as an example of one of their voyages.

TABLE I.

Ports from.	Ports to.	Distance.	Consumption of Coal.	Actual Steaming Time.			Average Speed.
		Miles.	Tons.	D.	H.	M.	Knots per hour.
<i>Outward—</i>							
London ..	Gravesend ..	22	7	..	2	34	..
Gravesend ..	Plymouth ..	300	53	1	2	4	..
Plymouth ..	St. Vincent ..	2,248	355	7	15	46	12·2
St. Vincent {	Cape of Good Hope.. }	3,948	659	13	22	50	11·8
Cape Town ..	Adelaide ..	5,714	859	18	0	40	13·2
Adelaide ..	Melbourne ..	520	85	1	17	30	12·5
Melbourne ..	Sydney ..	586	96	1	21	41	12·8
		13,338	2,114	44	11	5	12·5
<i>Homeward—</i>							
Sydney ..	Melbourne ..	580	102	1	23	21	12·2
Melbourne ..	Adelaide ..	500	100	2	..	..	10·4
Adelaide ..	Suez ..	7,455	1,500	26	6	26	11·8
Suez ..	Port Said ..	86	22	..	15	..	..
Port Said ..	Plymouth ..	2,990	512	10	16	45	11·7
Plymouth ..	Gravesend ..	300	54½	1	7	30	..
Gravesend ..	London ..	22	4	..	2	27	..
		11,933	2,204½	42	23	29	11·5

Totals for round voyage between Plymouth and Sydney after deductions made for Canal, and the distance between London and Plymouth :—

Distance in knots	24,561
Average speed per hour in knots	12
Total consumption of coal in tons	4,268
Consumption of coal per mile in cwts. ..	3·48

The speeds between Plymouth and Sydney give an average, say, of $12\frac{1}{2}$ knots per hour, extending over 43 days 6 hours 27 minutes; and the return voyage through the Suez Canal, after deducting the time occupied in passing through it and its mileage length, averages $11\frac{1}{2}$ for 42 days 8 hours 29 minutes, a performance which, having regard to the distances steamed over and the speed maintained, is, I believe, at the present moment without a parallel. The times occupied between the various ports show at a glance at what periods of their voyage the sails can be used with advantage.

The vessels at present employed are the

"Lusitania"	"Chimborazo"	"Cuzco"
"John Elder"	"Garonne"	"Aconcagua"

of about 4,000 tons register, and 550 to 600 nominal horse-power.

This company is building a large vessel on the Clyde at the present time; and among other well-known ship-owners, who are also adding to their fleet, may be mentioned the names of the Peninsular and Oriental Company, the British India Steam Navigation Company, Messrs. Money Wigram and Sons, and the Liverpool and Great Western Steamship Company (the Guion Line). This latter vessel is to be fitted with engines of the largest class of the three-cylinder vertical type; the high pressure cylinder will be 62 inches in diameter, and the low pressure cylinders each 90 inches in diameter, with a stroke of 5 feet 6 inches. The boilers are to carry a working pressure of 90 lbs. on the square inch, and the engines are to work up to an indicated power of 6,000 horses. The diameter of the crank shaft necks will be 23 inches, and the shaft itself will be made up in pieces. They are being constructed by Messrs. John Elder and Co.

It is not, I believe, generally known at the present day that a compound paddle-wheel engine was at work on the Thames between London and Richmond as far back as the year 1841 in a passenger steamer called the "Era." It was a Woolf's engine, with the high-pressure cylinder $17\frac{3}{8}$ inches in diameter, and the low pressure 29 inches, with a length of stroke of 20 inches; the boiler carried a working pressure of 40 lbs. on the square inch, and steam was cut off in the former at 6.6 inches in its length.

The engine was fitted with a surface condenser, steam regenerator, &c., on the system patented by Mr. Zander, a native of Sweden, the condensation of the steam being effected by its passing through a series of zigzag vertical plates, against the surfaces of which it was condensed. The boiler was on the water-tube system, on Mr. Spiller's plan—I believe the engines were made by him—and a saving of two-thirds of the ordinary consumption of fuel was claimed for the performance. Coke, and not coal, was used on board.

You will ask, and not unnaturally, how it was that, with such obvious advantages arising from the use of the compound engine, the system was allowed to slumber in London for so lengthened a period. The answer, I believe, is only to be found in the utter dislike that existed amongst steamship owners, engineers, and the travelling public in London to the general introduction of higher pressures than from 20 to 30 lbs. on marine boilers; and the fatal boiler explosion

on board the "Cricket" in the year 1847 tended greatly to this result. In time, however—but many years had glided away—the advantages of the compound engine, working from 40 lbs. on the square inch and upwards, became so apparent, that it has come to be the engine of the day. Pressures have been increased in transatlantic vessels to 90 lbs. on the square inch, and machinery to indicate 5,500 horses is being constructed for the Navy to work at a pressure of 120 lbs. per square inch on the boilers.

Generally during the last two years, steamship owners and others have been endeavouring rather to perfect what has been already done and profit by their experience than to introduce new schemes.

Boilers are now being made of iron 15 feet diameter and upwards, with a thickness of casing plates $1\frac{5}{16}$ inch, and with pressures creeping up to 90 lbs. on the square inch; boilermaking can no longer be left in the hands of the ordinary boilermaker, it has become imperative that all the various laps, joints, butt plates, &c., should be all fitted together by first-class workmen. The cylindrical form of boiler is universally adopted, and the pressure proposed for new boilers is fast approaching the average of 80 lbs. on the square inch; they are on the return tube system, and have circular fire-places and are fired at one or both ends as may best suit the requirements of the vessel; if on the latter principle they are fitted in some instances with a fire-box or combustion chamber common to all the fire-places, having Galloway's tubes introduced vertically in them; in others again the fire-boxes open; whilst some engineers prefer fire-boxes with a water space between them running across the diameter of the boiler, and others a separate fire-box to each separate fire-place.

Fox's corrugated furnace is being introduced. At a series of extensive experiments that were conducted at the Leeds forge before officials connected with the Admiralty, Board of Trade, and Lloyd's, it was proved that such a furnace of the same diameter and thickness of plates is about cent. per cent. stronger than the ordinary circular form, and it has (due to its corrugations) considerably more heating surface. An interesting trial, in two mail steamers of about the same tonnage dimensions, has just been made with these furnaces, the engines being duplicates of each other. In the one, the boilers were fitted with 18 plain furnaces, and had a grate surface of 294 square feet; in the other the boilers had 12 corrugated furnaces, and a grate surface of 260 square feet, the steam generative power of both was practically the same, and the speed of the two vessels equal.

Hepburn's expansion ring is made of the same thickness as the shell and connects the two centre plates in boiler casings thus:

with a view to obviate the ill effects of the unequal expansion that takes place in the shell, due to the difference of temperature between the top and bottom of boilers, and which during the period of raising steam is so great that pipes connecting the lower water spaces with the upper portion of the water surface are frequently fitted and a circulating current set in motion by means of a donkey pump, Weir's hydrokineter has also been introduced for a similar purpose, namely, to produce as equal a temperature as possible in all parts of the boiler. To continue this circulation after steam has been got up and during the voyage, Messrs. Menzies and Blagburn have fitted many vessels with their circulating tubes with the avowed object (1) to cause the water to circulate from the top where it is the hottest to the bottom, and so keep the thermal condition of the boiler casing equal, and (2) to carry also the protecting properties of the zinc plates that are placed to check the chemical action, from the upper portions of the boiler, to the parts below the fire-grates that at present suffer most from this destructive cause through want of proper circulation. The more effective the circulation the greater the evaporative power of the boiler, and with it is produced a less tendency for it to prime. Weir's feed-heaters are also finding favour with marine engineers, and the efficiency of boilers has been increased by their adoption; but it is only right for me to state that the Admiralty experiments tend to show that, if the most valuable properties of zinc plates are to be obtained, they should be spaced all over the inside of a boiler, at distances of not more than 6 feet apart. Other improvements have also been tried, such as building combustion chambers of bricks, making brick furnaces, &c., with a view to reduce both the weight of the boiler and the amount of water contained in it, and at the same time avoid the flat surfaces that require to be stayed in the fire-boxes, but in none of these cases have results equalled anticipation, and in most cases they have been condemned and removed.

Different forms of boilers have been introduced lately mainly with a view to carry higher pressures. Those of the water-tube principle with horizontal or slightly inclined tubes have not proved successful at sea, either from defective circulation or the tubes becoming choked up with deposit.

"Rowan's boilers" with vertical tubes have been at work for ten years, and a Passenger Certificate has been lately granted to a passenger steamer on the Tyne for three months, with machinery fitted on Mr. Loftus Perkins's system, where a pressure of 450 lbs. on the square inch is introduced, and it will be extremely interesting to hear the Report of the Surveyors of the Board of Trade when, at the end of the three months, a renewal of the certificate will doubtless be applied for. Gas coke is the description of fuel used.

Recent experience has taught us the great advantages that would accrue if access could be obtained to all the internal parts in boilers, and there is considerable room for improvement in this direction in the designs of many of those at work; but if a perfect form of boiler were produced to-morrow, several years would have to elapse before all those now at work would be worn out and replaced. Meantime,

the test of sounding by the hammer and drilling to ascertain the existing thickness of the plates must continue; but even with all the care bestowed by the employés of some owners and the Board of Trade officers, immunity from fatal accident has not been secured. I should like to see every plate that it is considered necessary to subject to the hammer test first carefully marked out in small squares, and a trained boilermaker, a lithesome spare man, capable almost of getting anywhere, engaged for the work. Let him make his mark thus \ (left to right) in each square as he proceeds in his examination; and let his superior officer, be he an engineer of the owners or an officer of the Board of Trade, follow him as far as may be in his power, make his mark the reverse way, and thus form a cross, and no portion of a plate should thus escape notice. It is only a revival to a certain extent of a good old custom allowed to fall into disuse, for I remember the time when, in most of the leading boiler shops, no plate that was to be exposed to the action of flame was permitted to be worked into a boiler without such previous test, and many a blister was thereby detected and the plates condemned.

x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x
x	x	\	\	\	\	\	\	\
\	\	\	\	\	\	\	\	\
\	\	\	\	\	\	\	\	\
\	\	\	\	\	\	\	\	\
\	\	\	\	\	\	\	\	\

The more serious character of the accidents that arise from the use of higher pressures, calls on all steamship owners for the exercise of the greatest care and caution in the periodical examination of their boilers. There are many of them that would find very great advantage from every repair and the result of every survey being duly noted in a book, and an entry made of any alteration effected in the working pressure of the boilers; such entries would enable them to trace without difficulty the history of all repairs executed since the particular boiler was first set to work, a history which, if properly recorded, would prove very valuable. I am induced to lay stress on this, for it is not long since I had a case before me officially where the owners preserved no records at all, and their superintendent engineer, a man who had been some months in their service, and in whom, up to that time, they had placed entire confidence, admitted, in cross-examination, that he did not know the pressures at which the safety-valves on the boilers of their different vessels were loaded. I need scarcely add that the fleet were not under Board of Trade inspection.

The Steam Department of the Admiralty have adopted a very excellent form of report for their periodical surveys, one well worthy the attention of many shipowners. It should be remembered that whilst reducing pressures on boilers in the Royal Navy means reducing the speed of the ship, and though the loss of speed is of less consequence probably there than under similar circumstances to them, boilers cannot receive too much attention and care at their hands with the view to ensure greater freedom from heavy repairs. Each day occu-

pied on such repairs involves a loss of the services of their vessel—in fact, a monied loss.

At the last annual session of the Institution of Naval Architects, two very interesting and instructive papers were read on “Steel for Shipbuilding” and “The Use of Steel for Marine Boilers, and some Recent Improvements in their Construction,” the former by Mr. Martell, the Chief Surveyor, and the latter by Mr. Parker, the Chief Engineer of Lloyd’s Register of British and Foreign Shipping. I commend them as worthy the perusal of all naval Officers; a very large amount of practical and useful information is contained in them.

In reply to a question put to him, Dr. Siemens thus described the nature of the material:—“Chemically speaking, the only difference is, that what we call mild steel is pure iron; it is more essentially iron than what is commonly sold as such; but, as regards the physical properties of the material, it differs in many points from iron, and ought not to be confounded with it; because, if we were to call it iron and confound it with iron, we should think it right to treat it in the same manner, whereas it requires in many respects different treatment.” Mr. Parker spoke of an average tensile strain of 28 tons on the square inch being the result obtained from over 80 tests.

In March of last year the Committee of the above Society passed sundry resolutions in regard to the use of steel in the construction of marine boilers:—

“In all cases where it is proposed to construct steel boilers for vessels classed or intended for classification in this Society’s Register Book, the Committee will be prepared to sanction a reduction in the scantlings of such boilers from those prescribed in the Society’s rules for boilers made of iron in the shell plates and stays to the extent of 25 per cent., provided the following conditions be fulfilled:—

- “1. The material to have an ultimate tensile strength of not less than 26, and not more than 30 tons per square inch of section.
- “2. A strip cut from every plate used in the construction of the furnaces and combustion chambers, and strips cut from other plates taken indiscriminately, heated uniformly to a low cherry-red and quenched in water of 82 degrees Fahrenheit, must stand bending to a curve of which the inner radius is not greater than one and a-half times the thickness of the plates tested.
- “3. All the holes to be drilled, or if they be punched, the plates to be afterwards annealed.
- “4. All plates that are dished, or flanged, or in any way worked in the fire, except those that are in compression, to be annealed after the operations are completed.
- “5. The boilers, upon completion, to be tested in the presence of one of the Society’s engineer-surveyors to not less than twice the intended working pressure.”

These resolutions were considered necessary, as it had been proved

that, in working these plates, the material, unlike iron, has its essential qualities very much injured by the ordinary operations to which it is subjected. The material is injured to the extent of 33 per cent. of its ultimate strength by the mere operation of punching, but by riming the holes out to $\frac{1}{16}$ of an inch larger, or by annealing the plate after it has been punched, the whole of the strength is returned. Another operation which injures steel to a greater comparative degree than iron is "flanging," and it is necessary in order to overcome the effects of this process to have the plates that are flanged subsequently annealed. If this precaution be not taken, it will probably be found that, after the work is completed, the plates will crack, and this circumstance has given rise to many surmises as to the cause of the apparently mysterious fractures that have been found in some steel plates. In conducting the operation of "flanging" with ordinary boilermakers' plant it becomes necessary to heat the plates locally, the effect of which is to induce in the vicinity of the heated parts a state of initial stress which in steel is much more severe than in iron. The annealing is sufficient, however, to set at rest all the disturbed particles, to relieve these strains, and thus restore the material to its normal condition. To reduce such mishaps, a firm of steel makers is now preparing plant to stamp out at two heats the front plates of a modern boiler ready flanged to receive the furnaces, and roll plates 40 feet long for casing plates, so that only one joint will be required circumferentially in many boilers.

During the last year, five cases of cracked plates have, I believe, occurred. It should be stated that these fractures were not confined to steel manufactured by any particular firm or by any particular process; they stood all the tests necessary, and without any apparent cause cracked in a most mysterious manner. Each of these cases has been investigated, and it has been proved beyond a doubt that the defect arose from improper treatment, especially in neglecting to anneal after "flanging." (See Appendix A.)

In the construction of steel boilers greater care and attention *must* be exercised with the workmanship than is required in the case of iron boilers, and the difference between the two materials and the consequent different manipulation required in each case must be realized, not only by the manager, but by the workmen who will have to use the material, for if the rivet holes in steel plates are "drifted" heavily and knocked about as iron plates usually are in boilermaking the material will be injured. We may expect to see steel boilers extensively used in preference to those made of iron where lightness or increase of pressure is an object, whilst if they are made with the care which this material requires, and it prove eventually as durable as iron, it will become a question whether a considerable reduction in the factor of safety may not still be found compatible with perfect safety and efficiency.

With regard to the relative amount of corrosion in steel as compared with iron very little can as yet be said, as so very much depends on the management. It is a question that can never be properly solved until the steel boilers at present in use have run for some

time longer. The feeling is rather at the present day that steel may not prove as durable as iron, but a recent report from Captain Dent, R.N., informs me that the steel boiler on board the London and North Western Railway Company's steam vessel the "Duke of Sutherland," running from Holyhead under his superintendence, appears to the eye to be in the same condition as the iron one with which this vessel is also fitted, the two boilers being exactly similar in all their dimensions, the thickness of plates in the case of the steel one being kept up to the same scantling as the former. Up to the present time about 50 boilers have been and are in process of construction in accordance with the above, and to enable you to go fully into the question, should you desire to do so, the Society's rules for the construction of iron boilers are attached to this paper. (See Appendix B.)

There is one point in them, however, to which I desire to draw your attention: the Society have adopted a varying contract in their formula for strength of casing plates, whether the material used be iron or steel.

Experience has so far taught them, that the length of life of the casing is longer than any other portions of a boiler, and that on the removal of the latter on account of the inner portions being worn out, the casing plates have been found to be in good condition.

With a view the better to equalize this they now allow a higher constant for thicker plates than for thinner ones, on the grounds that if a $\frac{3}{4}$ -inch plate loses one-sixteenth of its thickness from oxidation or other causes, the loss is only $8\frac{1}{3}$ per cent. of its original thickness, whereas in the case of a $\frac{1}{2}$ -inch plate it would amount to $12\frac{1}{2}$ per cent.

The Board of Trade has also somewhat reduced the scantling of casing plates in iron boilers, but as regards the introduction of steel plates, the Board of Trade has hitherto taken each case on its own basis, and made it a subject for special arrangement, whilst the Admiralty has in the few instances in which this material has been introduced in the construction of boilers for the Royal Navy only reduced the thicknesses below those required for iron plates by a very small amount. It is not, however, surprising that the Admiralty is cautious; in fact, looking to the peculiar character of the services on which the vessels are employed, such action is only prudent in view of the present uncertain knowledge as to the relative durability of the two materials.

Lloyd's Committee are carrying out another series of experiments as to the relative corrosion of iron and steel plates, each specimen weighed correctly to the $\frac{1}{50000}$ th part of its weight. They consist of six series of steel and iron discs obtained from ten of the principal iron and steel manufacturers in the Kingdom. Each disc is $4\frac{1}{2}$ inches diameter, $\frac{1}{4}$ inch thick. Half of them are turned bright all over, and the remainder have the scale left on them, and they are all weighed accurately. Each series is made up of 22 discs suspended on iron rods, insulated by glass tubes and ferrules, as shown in the one handed round to you.

They are disposed of as follows:—

Series A. Exposed to the action of the atmosphere.

" B. " " sea water.
 " C. " " bilge water.
 " D, E & F. " " hot water.

and steam in marine boilers worked under various conditions in ocean-going steamers.

The specimens will be accurately weighed at intervals, and the extent of the corrosion correctly recorded. An accurate analysis of each specimen has also been made.

But interesting and instructive as such experiments must be, the durability of the material in practical use in boilers partly or wholly constructed of it can alone solve the problem, whether steel is destined eventually to supersede iron for such purposes.

Thus far our attention has been more particularly directed to what has been and is going on in the commercial marine, and I now desire to call your attention to the modern machinery being introduced into the Royal Navy.

It is between six and seven years ago that Sir Joseph Whitworth drew the attention of marine engineers to his then new material, fluid pressed steel, having a tensile strength of 40 tons to the square inch. The metal is submitted to great pressure, whilst in the fluid state, by which means perfect soundness and homogeneity are obtained; subsequently it is forged to shape by hydraulic pressure. The distinguishing characteristics deservedly claimed for it are soundness, strength, and ductility. It is made of various tempers to suit all purposes, and it is specially adapted to those in which it is exposed to sudden and violent strains. The Admiralty at once decided on trying it for the liners of the high pressure cylinders in compound engines, and the success has been such that they have entirely abandoned the use of cast iron for them, and in some vessels the liners of both the high and low pressure cylinders are made of it. As regards its weight, a cylinder liner made from a hoop of fluid pressed steel and enlarged to size by forging having an outside diameter of $81\frac{1}{16}$ inches, a thickness of $1\frac{3}{4}$ inch, and a length of 59 inches, weights 65 cwt. Amongst the earlier vessels so fitted may be mentioned the following:—

TABLE II.

Name of Ship.	Diameter of Lining.	Length of Lining.
	Inches.	Inches.
"Amethyst"	55½	41
"Audacious"	77	46½
"Euryalus"	73	57½
"Inflexible"	70	52½
"Iris"	75	41
"	41	38½
"Mercury"	75	41
"	41	35½
"Rover"	72	57½

In the case of the "Audacious," having expansive engines with surface condensers and working with 30 lbs. pressure on the square inch, the liner was fitted to replace the original cast iron one, which had cracked after having been at work for some time, and there has been no further trouble since.

At about the same time Sir Joseph Whitworth urged its adoption for screw propeller shafting, and a forging made from a hoop of it, and forged hollow, having a length of 33 feet $6\frac{1}{2}$ inches, outside diameter $17\frac{1}{2}$ inches, diameter of hole $11\frac{3}{8}$, thus leaving the metal in the body of the shaft $3\frac{1}{8}$ inches in thickness with a diameter of collars (finished) of $33\frac{1}{2}$ inches, weighs 8 tons. Such a shaft made of solid wrought iron in the ordinary way would weigh 13 tons or 60 per cent. heavier than the hollow steel one. Table III gives you the particulars of the shafting belonging to the first five vessels on board which it was fitted.

TABLE III.

Name of Ship. H. M. S.	Total length of Shafting.	Number of Lengths.	Total Weight.	Weight if made of solid Wrought Iron.
	Ft. Ins.		Tons.	Tons.
"Bacchante"	75 11 $\frac{1}{2}$	5	19	29 $\frac{1}{2}$
"Inflexible"	283 9	14	62 $\frac{1}{2}$	97
"Iris"	139 0	7	29	43
"Mercury"	139 0	7	29	43
"Euryalus"	76 11 $\frac{1}{2}$	5	19 $\frac{1}{2}$	29 $\frac{1}{2}$

In the case of the "Inflexible" you will observe that there is a saving in weight in favour of the fluid pressed steel shafts of 34 tons, an amount of weight of very considerable moment in heavily armoured plated ships.

Sir Joseph Whitworth is now directing his attention to the construction of connecting shafts or crank axles; his idea at present appears to be to make them in pieces and then screw all together. Valuable as this material has shown itself to be, I am not aware of its having been introduced in any one case into the commercial marine; although more costly than iron, considerable weight would, by its adoption, be saved, and continuously carrying extra weight involves the continuous consumption of more coal.

At the "Great Western" Steamship era to which I have alluded, the steam fleet of Great Britain consisted of 66 paddle-wheel vessels, of which 28 were employed at home in the post office service. For its present condition I must refer you to the last number of the Navy List, but I may mention that a corvette has done her $18\frac{1}{2}$ knots in Stokes Bay, and after nearly 18 years surpassed the speed of the "Leinster" and "Connaught," two of the present Holyhead mail steamers, by half a knot per hour, and that the consumption of coal on board our heavy ironclads has been reduced to a rate of con-

sumption per indicated horse-power equal to anything yet accomplished afloat.

Two small but very important additions have within the last few years been fitted in all vessels belonging to the Royal Navy. In the first place I allude to the self-acting hanging non-return valve, introduced between all boilers and their main stop-valves, with the object that if the boiler should from any cause become injured and its own steam escape inboard, no steam from any one of the other boilers should be able to enter it through the steam pipes, thus preventing any addition to the volume of steam the injured boiler originally contained, and reducing risk under this head to a minimum. The value and efficiency of such valves has been clearly demonstrated. The second addition is the introduction of what are called "change valves." It was considered that it would be highly advantageous that in all unarmoured vessels on board which the boilers are worked at high pressures, for obvious reasons the Officer in command should be enabled to take his vessel into action at pressures of steam, say from 10 lbs. to 20 lbs., or even less, and this has been carried out by the introduction of valves, by the opening and closing of which the engines cease to work on the compound system, and steam in the boilers being reduced to these low pressures it is admitted directly into the low pressure cylinders. As this has been carried out by more than one arrangement, I deal with it in my description of the machinery in some of the vessels belonging to our Royal Navy, the principal dimensions of which will be found in Appendix C, and I propose to begin with the "Iris."

H.M.S. "Iris."

This steel despatch vessel, of 3,735 tons and 7,000 indicated horse power (as described in the Navy List), is fitted with twin-screw engines (Plate XXIV), which were designed and manufactured by Messrs. Maudslay, Sons, and Field, and consist of two pairs of horizontal compound engines, each pair being placed in separate watertight compartments, forming two distinct engine rooms. Each pair of engines has its own line of propeller shafting as in ordinary cases.

These engines, besides being fitted with all the most modern improvements, have in addition an arrangement of valves and pipes, by which steam from the boilers can be used direct in all the cylinders, so as to be enabled to work them with steam of very low pressure on all the pistons (see Plate). This arrangement was suggested in consequence of the very great advantage that it was considered an unarmoured vessel like the "Iris" would derive from being able to go into action with steam in the boilers of only a few pounds' pressure above that of the atmosphere, and it was estimated by Messrs. Maudslay that about two-thirds of the ultimate speed of the vessel might be obtained by this arrangement with steam in the engines at the atmospheric pressure. This, in the case of the "Iris," would be a speed of from 12 to 12½ knots per hour.

As saving of weight was a great object in these engines, wrought iron was used as much as possible in the framing and guides, and the

lines of propeller shafting were made, where advisable, of Whitworth's fluid compressed steel, whilst the barrel parts of the boiler casings were made of the Landore Company's mild steel, similar in quality to that of which the vessel is built.

The engines have in all eight cylinders, four high pressure and four low pressure. The high pressure cylinders are bolted on to the front of the low pressure ones, and partly recessed into them; this arrangement reduces the length of the engines on the athwartship lines of the vessel, and at the same time the cover of each cylinder can be taken off, and the pistons examined and overhauled without the removal of the high pressure cylinders. Each engine is also complete in itself, and can be used as a single engine in case of any accident happening to the other. The slide valves of each set of high and low pressure cylinders are worked by the same eccentrics and link motion, the high pressure cylinders being also fitted with a separate expansion valve working on the back of the slide valve, receiving its motion by a separate eccentric, and slotted levers for regulating the amount of expansion.

The space for the machinery being very limited, the surface condensers and air-pumps have been placed in the wings behind the cylinders. They are constructed to suit the form of the vessel, and are made entirely of brass. The air-pumps stand vertically, and are single acting, one to each set of engines, 43 inches diameter, with a stroke of 21 inches; they are worked by means of bell-crank levers, with rods passing direct from the foremost low pressure piston of each set. The cold water is circulated through the condenser by two centrifugal pumps 3 feet 9 inches diameter, driven at about 120 revolutions per minute by small independent engines. These pumps are arranged also for pumping out the water in case of accident as bilge pumps, and are capable of discharging 500 tons of water per hour.

The boilers are twelve in number, placed also in two different watertight compartments, six in each compartment; these, like the condensers, are made of different form and size to suit the space in the vessel; they are placed in the wings with the stokeholes amidships. There are two fixed funnels, that for the forward set of boilers being 7 feet 7 inches diameter, and that for the after set being 8 feet 4 inches diameter.

The screw propellers as originally fitted were four-bladed, with a diameter of 18 feet 6 inches. With these propellers set at 18 feet 2 inches pitch, and the engines working up to 7,502 indicated horse power, with 91.15 revolutions per minute, a speed of vessel of 16.577 knots was obtained. This speed not being considered satisfactory, the vessel was tried with two of the blades removed from each propeller, the engines being worked up to as much power as was considered safe to transmit through the remaining blades; this trial gave a very considerable increase of speed in proportion to the power exerted, the speed being 15.726 knots, with 4,369 indicated horse power; but as the propellers in this condition caused an excessive vibration in the vessel, it was determined to try two new four-bladed propellers of reduced diameter, namely 16 feet 3 inches. With these propellers set

at a pitch of 20 feet, a speed of 18·572 knots was obtained, the engines working up to 7,713 indicated horse power, with 97·18 revolutions per minute, thus adding nearly 2 knots to the speed, with an addition of only 211 horse power. At the same time it was determined to try two new two-bladed propellers of sufficient area and strength to transmit the whole power of the engines through them; these were made 18 feet 1½ inch diameter with a pitch of 21 feet 5 inches, and on trial gave a result of 18·587 knots per hour, with an engine power of 7,463 horses, which it will be seen is a still higher speed compared with the power exerted than was obtained with the new four-bladed propellers; but in this case, as in the former experiment with the two-bladed screws, the vibration of the vessel was so excessive, that the four-bladed propellers of the reduced diameter were finally adopted.

For the sake of ready comparison, these results are shown in the following table:—

TABLE IV.

Date of Trial.	No. of Blades	Diameter of Propeller.	Pitch of Propeller.	Revolutions per Minute.	Indicated Horse Power.	Speed of Vessel in Knots.	Slip of Propeller per cent.
1878		Ft. Ins.	Ft. Ins.				
4 Feb..	Four	18 6½	18 2	91·15	7,502	16·577	1·5 neg.
15 „	Two	18 6½	18 3	88·83	4,369	15·726	1·8 pos.
3 July.	Four	16 3	20 0	97·18	7,713	18·572	3· „
Aug..	Two	18 1½	21 5	93·	7,463	18·587	5· „

The total weight of machinery, including two auxiliary pumping engines with water in the boilers and surface condensers, but exclusive of spare gear, is 968 tons.

The arrangement of change valves adopted by Messrs. Maudslay, Sons, and Field, is one patented by Mr. Sells of that firm in 1876, and can be applied to compound engines made with two or four cylinders. By it the high and low pressure cylinders, besides being worked in the usual expansive way, can, if so desired, be directly supplied with steam from the boilers, and directly discharge their exhaust into the condenser by an arrangement in connection with the cylinder valves, by means of which the passage between the eduction of the high pressure cylinder and the low pressure slide jacket can be closed and a communication opened between the low pressure slide jacket and the main steam pipe, so that when it is desired to work with a considerably reduced pressure of steam in the boilers, both the high and low pressure cylinders are supplied with steam at the same pressure, and the eduction from both is led into the condenser, the engines being thus worked as ordinary coupled engines and the combined areas of all the cylinders being utilized.

In order that the working of the engine or engines may be readily changed from that of a compound engine, or a pair of compound engines, to that of a simple double cylinder engine, or pair of double

engines and conversely, duplicate passages and pipes are provided from the eduction of each high pressure cylinder, one of these leading to the valve chest of the low pressure cylinder and the other leading to the condenser. Duplicate passages are also provided to the supply of each of the low pressure cylinders, one of these leading from the eduction of the high pressure cylinder, and the other from the steam pipe. Each of these passages is provided with a shut-off valve, or each pair may be provided with a duplex valve, whereby, when the one of the pair is opened, the other is closed.

When the engine is to be worked as a compound engine, the valves are set so that the steam discharged from the high pressure cylinder passes to the low pressure cylinder, whence, after having done its work, it is conveyed to the condenser; but when the engine is to be worked as a simple double cylinder engine, the valves above mentioned are altered, so that the steam discharged from the high pressure cylinder passes directly to the condenser, and the low pressure cylinder receives its steam directly from the steam pipe, discharging as before into the condenser.

Plate XXIV,¹ Fig. 1, represents a section through the low pressure valve casing with both cylinders on the same axis. *A* is the high pressure cylinder and *B* the low pressure cylinder having the slide facing *C*; *D* is the exhaust pipe from the high pressure and *E* the exhaust pipe from the low pressure cylinder; *F* is a branch from the main steam pipe; *G* is a duplex valve which can seat either, as shown in Fig. 1, in which case the exhaust from the high pressure cylinder flows by the pipe *E* to the condenser; *H* is a shut-off valve which when seated, as shown, prevents the supply of steam from the main steam pipe to the low pressure cylinder, but which can be opened so as to supply steam thereto when the valve *G* is moved to *g*.

Fig. 2 is a sectional plan of the cylinders *A* and *B* of a compound engine, placed side by side, showing an arrangement of valves for such engines. *C* is the low pressure slide jacket; *D* is the discharge passage from the high pressure cylinders; *E* is the exhaust pipe leading to the condenser, and *F* is the steam pipe from the boilers; *G* is a duplex valve whereby the exhaust from the high pressure cylinder can be permitted to flow into the reservoir supplying the low pressure cylinder, or can be made to pass to the condenser when the valve *G* is moved to *g*; *H* is a shut-off valve, which either cuts off or admits steam from the steam pipe to the low pressure reservoir.

The next vessel whose machinery I draw attention to is the "Inflexible."

H.M.S. "Inflexible."

The "Inflexible," of 11,406 tons and 8,000 indicated horse power, according to the Navy List, is fitted with twin-screw engines, by Messrs. John Elder and Co., of Glasgow, and each pair stands in an engine room separate and distinct by itself, the two being separated

¹ The Institution is indebted to the proprietors of "The Engineer," for the reproduction of this plate.—ED.

by a longitudinal watertight bulk-head with watertight doors fitted in it running along the centre line of the ship.

The arrangement of the stoke-holes (four in number) differs from that on board any other iron-clad vessel in the Royal Navy, two of them being forward and two abaft of the engines, and in each stoke-hole there are three boilers, making twelve in all. The engines are of the compound type, having three cylinders, one high and two low pressure.

The working barrels of the cylinders are cast separately and distinct from the casings, the barrel of the high pressure cylinder being made of Whitworth's fluid compressed steel, and those for the two low pressure cylinders of cast iron.

Each piston has two piston rods 7 inches in diameter with one cross-head common to both.

The slide valves are of the piston type with cast iron packing rings, and are worked by Gooch's gear, which gives a constant lead to all grades of expansion. An expansion valve is also fitted to each cylinder having ports round the valve chambers, and is worked by a vibrating motion.

The engines are reversed by means of a steam cylinder fitted with an hydraulic break assisted by a starting valve, from which steam passes into the low pressure valve casings. The steam after passing through the high pressure cylinder passes into the low pressure cylinders, whence it is exhausted into two independent surface condensers.

The surface condensers are also fitted with a common injection pipe, and so arranged that they can be worked as common condensers. Each condenser has its own independent air pump, 34 inches diameter with a length of stroke of 2 feet 3 inches, worked by levers from the piston cross-heads. The circulating water is forced through the tubes of the condensers by a centrifugal pump worked by a separate engine. It is also fitted as a bilge pump, being placed at a high level in the engine room for the purpose of pumping the water out of the ship in the event of emergency arising, separate connections being fitted to the pump for that purpose. Each set of engines is fitted with two feed and two bilge pumps, each $7\frac{1}{2}$ inches diameter and 2 feet 3 inches length of stroke, worked from the air pump levers.

The crank shaft is of wrought iron, made in three pieces coupled together, and the cranks are placed at an angle of 120 degrees to each other. The thrust block is of cast iron, fixed to the foundation plate; the thrust being taken in the usual way on brass collars. The propeller shafting is hollow and is made of Whitworth's fluid compressed steel.

The boilers (Plate XXV), are arranged in four separate compartments—two before and two abaft the engine room; the funnels are placed at the extreme ends of both the fore and aft boiler rooms to suit the requirements of the turret arrangements. The arrangement of engines and boilers, which is special to this ship, was adopted for the purpose of getting the whole of the machinery within the armoured citadel, and although this arrangement of machinery is novel, there was on the six hours' full power trial as good a supply of air to the furnaces, and as good ventilation in the engine and boiler rooms

generally, as any ship in the Service. This is proved by the fact of the large power obtained during the six hours' trial without any steam blast being used.

The boilers, twelve in number, are of an oval shape having flat sides, and of three different sizes. The four smallest boilers, in addition to their connections to the main steam pipe, are fitted with a separate set of steam pipes for supplying the auxiliary engines with steam.

At the six hours' official trial on the 14th November, 1878, at Portsmouth, the average indicated horse power exerted was 8,487, with $73\frac{1}{4}$ revolutions per minute, and with a pressure of steam of 61 lbs. on the boilers, and the maximum indicated power attained during the run amounted to 8,909 horses, the average consumption being 2.06 lbs. of coal per indicated horse power per hour.

The use of piston slide valves is not altogether new in engines of the Royal Navy. Thirty years ago they were fitted in the 4-cylinder engines constructed by Messrs. Maudslay, Sons, and Field for the Royal Navy, as also in the engines of the "Basilisk" 400 horse power paddle wheel frigate, and the Holyhead Mail Packet "Llewellyn" by Miller, Ravenhill and Co., but were abandoned at that time by both firms in consequence of the difficulty of handling them, neither steam nor hydraulic pressure having at that period been applied to the starting gear of marine engines, a system now some years since introduced into large engines in the Royal Navy as also into those in the commercial marine.

H.M.S.S. "Nelson" and "Northampton."

I follow on with the sister ships, "Nelson" and "Northampton."

The "Nelson," of 7,323 tons and 6,000 horse-power, as recorded in the Navy List, is also fitted with twin-screw engines, by Messrs. John Elder and Co., a watertight bulkhead rising from the keel, separating the engine rooms on the fore and aft line of the vessel. The engines are of the 2-cylinder vertical type, and the shafting is all made of hammered scrap iron.

The official trial of them took place at Plymouth in March, 1878, and at the full power trial of 6 hours' duration the average indicated horse power was 6,246, with 79.05 revolutions per minute, and a pressure of steam on the boiler of 60 lbs. on the square inch; at the half-power trial of 4 hours' duration the indicated horse power was 3,083, with 63.35 revolutions per minute, and a pressure of steam on the boilers of 60 lbs.

The average consumption of coal during the full power trial being 2.14 lbs. per indicated horse power per hour, and during the half-power, trial 1.47 lbs. of coal per indicated horse power per hour. This was also obtained without the use of the steam blast. The above two results are equal, if not superior, to any equally well authenticated performance up to the present time.

But interesting as these recorded facts are, the peculiar novelty in these particular engines is the abandonment of the ordinary heavy cast iron foundation frames. With a view to reducing the weight of

the engines as much as possible, these heavy cast iron sole frames are dispensed with, and four light forgings to carry the crank shaft bearings and the lower ends of the columns are substituted. These light sole plates are carried by four transverse box girders, the sides of each are built immediately over two of the ship's frames, the frames and superstructure together forming a box girder 38 feet long, 7 feet deep in the centre, and 3 feet 3 inches deep at the ends; the load being principally carried at the centre of the engines, a distance of 12 feet on either side from the centre of the girder. The lateral rigidity of these girders is assisted by inserting brackets between them over the keelsons.

The heavy cast iron vertical frames, on the top of which the cylinders are always placed, are also abandoned, and light wrought iron engine columns and girders substituted; they are trussed diagonally from one engine to the other, and to the transversed girder near their ends. (Plates XXVI and XXVII.)

The machinery of H.M.S. "Northampton" was manufactured by Messrs. John Penn and Son, of Greenwich, and consists of two sets of inverted 3-cylinder engines driving twin-screws. They are of their usual vertical type, fitted with surface condensers. When working at the full power of 6,000 horses, they are simple expansive engines, working with steam of 60 lbs. pressure cut off at about one-fifth of the stroke, and making 85 revolutions per minute. When working, however, at half power the engines are compound engines, the steam from the boilers being admitted into one cylinder only of each set, and expanded simultaneously into the other two before passing into the condenser. The power exerted under these circumstances is 3,000 horses, and the number of revolutions 68. This compound system is also used for any less power than 3,000 horses. The engines may also be worked as simple expansive engines with low-pressure steam. Therefore at these reduced powers (which are those ordinarily used by men-of-war when cruising) the vessel has all the advantages of compound engines in point of economy, &c., while there is an actual gain at very small powers in not having a low pressure cylinder disproportionately large.

You will of course perceive that this arrangement, when working with the three cylinders all taking steam from the boilers, requires no change valves to work with steam of any reduced pressure.

The alteration from one system to another is effected in a few minutes by opening or closing, as may be required, stop-valves placed in the exhaust pipes, and in the pipe leading from the first cylinder to the other two. The change can be effected, if necessary, without stopping the engines.

Each cylinder is supported upon two cast iron columns, which carry the piston rod guides in the usual manner; the three cylinders of each set of engines being tied together by wrought iron rods, which are continued to the transverse bulkheads of the ship to prevent derangement when ramming. Each cylinder has a double-ported slide on the equilibrium principle, and an expansion slide working at the back of it, so fitted as to cut off the steam at any point between $\frac{1}{10}$ and $\frac{9}{10}$

of the stroke. The main slides are worked by link-motion in the usual manner, and steam starting-gear is fitted in order that the engines may be reversed as rapidly as possible. The alteration of the cut-off of the expansion valves is effected by hand-gear, and it is not necessary to interfere with this gear when stopping or reversing the engines.

An important advantage claimed by the makers of these engines from the three cylinders being equal, and from the cranks being placed at equal angles, is an extreme evenness of motion at slow speeds arising from their perfect balance. This will be appreciated by those who have seen unbalanced 2-cylinder compound engines driven slow.

It may be added that in any case where weight is of great importance, it would be easy to replace the cast iron columns and frames used in the "Northampton" by wrought iron or steel, by which, no doubt, a considerable saving of weight would be effected.

The vessel came round from Glasgow to Plymouth under her own steam. She has since been under weigh on trial, and her machinery has been accepted by the Admiralty. So soon as she is commissioned, it is proposed that a series of trials should take place to test her consumption of coal at various speeds, and, I need scarcely add, these are looked forward to with great interest.

H.M.S. "Shannon."

I now come to H.M.S. "Shannon." She is an armour-plated frigate, described in the Navy List as of 5,439 tons and 3,378 indicated horse power, and was the first vessel in the Navy fitted with *change valves*, which were decided to be introduced during the construction of her engines. Her engines, made by Messrs. Laird Brothers of Birkenhead, are of the usual horizontal type, having four cylinders, two high pressure ones and two low pressure, with surface condensers.

On their official trial the engines exerted an indicated power of 3,542 horses, with an average of 65 revolutions per minute.

Plate XXVIII shows you a section through her main slide and expansion slide valves, and it requires no explanation from me. The change valves are in point of fact stop valves, and are so arranged that when steam is to be used of a reduced pressure, it acts only on the larger pistons of the low pressure cylinders, whilst the small pistons are moving backwards and forwards in steam common to both sides of them.

The "Comus" Class.

These vessels are constructed of steel and iron cased with wood, of 2,383 tons as per the Navy List, and 2,800 indicated horse power. The "Comus," "Champion," and "Carysfort" were built and engined by Messrs. John Elder and Co.

The screw propeller of the "Comus" is driven by a set of horizontal compound engines with return connecting rods. The engines have one high pressure and two low pressure cylinders, and are so arranged as to be capable of being converted into simple engines to work at

30 lbs. on the square inch or under, by means of a separate flat-faced valve (or change valve).

The high pressure slide valve is placed on the forward side of its respective cylinder, is flat-faced, and driven directly from the crank shaft by means of eccentrics and the ordinary link motion. The valves of the low pressure cylinders are placed on the top of them, receiving their motion from eccentrics, and link motion through an intermediate or weigh shaft and levers. The slide valves of all three cylinders are single ported, and are fitted with balance rings on the back of them for the purpose of relieving the pressure.

The usual expansion valves are dispensed with, and none are fitted, but when it is desirable to alter the rate of expansion this can be done by "linking up" all the valves at the same time; as is well known the opening of ports for the admission of steam is often very much reduced when working "linked up;" to obviate this, the ends of each valve have an extra port for the admission of steam, these ports being so arranged as to open on to the face at the lap portion of the valve, the admission of steam being controlled by fixed plates attached to the slide valve casings.

The engines are changed from compound to simple, and *vice versa*, by means of a flat-faced slide valve placed inside a chest, having ports with connections to the low pressure valve casings and to the condenser, the change being effected by removing the valve along the face and thus uncovering the communication from the boilers to the low pressure valve casings, still leaving the communication open to the high pressure cylinder, thus making the steam common to all the cylinders, and at the same time covering the high pressure exhaust connection to the low pressure casing, and opening a direct communication with the surface condenser. Before changing the engines from compound to simple they must be stopped, and the boiler pressure reduced from 60 lbs. on the square inch to 30 lbs., or any lower pressure desired, and while this is being done, the "change valve" is moved as above described. The time required to effect this was found to be in the case of the "Comus" only four minutes, so that the time from working compound to again working as simple engines was not more than five minutes, and the engines made at full speed $96\frac{1}{2}$ revolutions per minute, and exerted on their official trial an indicated power of 2,406 horses.

The propellers of the "Comus" and "Champion" are fitted to lift on the usual method adopted in Her Majesty's Service; the propeller of the "Carysfort" is of the feathering description, also with two blades. The feathering gear of the "Carysfort" is enclosed in the propeller boss, which is slightly enlarged for that purpose, and is actuated from the inside of the ship by a shaft passing through the stern shaft, which is hollow, having on the inner end of it a worm, which is worked by a small worm contained in the aftermost coupling. On the outer end of this internal shaft is keyed a double-ended lever, and the stems of the propeller blades have each a lever cast with it; the connection between the double-ended levers and those on the propeller blades is effected by means of links having "ball and socket"

joints; this kind of joint being necessary on account of the angular motion of the different levers not being in the same direction to each other. When it is required to feather the blades, the engines are stopped with the propeller blades vertical, and kept in this position by the friction break; then by turning the small worm with a ratchet lever, motion is given to the inner shaft, lever and links; and the blades thus feathered. The motion is sufficient to alter the blades from the working pitch to a fore and aft position.

The hulls of the "Cleopatra," "Conquest," and "Curaçoa" were also allotted to Messrs. John Elder and Co. for construction, and their machinery to Messrs. Humphrys, Tennant, and Co., of London; the engines are on the horizontal system, and the cylinders are four in number, two high pressure and two low pressure. At the official trial of the "Cleopatra," the engines made 108 revolutions a minute, and developed an indicated power of 2,616 horses. The "change valves" as fitted are an arrangement of the ordinary stop valves.

Torpedo Vessels.

The two firms engrossing most attention at the present time as constructors of *torpedo vessels* and their machinery, are Messrs. Thornycroft and Co., and Messrs. Yarrow and Co.; a paper was read at this Institution about two years ago by a member of the first-named firm, and the author regrets that he has not received any information from them for this paper.¹

Messrs. Yarrow and Co., of Poplar (Plate XXIX), drive the propeller only (which is of the ordinary form) with the main engines, and fit an auxiliary pair for working the air pumps. The former have inverted cylinders on the compound system, bolted together, standing on columns attached to the cast iron foundation frame; the slide faces on the cylinder are of iron, but cast separately, and are pinned on; the slide valves are of brass; all the moving parts usually made of wrought iron are of Bessemer steel, with holes drilled through the larger ones with the object of saving weight; the propeller is forged of steel subsequently tooled up and finished accurately to the dimensions required. The diameter of the high pressure cylinder is $12\frac{1}{2}$ inches, that of the low pressure is 22 inches, with a length of stroke of 12 inches, and when running at their greatest speed the engines make about 500 revolutions per minute, the steam gauge indicating 130 lbs. pressure of steam. The surface condenser is circular, and made of copper. The tubes are of brass, and are placed horizontally, the water passing through them. The boiler is of the locomotive type, the casing being made of steel plates, the furnaces either of copper or of Lowmoor iron, and the boiler is always proved by hydraulic pressure to double the working one on the square inch prior to being set to work. Following the French system, they have a hole drilled through all their screw stays, so that in the event of a stay giving way in the body when steam is up, the leak at once shows itself. The furnace is dependent for its supply of air on a fan blast. In all vessels fitted by this firm they introduce the improvement patented by Mr. Yarrow in

¹ See Journal, Vol. xxi, page 611, *et seq.*

August, 1878, which has for its object the security of immunity from danger to the engineers when on duty in the event of a failure occurring in some portion of the boiler or boilers, such as the bursting or fusing of some of the tubes, &c. Trouble has been experienced in consequence of this latter occurrence taking place in some torpedo vessels belonging to foreign Governments. This improvement is obtained by the introduction between the fan which supplies the forced draught and the furnace of valves so arranged, that whilst they allow the air to pass freely to it from the fan act as non-return valves to any current of air or steam that may attempt to pass through them in the opposite direction.

The fan A is driven in any suitable manner so as to draw air from the external atmosphere through a pipe B, and direct the same into the stokehole C; D is the boiler, and E is the furnace with the fire door F, and ash-pit at G. Bulkheads are provided at I, I, and I', the central one I' is thus interposed between the fan A and the fires at E, and in this central bulkhead openings are formed which are fitted with valves K, arranged in such a manner as to be opened by the air to allow it to pass freely in the direction indicated by the corresponding arrows from the fan to the fire, but to be closed by a current in the opposite direction. The fire door is arranged to close by its own gravity, so that it may be always closed unless opened at the will of the stoker by a treadle motion. By means of this arrangement any current taking place in the opposite direction to the arrows from the sudden egress of steam or flame gases, the valves will immediately close.

In some of the last new vessels they have abandoned the ordinary arrangement of standing funnel or funnels; the smoke box is connected with uptakes leading to both sides of the vessel in which dampers are fitted, and the smoke and gases are emitted through either the larboard or starboard one as occasion may require, the object being to do this on the *lee* side as far as practicable in approaching an enemy, and in their latest vessels this arrangement is carried right aft to enable the smoke, &c., to pass out at the stern of the vessel.

They have also introduced a second rudder which acts simultaneously and by the same gear with the one at the stern; it is placed well forward in the vessel, only about 10 feet from the stem. When at work it projects below the keel, and experience shows it affects the turning powers of the vessel in a very marked degree, as the latter can turn in a circle having a diameter of from 3 to $3\frac{1}{2}$ times its own length. When not at work, or the vessel has to take the ground, this forward rudder is drawn up into a kind of well, built in the vessel for it, and in which it can be examined at any time at the desire of the Officer in command.

One of these vessels fitted on this system recently, when out on trial, performed a figure of 8 across the tide at high water about two-thirds flood, opposite the Houses of Parliament above Westminster Bridge, the number of revolutions of the engines at the time indicating a speed of vessel of about 15 knots an hour.

In a torpedo vessel 86 feet long, Messrs. Yarrow have obtained the high speed of a trifle over 21 knots per hour at the measured mile; the machinery exerted an indicated power of 500 horses, and the total

weight of it, including water in the boiler, was 13 tons, being $\cdot 52$ of a cwt. per indicated horse-power. On the 19th of March a higher rate of speed was obtained at an official trial, in Long Reach, of a vessel 86 feet long, 11 feet beam; the mean of 6 runs gave an average speed of 21.93 knots; the best pair of runs gave 22.25 knots, with a maximum revolution of 540 per minute, and a pressure of steam of 124 lbs. on the square inch, and this extraordinary result was obtained with a steel screw, 4 feet 4 inches diameter, 5 feet pitch.

The great objection to the form of boiler of the locomotive type for use in torpedo boats is its weight and the risk involved in a sea-way owing to the fluctuations of the water level, which may momentarily expose a portion of the tube ends or fire-box top to the action of the flame without being covered with water, and the experiments being conducted at Portsmouth with the Herischoff type of boiler have recently attracted attention. The boiler casing, as you know, contains a coiled spiral tube, and is a water-tube boiler.

Messrs. Yarrow and Co. are also about to introduce a form of water-tube boiler which appears to possess some good qualities, but which Mr. Yarrow tells me has not been sufficiently tested to pronounce it free from defects, which may possibly be found only after long usage.

The main features of the boiler are that the tubes are filled with water. A circulating pump is provided to keep on a constant supply of water through all the tubes.

The boiler appears to be very compact and light, and I have myself seen steam got up to 80 lbs. per square inch in between seven and eight minutes.

One essential feature in a good boiler no doubt is facility of repair, and that is one of the main points Messrs. Yarrow and Co. have had in view in designing this boiler. At present only one such boiler has been made by them, of about 25 indicated horse-power, which has run about 1,000 miles, using Thames water, without any apparent difficulty in maintaining steam, and without any trouble having been experienced with it.

I simply draw attention to these boilers as pointing to the direction in which improvements in the future may be made.

The results obtained in the "Lightning" and other early torpedo vessels led the Admiralty to determine to try such machinery on a large scale, and the following description will be interesting to you:—

H.M.S. "Polyphemus."

H.M.S. "Polyphemus" is a ram building of steel of 2,640 tons, and to be propelled by double screw engines of 5,500 indicated horse power, at the present time being constructed by Messrs. Humphrys, Tennant, and Co. The engines are of the horizontal single piston rod type as usually made by that firm, each pair of engines having their high and low pressure cylinders. There are to be no expansion valves, and everything about the engines is, as far as possible, schemed for simplicity and saving of weight, therefore in this case the old practice

of the double throw shaft with three bearings is resorted to, consequently it will be made in one piece. The piston rods, slide valve rods, and all bolts will be made of steel. The inboard propeller shafting will be made hollow, and of Whitworth's fluid compressed steel. The surface condensers will be of brass. The boilers will be ten in number, on the locomotive principle, to carry a working pressure of 120 lbs. on the square inch, having iron fire-boxes and brass tubes, with steel casing plates $\frac{5}{8}$ inch thick. The stays are all to be made of steel. All the steel used in the construction of the boilers will be supplied by the Landore Steel Company. The uptakes of the boilers will all lead into one chimney, which will be fixed. The boilers themselves will stand athwartships, and be divided into two groups of three, and two in each, with a fore and aft bulkhead running between them, thus making four stokeholes, which will be air tight; and when the engines are working at full speed the furnaces will be fed by air by a fan blast. It is anticipated that at lower speeds the air passing through the downcast shafts in the usual way may prove sufficient to supply the furnaces.

The total estimated weight of the machinery, including water in the boilers, is 490 tons, including the extra weight of spare gear, taken at 10 tons. At 490 tons the weight gives an average of only 1.782 cwt. per indicated horse power, and should the contemplated results be satisfactorily obtained, a great change in the type of machinery for future vessels in the Royal Navy would appear to be imminent.

In the summer of last year our attention was called to a steam launch belonging to the American Navy, and which had been brought to London by Colonel Mallory, of the United States Navy, fitted with a propeller capable of acting either as the steering or the propelling power, and possessing another great advantage, in that the main engines never required reversing for the vessel to go astern. I cannot do better than allude to the advantages claimed for this propeller.

A vessel can be moved ahead, astern, or sideways, or be turned in a circle the diameter of which does not exceed her own length, and otherwise manœuvred, with perfect ease and great rapidity by the helmsman without stopping or reversing the engines. She can, on approaching a quay, be moved sideways to and fro without first going astern or ahead, and can be steered with the same readiness in whichever direction she is moving, and for this no rudder is required, although it may be prudent to carry one on board to be shipped in case of accident to her machinery.

The engines always move in the same direction, and no reversing gear is required. The course of the ship is reversed by turning the propeller round its axis through half a circle, and the general handiness of the vessel's movements reduces very greatly the risk of collision.

The system had been successfully tried in America, and one vessel is stated to have steamed nearly 5,000 miles fitted on this system without a rudder, and the plan had been examined and reported on favourably by the engineers of the United States Navy.

Plate XXIII in this volume of the Journal¹ shows the position of the propeller and the machinery for driving it in a steam launch. The former is carried on a short horizontal shaft within the boss of the propeller, which is elongated for the purpose of receiving it, and to one end of which the blades are attached, and motion is conveyed to it by a pair of mitre wheels driven by a vertical shaft enclosed in a tube. To this shaft a small pair of horizontal engines are attached, which stand aft and occupy the space through which the ordinary tiller works; they are always working in the same direction *ahead*. The ordinary steering by the propeller is performed by hand, but steam power is in reserve when rapid manœuvring is required. And you will observe a pair of steering engines at the base of the column carrying the steering wheel capable of being rapidly thrown in and out of gear by means of a lever, so that the propeller itself can be rapidly revolved around its vertical axis from ahead to astern or *vice versa*, or fixed temporarily at any required number of degrees in the entire circle, and whatever its position it always revolves around the same horizontal plane, whilst the vessel herself can be brought to a state of rest by the use of this motion. A tell tube or indicator is fitted, which communicates to the steersman the exact position of the propeller. The perfect command over the vessel possessed by the steersman was most clearly demonstrated, whether the launch was moving ahead, astern, or sideways, and she turned in a circle having her own length for its diameter.

The Admiralty has ordered a steam launch to be fitted on this system, and it may come into use for such purposes, but the great weight the system necessitates being placed in the extreme after part of the vessel will probably limit its introduction into torpedo vessels.

Credit for what they are doing in connection with steam navigation is deserved by very many whose names I have not brought under your notice; there is so much that is interesting going on at the present time, that I have found it impossible to condense within the limits of a paper (lengthy as this has been) all the information that I could have desired to lay before you. I have given you an outline of what is being carried out in our commercial marine fleet, and I have dwelt at some length on the different types of machinery recently constructed and being constructed for vessels of the Royal Navy. I feel our thanks are due to the Lords Commissioners of the Admiralty, Lloyd's Committee of British and Foreign Shipping, many of my own engineering friends, steamship owners and others, who so liberally responded to the request I made them, and enabled me to lay before you their present experience. I have attempted to do this in a form that I hope will prove satisfactory to the Council and Members of this Institution as also to them. My facts are authentic; and permit me, in conclusion, to express the hope, that whilst they may prove instructive at the present time, this record of them may conduce to future progress in Ocean Steam Navigation.

¹ See Mr. White's paper on "The Turning Powers of Ships," *ante*, page 557, *et seq.*—Ed.

APPENDIX A.

No. 400.

*Lloyd's Register of British
and Foreign Shipping,
2, White Lion Court, Cornhill, London, E.C.,
27th April, 1878.*

SIR,

It has been brought to the notice of the Committee that in the case of some of the steel boilers now being constructed for vessels intended for classification in the Society's Register Book, the care necessary to be exercised in the working of this material has not been sufficiently recognised, and the plates have in consequence been greatly injured by the improper treatment to which they have been subjected, having in some instances cracked after they had been riveted up.

The Committee feel that it is of the utmost importance that the special qualities of the material should be duly appreciated by those engaged in the working of it, as the frequent occurrence of such unsatisfactory results, although due to improper manipulation, might tend to throw unjust suspicion upon steel for the purposes of marine boiler making.

I am therefore directed to request that you will bestow special care and attention upon the workmanship generally in the steel boilers building in your district. In addition to satisfying yourself that the requisite tests are satisfactorily carried out, you should take the necessary precautions to insure that all plates which are flanged or otherwise locally worked in the fire are subsequently annealed; and as there has been found to be considerable disparity in the shearing strength of the steel employed for rivets, this matter should likewise receive your careful attention.

In any case where there may be an absence of the needful care in the working of the material, you should draw attention of the Boilermaker to the fact, and if necessary report the circumstance to the Committee.

I am,

Your obedient Servant,
BERNARD WAYMOUTH,
Secretary.

APPENDIX B.

LLOYD'S REGISTER OF BRITISH AND FOREIGN SHIPPING.

Rules for Determining the Working Pressure in New Boilers.

Cylindrical Shells.—The strength of circular shells to be calculated from the actual strength of the longitudinal joint by the following formula:—

$$\frac{C \times T \times B}{D} = \text{working pressure.}$$

where C = constant as per following table.

T = thickness of plates in inches.

D = mean diameter of shell in inches.

B = percentage of strength of joint found as follows—the least percentage to be taken.

For plate at joint $B = \frac{p - d}{p} \times 100$.

For rivets at joint $B = \frac{n \times a}{p \times T} \times 100$ with punched holes.

$B = \frac{n \times a}{p \times T} \times 90$ with drilled holes.

(In case of rivets being in double shear, $1.75a$ is to be used instead of a)

where p = pitch of rivets.

d = diameter of rivets.

a = sectional area of rivets.

n = number of rows of rivets.

NOTE.—In Steel Boilers it is required that the strength of the rivets used to resist shearing should be shown to be at least 26 tons per square inch. If it is less than 26 tons per square inch, the rivet area should be proportionately increased.

TABLE OF CONSTANTS.

IRON BOILERS.

Description of Longitudinal Joint.	For Plates $\frac{1}{2}$ inch thick and under.	For Plates $\frac{3}{4}$ thick and above $\frac{1}{2}$ inch.	For Plates above $\frac{3}{4}$ inch thick.
Lap joint, punched holes	155	165	170
" drilled holes	170	180	190
Double butt strap joint, punched holes..	170	180	190
" " drilled holes ..	180	190	200

STEEL BOILERS.

Description of Longitudinal Joint.	For Plates $\frac{3}{8}$ thick and under.	For Plates $\frac{9}{16}$ thick and above $\frac{3}{8}$.	For Plates $\frac{3}{4}$ thick and above $\frac{9}{16}$.	For Plates above $\frac{3}{4}$ thick.
Lap joints.. ..	200	215	230	240
Double butt strap joints..	215	230	250	260

Note.—The inside butt strap to be at least $\frac{3}{4}$ the thickness of the plate.

NOTE.—For the shell plates of superheaters or steam chests exposed to the direct action of the flame, the constants should be $\frac{2}{3}$ of those given in the above tables.

Proper deductions are to be made for openings in shell.

All manholes in circular shells to be stiffened with compensating rings,

The shell plates under domes in boilers so fitted, to be stayed from the top of the dome or otherwise stiffened.

Stays.—The stays supporting the flat surfaces are not to be subjected to a greater strain than 6,000 lbs. per square inch of section if of iron, and 8,000 lbs. if of steel, calculated from the weakest part of the stay or fastening, and no steel stays are to be welded.

Flat Plates.—The strength of flat plates supported by stays to be taken from the following formula :—

$$\frac{C \times T^2}{P^2} = \text{working pressure in lbs. per square inch.}$$

where T = thickness of plate in sixteenths of an inch.

P = greatest pitch in inches.

C = 90 for plates $\frac{7}{16}$ thick and below fitted with screw stays with riveted heads.

C = 100 for plates above $\frac{7}{16}$ fitted with screw stays with riveted heads.

C = 110 for plates $\frac{7}{16}$ thick and under fitted with screw stays and nuts.

$C = 120$ for plates above $\frac{1}{16}$ fitted with screw stays and nuts.

$C = 140$ for plates fitted with stays with double nuts.

$C = 160$ for plates fitted with stays with double nuts, and washers at least $\frac{1}{2}$ thickness of plates and a diameter of $\frac{2}{3}$ of the pitch, riveted to the plates.

NOTE.—In the case of front plates of boilers in the steam space these numbers should be reduced 20 per cent., unless the plates are guarded from the direct action of the heat.

Girders.—The strength of girders supporting the tops of combustion chambers and other flat surface to be taken from the following formula:—

$$\frac{C \times d^2 \times T}{(L-P) \times D \times L} = \text{working pressure in lbs. per square inch.}$$

where L = length of girder.

P = pitch of stays.

D = distance apart of girders.

d = depth of girder at centre.

T = thickness of girder at centre. All these dimensions to be taken in inches.

$C = \begin{cases} 6,000, & \text{if there is one stay to each girder.} \\ 9,000, & \text{if there are two or three stays to each girder.} \\ 10,200, & \text{if there are four stays to each girder.} \end{cases}$

Collapsing of Circular Furnaces.—The strength of furnaces to resist collapsing to be calculated from the following formula:—

$$\frac{89,600 \times T^2}{L \times D} = \text{working pressure in lbs. per square inch.}$$

where 89,600 = constant.

T = thickness of plates in inches.

D = outside diameter of furnace in inches.

L = length of furnaces in feet. If rings are fitted, the length between rings to be taken.

The pressure in no case to exceed $\frac{8,000 \times T}{D}$

Donkey Boilers.—The iron used in the construction of the fire-boxes, uptakes, and water-tubes of donkey boilers shall be of good quality, and to the satisfaction of the Surveyors, who may in any cases where they deem it advisable apply the following tests:—

Thickness of Plates.	To bend cold through an angle of	
	With the Grain.	Across the Grain.
$\frac{5}{16}$	80°	45°
$\frac{3}{8}$	70°	35°
$\frac{1}{2}$	55°	25°
$\frac{5}{8}$	40°	20°

The material to stand bending *hot* to an angle of 90 degrees, over a radius of not less than $1\frac{1}{2}$ times the thickness of the plates.

Lloyd's Register of British and Foreign Shipping,
2, White Lion Court, Cornhill.

The CHAIRMAN : I am sure we have all listened with the greatest interest to the very remarkable collection of facts so lucidly and ably put before us by Mr. Ravenhill. I think all naval Officers will derive a certain amount of satisfaction from seeing how very admirably the Admiralty have kept pace, if not absolutely led the way, in all the modern improvements in steam engines, and that the reproach which has been sometimes cast upon their performances, that they were slow to adopt improvements, has no foundation in fact. Certainly not, in so far as regards these very various and very interesting new methods of applying steam to the propulsion of ships, which have been so well described by Mr. Ravenhill. The particular points which he has brought before us are 'the very great advantages of compound engines, and the extraordinary diminution in the consumption of coals that follows from their use ; also the remarkable increase, which really almost passes one's belief, in the pressure now used on the safety valves of steam boilers. Instead of pressures of 5 lbs. per square inch, we hear from Mr. Ravenhill that an average of 80 lbs. is now obtained, and that they are going on to 90, and he mentioned some vessel which was working with something like 150 lbs. on the square inch. Of course these enormous pressures will require very great care, and I feel perfectly certain the naval Officers and engineers who are succeeding us will use with the greatest possible care, and with every appliance that science can bring to their aid, these most powerful inventions, and support the honour of the flag, and the bright and glorious name the British Navy has always held. I shall say no more upon the subject, except that one or two very ingenious things, so ingenious that one can hardly pass them by without a word of notice, have been brought before you. That system of the change valves, by which you change from a compound engine of high pressure to a low pressure, and an ordinary working engine, will be found, I am perfectly certain, a very great advantage, in many instances in which you have to go into action, and in which you would not like to use so high a pressure as 80 or 90 lbs. ; consumption of coal I have adverted to ; it is a most important consideration with ships so loaded with armour plating that any means should be taken by which we can lighten the load of other matters we have to carry. When we can spare hundreds of tons in our engines and coals we can apply some portion of that saving to the armament, both offensive and defensive, of our ships. Another very ingenious matter is the way in which the weights of heavy masses of cast iron may be greatly diminished by substituting steel. It is in the substitution of steel for iron that we shall find a remedy for the enormous weights our ships have now to carry, and which will enable them hereafter, without any increase of their dimensions, to support stronger armour, bigger guns, and greater speed. We shall be glad to hear any gentleman who feels disposed to enter into this discussion, and to ask any questions which may enable the lecturer to give such explanations as may seem requisite.

Commander CURTIS : I am sure all naval Officers must be very much indebted to Mr. Ravenhill for the way in which he has explained the compound engines, for it is to those and the use of high pressure steam that we owe the present economy of fuel. I should like to ask if combustion chambers could not be made under the boiler with return tubes through the steam. Mr. Thornycroft asked me if I could propose anything to prevent coals going up the chimney, and the foreman of one of Merryweather's engines told me he had frequently to cut coal out of the tubes. Professor Siemens utilizes all the gases he gets from coal, and if the coal was burnt downwards, if you had the ash-pit door double, also furnace door, syphons for air to pass up and through, and also the stoke door, the inner part perforated and shut, and had perforated air tubes or syphons going into the combustion chamber, you would allow the gases, after they have passed through the fire, to pass through the tubes, as carbonic acid and carburetted hydrogen, and go up through the under tubes and return tubes through the steam into the funnel. I have a specimen in my pocket of coal dust taken from the smoke box of a locomotive that had not been consumed at all in passing through the furnace or over it, and in locomotive engines in the course of a week there will be found 5 or 6 cwt. of unconsumed coal dust. Now I maintain it is perfectly possible to consume every atom of carbon by passing the gases of it through the incandescent fire, and not to pass carbonic oxide and coal dust up the funnel by putting on the exhaust. A Sheffield man told me that there are always two draughts in a chimney, an up draught and a down draught. I said,

"If that is the case, I would utilize the down draught to feed my fire." I took a sheet of iron, and closed from the lower bar to the hearthstone, previously having opened out a hole at the back of grate to communicate with chimney at back, and, to my surprise, the fire went down. I closed the register, and my fire burnt down so fiercely, that it actually melted the fire grate, quite a white glow of heat. I believe combustion chambers could be made to burn downwards so that you would have no smoke at all, except at first lighting, and consume all the carbon. Directly you put the coal on the fire it gets heated, and there are certain quantities of gases passing up the chimney not heated sufficiently to be burned, in fact, not in combination, "only mixed." If that gas passed through a fire it would be entirely burned in combination—either carbonic acid or carburetted hydrogen, and I think you might have heat accumulators of brick stacks in smoke box, somewhat in the way that Professor Siemens has in his mode of making steel on the hearth. By that means you will accumulate an immense quantity of heat.

NOTE.—By down draught combustion chambers, the water would be heated from the bottom of boiler, gases in proper quantities for combination, thereby obtaining heat sufficient to consume all the carbon and hydrogen, in fact, you will then obtain as nearly as possible to the chemical theoretical perfection, and not the prodigious waste that is going on now.

The present mode of supplying the air, I venture an opinion, is crude, as the air should be supplied equably to the fuel, and that is to be done by air syphons and natural gravitation. The air when heated will expand; it cannot return through the syphons, but must, by natural laws, pass through the minute interstices of fuel, having united with the gases of the fuel, and take its exit through the under tubes and return tube flues up the up tube and funnel.

MR. J. F. FLANNERY: I should like to say how much some engineers, including myself, appreciate this paper of Mr. Ravenhill's, because he has collected some very valuable information. I would especially refer to the particulars of the Orient Line, which are very startling, very interesting, and very instructive. I should like to ask Mr. Ravenhill one or two questions on two or three points of detail, and first about Fox's corrugated furnace. Mr. Ravenhill gives us the particulars of two vessels, one of which had a grate surface of 294 square feet, and another had a grate surface of 260 square feet, the steam generative power of both being practically the same, and the speed of the two vessels equal. I should be glad if Mr. Ravenhill could add what is the coal burnt, and also state whether the conditions of stoking were nearly the same, because the difference between the grate area in the two cases does not seem to me to be sufficient to cause the experiment to be an entirely conclusive one as to the power of the Fox furnace as compared with the other.

The next point I have noted is with regard to the alteration in the factor of boiler shell, namely, when the shell is of great thickness, a certain amount of production of rust will reduce the strength in a different ratio of percentage in a thicker plate than in a thinner one. No doubt it is very desirable to introduce that difference in the form of a factor, but it seems very like too great a refinement unless in the case of very large boilers, and I very much doubt the applicability of a general rule producing such a factor. In the special case of steel boilers no doubt such a provision might be usefully made.

Mr. Ravenhill refers to the difficulty of keeping crank shafts from breaking, and states that Sir Joseph Whitworth is now directing his attention to building up crank shafts in different parts. I am not aware whether it is generally known that in that very engine of which you have a model before you—the White Star Line, that system is now being tried. I do not know whether the crank shafts are yet fitted, but they are made entirely in pieces, each piece is separate; that is rather an interesting fact, and I venture to mention it; we look for the result of that experiment also with much interest.

I should like also to refer to the model which is now upon the table—the Mal-lory propeller. I am quite willing to grant the whole of the advantages which are claimed to that system, which are, that it will quickly stop or leave a boat dead, reverse her, and enable her to steer extremely well; and the greatest difficulty, I apprehend, that has been experienced in torpedo boats, is to cause them to steer well. From the date of the first trial of the "Lightning," to the later improvements

which experience has introduced, the greatest difficulty has been found in getting torpedo boats to steer. That invention of Colonel Mallory will no doubt remove a great deal of that difficulty, but it induces another which Mr. Ravenhill indicated, namely, the altered and almost impracticable position of the propelling machinery. But there is still another difficulty which Mr. Ravenhill only hinted at. I do not know whether he intended to express it, that is, the use of a donkey engine for turning for steering purposes the frame carrying the revolving propeller. The action of the gearing pressing round the propeller itself in one direction—the power in a large torpedo boat being probably some 400 indicated horses—causes a tendency to turn the helm in one direction, and if it is desired to turn it in the other direction, you have to work against a large portion of the power of the main machinery working the gearing for propelling the ship; that seems to me to be a disadvantage, and to add to the gearing you must necessarily have for the driving power. To make this paper complete, Mr. Ravenhill might have added particulars of another invention which has been lately tried, and with the same objects; it is the invention of a Hungarian gentleman, named Kemstatten, and the particulars of it are something like these: Aft the rudder or inside of it is carried a propeller, which is worked from the main shaft which is in the same horizontal portion as usual, by a universal joint, and that universal joint will give a moderately steady action to the steering propeller up to angles of 45° from the centre line of the ship; there are not in this arrangement the same features of objection which can be urged against the Mallory propeller, and the practical results are sufficiently important to warrant very careful attention to this invention. It has been tried on the Thames, and I have in my hand some particulars of the results. Mr. Ravenhill tells us a boat fitted with the Mallory propeller made a circle of 8.

MR. RAVENHILL: No, a torpedo vessel with two rudders.

MR. FLANNERY: It was at all events a vessel which steered practically well, because it made the figure of 8 in front of the hospital.

MR. RAVENHILL: Going 15 knots.

MR. FLANNERY: The "Hunstanton" made the figure of 8 inside the piers of Westminster Bridge. One of the gentlemen who was present is here, and could speak to that result if it were necessary. I think the whole circle was made in 58 seconds, and the boat was reversed in complete revolution in 58 seconds, and she went inside of one pier and outside the other with, I dare say, as great speed as could be shown by making the figure of 8 in front of the hospital.

THE CHAIRMAN: Could you tell us the length of that boat?

MR. FLANNERY: I think about 65 feet. I do not know whether it is given in the particulars of this pamphlet, but I shall be pleased to lay it on the table.

I can only say that this paper of Mr. Ravenhill's will take rank side by side with the former paper given by him before the Institution of Naval Architects as a reference for figures, and there is yet so much to be studied and recorded that I hope it will not be long before we have another such a one from him.

ADMIRAL SIR COOPER KEY: I would ask Mr. Ravenhill to be good enough to give us the results of these experiments on the corrosion of iron and steel plates; one can hardly tell it by inspection. I think they were tried under various circumstances—in warm water, cold water, air, and steam—and it would be very interesting to know what the result was.

CAPTAIN SCOTT: Mr. Ravenhill has spoken of the importance of the valves for altering the steam pressure from high to low. Would he likewise kindly tell us what time would be required to raise the steam from, say, 14 lbs. to 60 lbs. pressure on the square inch; for although it is very desirable to burn a small amount of coal by going at low speeds, it is more important still to be able to handle your ship quickly in action, and to charge with the utmost speed. I need scarcely say that most of those young Officers who are prepared to take part in future operations think that the ram is certainly the most formidable of the weapons that can be used at sea, and therefore I think the valve question as respects the time that would be taken in performing the operations needed, and raising the steam from a low to a high pressure, is a very important one.

MR. RAVENHILL: With reference to the observations that fell from Commander Curtis, I may say I do not think any one will argue that the boilers of the present

day are perfect boilers. Of course I feel diffidence in going into minutiae on an occasion of this kind, when I really have been able to lay before you, through the kindness of friends, such valuable data as the Institution now possesses.

With reference to Mr. Flannery's remarks about Fox's corrugated furnace, he knows perfectly well the difficulty of getting at full detail. I should like to have been able to give this information a little more fully than I have done, but I was unable to do so. What I wished to convey was this—that the two steamers were of about the same tonnage dimensions, with speeds practically alike. I only know the name of one of them myself, and that I must not mention. In the one the boilers were fitted with eighteen plain furnaces, and had a grate surface of 294 square feet; in the other the boilers had twelve corrugated furnaces, and a grate surface of 260 square feet. The power the engines exerted was as nearly as possible the same. As regards the relative quality of the stokers employed, you must take, I suppose, an average. We know perfectly well that there are some firemen better than others, but in running over a series of time you may assume the firing in both ships would be very much alike. I do not know whether that meets what you wanted to get at?

MR. FLANNERY: It is that the difference between the area of the fire-grate in the one case and in the other case is not sufficient to prove the advantage of Fox's corrugated tube as regards evaporation, unless it be stated at the same time what was the quality of the coal and the consumption.

MR. RAVENHILL: I do not attempt to put forward Fox's corrugated furnace as being superior. If you ask me the quality of the coal consumed, I tell you candidly I cannot tell you.

MR. FLANNERY: It was necessary to make the information more complete, as it was a very interesting subject.

MR. RAVENHILL: That is right enough, but I say I have not got it. With reference to the Hungarian vessel you were speaking of, I did hear that there was such a vessel on the Thames, but beyond that I know nothing. I was induced to allude to Mallory's propeller because the Admiralty have thought right to try it in a steam launch. With reference to your remarks about the working of donkey engines and gear, I think, in speaking of the system as I did, I conveyed my own feelings when I said it may do for steam launches. I need not tell you that many years ago gear in connection with the screw propeller was altogether abandoned, I for one do not think for a moment the days will come when we shall ever see it in use again. I should be very glad if you would give me an opportunity of seeing the Hungarian ship you speak of, and witness trials such as you speak of, so that I could speak from my own knowledge. I am quite sure, if I may venture to say so on the part of this Institution, they would allow me to add the result of that trial to this paper.

MR. FLANNERY: I think I may promise that you shall have the opportunity.¹

MR. RAVENHILL: With reference to the remarks of Sir Astley Cooper Key, I may say the experiments I have alluded to are at the present moment being carried out, but it will be some time before Lloyd's Committee will be prepared to give any opinion upon the subject. Captain Scott put a question to me as to how long it would take to get up steam again after having used the change valves, say when steam had been reduced down to low pressure. If he had put it the other way I could have answered him from experiment. It is in a portion of my paper that I have had to omit, and which if you will allow me I will read:—"Before changing the engines from compound to simple they must be stopped, and the boiler pressure reduced from 60 lbs. on the square inch to 30 lbs., or any lower pressure desired, and while this is being done the 'change valve' is moved as above described; the time required to effect this was found to be in the case of the 'Comus' only four minutes, so that the time from working compound to again working as simple engines was not more than five minutes." I am not aware that any experiments have been made the other way, so much would depend on the state of the fires at

¹ Up to the date of this Journal going to press, this opportunity had not been afforded me.—J. R. R.

the time; such a trial is generally made when the fires are dead and nearly burnt through, and there is no intention of getting steam up again. I am afraid I cannot give the time it would occupy except as a guess, and I would prefer not to guess.

The CHAIRMAN: There is nothing more to be done than to express the thanks of this meeting to Mr. Ravenhill for the most interesting and valuable collection of facts that he has put before us. This paper, in connection with that read at the Institution of Naval Architects, has contributed most important information with reference to the advancement of science in connection with steam machinery. Mr. Ravenhill is, as you well know, a practical man, who has in his day turned out engines that will compare with any. The kindness of those great and eminent manufacturers of engines who during part of his lifetime were his rivals in designing and constructing the splendid machines described to-day, and are now working cordially with him to give us, the British nation and Navy, the advantage of their immense practice and skill, has enabled him to come here and to give us a mass of valuable information and instruction, of which we cannot say too much. I think I know something myself of the trouble and difficulties that attend the collection of facts, for very often indeed, when I have tried to get at facts, I have found that they were, to use an expression which you may all have heard of, uncommonly slippery things, and that when you want to rectify by reference certain errors and mistakes which, with the best intentions, will creep into papers intended for use, you will find the difficulties of getting those errors and imperfections corrected are extremely great. I say that every one of us who has taken the trouble to master facts will be aware of the infinite trouble and labour that Mr. Ravenhill has taken in compiling this admirable paper. We should therefore, I think, facilitate his making this paper perfect in every possible way, and any attempt he may make to render it more complete will be received with thanks by the Council. I have only now to thank him most cordially in your name.