9TH AUGUST, 1894.

NOTES ON THE DESIGN AND CONSTRUCTION OF DOUBLE-ENDED SCREW FERRY BOATS.

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IN bringing this subject forward for the consideration of this Institution the author feels a considerable amount of reticence, because he knows so little about it. Double-ended screw boats are so few in number, either here or elsewhere, that he thinks he is safe in calling it a new field, in spite of the fact that sixteen or more years have passed since the first successful craft of the kind was built. Really very few have been built, and those few quite recently; but of late so much success has attended the efforts of those reponsible for the design of double-ended screw boats that they have now become recognised pretty generally as the ferry boats of the future, and, therefore, though, as a matter of fact, we are only as it were on the edge of this new sphere, and there is so much yet to be learned respecting it, he considers it a privilege to convey to you, and through you to those directly interested, what little he has learned by his experience with the two boats he has had the honor of designing for the Balmain New Ferry Company, in the hope that his mistakes may be avoided, and that those points which results have shown to be in the right direction may be developed and ultimately perfected, till this particular class of boats willl be recognised as the best suited for the ferry services of this and all other ports, for such will certainly be the case, and, if that is to be so, then the matter becomes a very important one, and it is that importance alone which emboldens him to touch the subject, be it ever so lightly, in this Paper.

The author's first experience of Double-ended Screw Boats was at Liverpool, England, in 1879, while acting as draughtsman for Mr. Alexander Richardson, who designed the "Oxton," a double-ended twin screw boat for the heavy cart traffic across the Mersey, and though an expensive type, owing to the necessity for light draft, and, consequently, a double set of engines, she was considered a distinct success, so much so that she was afterwards used to run passengers in conjunction with such boats as "Primrose" and "Daisy," almost a clean copy of which is the Port Jackson Co.'s "Brighton." Other boats like the "Oxton" were built, but of them he has no record. They served, however, to establish the fact that screws at each end keyed to the same shaft and driven direct, was an economical method of propulsion, made the boats easy to steer, and admitted of far greater beam of hull proper for given sized docks, and so made the plan well adapted for both passenger and traffic services.

Some six years ago, in response to an invitation from the Balmain Ferry Company for competition designs, and again in 1889 from the North Shore Ferry Company, the author prepared designs for double-ended screw boats, but being unsuccessful in both cases he could only compare, indirectly, his designs with the actual results, and though such comparisons are only useful in a general sort of way, it may interest you somewhat to see the modifications his ideas have undergone during that time. The models of those two boats are before you (Plate XIII, Fig. 1 and 2.), and you can compare them with those of the two actually built from, and as the names are on the boards there will be no difficulty.

The year 1891 saw the birth of the Balmain New Ferry Company, and with it a call for new boats, and the author was entrusted with the design and construction of one—the "Lady Mary"—and after some careful study as to what the requirements of the new service would be, they settled on 96 feet over all length, 22 feet beam, and 6 feet 8 inches draught, and to be propelled by double screws on one shaft, driven direct by compound surface condensing engines. Now, as the Directors of the Company were anxious to get 10½ knots, it became a serious question how it was to be done, seeing that the best results up to that date had been 10·14 with much more power than the purse in this case would admit of; so they figured on the biggest power they could afford to pay for, and having regard to the necessity for great stability, large surplus buoyancy for the heavy load to be carried, viz., 350 passengers, or about 23 tons dead weight, the great question was how to get a hull of these dimensions fine enough to do the speed.

There would have been little or no trouble with a single-ended boat, aplying the whole power, *i.e.*, 13 in. and 26 in. cylinders by 16 in. stroke, with 100 lbs. of steam to one screw, and no limit to drag aft; but it was quite a different matter in this case. It had been the experience in all previous boats of the class that the column of water off the bow screw impinging on the bow caused excessive wash there, and seemed to completely disarrange the natural flow of the bow wave, and to reduce this as much as possible the author decided to turn up the ends of the hull to get the water to flow under the bow instead of on either side of it, and further in hope of inducing it in that direction, cut out as much of the deadwoods as was practicable, having regard to the necessary strength. By referring to the model (Plate XIV., Fig. 1) you will see just how and to what extent this was done. The keel was run right out and the propeller post well secured to it and to the hull by strong brass plates and knees, and though it looks, both on the model and on the boat herself, to be a somewhat flimsy construction, it has stood well, and in spite of once taking the ground and severely binding the brass shoe which runs from the junction of the keel and post to the heel of the rudder, neither of the connections between post and keel or post and hull have moved in the least; and further, the most careful examination of the bearing in the post fails to detect any unfair wear—the bush is as good to-day as when it went in some eighteen months ago, showing that the construction thereabouts, light as it looks, is strong enough.

As our subject just now is not so much the stability and arrangement of ferry boats, but more the particular method of propelling them, the author need not go into the features of the rest of the hull beyond saying that in practice she has been found amply stable, roomy and comfortable. This turning up of the ends then with a view to avoiding one of the drawbacks to this particular method of driving proved a success to a limited extent; the wash was reduced considerably, but still not got rid of by any means, nor did the boat attain quite the speed that was hoped for, $10\frac{1}{4}$ knots being the best recorded on the measured mile. This shortcoming, however, was made up for by the fact that starting and stopping was done exceptionally quickly, and almost certainly made up for the less actual speed on a service such as the boat is used on.

You will see the boat's load line, and therefore the actual bottom is run right out to the stem; this, the author thinks, was a mistake, because, to get the rudder outside the propeller, it (the propeller) has to be set back from the actual entrance of the boat some three feet, and, therefore, the wash from it comes in contact not with the actual entrance, but on to a comparatively bluff part, and he concludes from that that it would always be better to keep the propeller outside the end of the load water line, even at the expense of a little over all length to protect the rudders. This was done in the "Lady Manning," as will presently appear.

One other important point before leaving this boat—the question of keeping her shape. In more cases than one, boats of this class had been known to hump in the middle, and to make sure that would not happen he made the keel 20 inches deep, floor 4 inches, and keelson 6 inches, which, when bolted together, made a girder 30 inches deep, and the result was that the deflection from a straight line was certainly not more than $\frac{1}{8}$-inch, and when the machinery was in she came back to the straight, and it may be noted that the weight of the machinery was within about nine tons that of the displacement, due to the entire length occupied by that machinery, an important point, the author thought, when calculating structural strength. Such a deep keel, of course, adds considerably to the wetted surface, but he was afraid there was no way out of it with boats constructed entirely of wood.

In designing the second boat, the "Lady Manning," the author had some (very little, certainly, but some) experience of actual results to go on, and leaving out the questions of stability, arrangements, etc., as before, and looking only to what particularly concerns our present subject, the points presented themselves somewhat in this way:—

1st. Speed had to be increased to at least 11 knots, the exigencies of the service demanding it for excursion purposes and such like.

2nd. Passenger-carrying capacity had to be largely increased, as the traffic was growing, and again, also, for excursions, etc.

3rd. It was not thought wise to increase the draft.

4th. It was absolutely necessary to keep the price as low as possible.

The author found, as we are constantly finding, that those three elements—speed, size and price—did not seem inclined to agree at all. It was clearly necessary to have more length for the first two reasons, viz., accommodation and speed; at the same time, Darling Harbour being so full of ferry boats, every extra foot of over all length is of importance, and so 115 feet was decided on as the limit, but afterwards increased to 116 ft. 6 in. outside the belting or extreme over all length. He was firmly convinced from the results of the "Lady Mary" that the outside effective length of load water line was from propeller to propeller, that portion of entrance beyond the propeller being useless so far as opening the bow wave was concerned, and as he was anxious to get rid of that heavy ugly wash off the fore-end, he adopted the course as shown on drawings (Plate XIV., Fig. 2), and kept the propeller 2 ft. 7 in. outside the normal load water line, taking care, however, to run the boat out in a sort of snout bow, so as to get all the length possible when under way. Of course, it is our every day experience that the wave pushed out ahead is the re-action of what is usually called the bow wave, and rises above the normal level, how much, of course, depends on the mean angle of entrance, and his object was to split that wave and so get a somewhat longer actual entrance when under way. It seems to act well, for the long, clean bow wave off the "Lady Manning" is perhaps one of her leading characteristics, and certainly one reason why she steams as well as she does.

Having settled that point he turned his attention to the next direction in which the "Lady Mary" seemed to be right, viz., to reduce to a minimum the obstruction to the water under the boat's bow, and though almost certainly there is no actual inducement for the water to draw under, the absence of obstruction can be called inducement for the sake of a short term. Here, then, a little difficulty presented itself. Strength was absolutely necessary to get it, at the same time doing away with the whole of the wetted surface due to shoe, lower part of post, keel and deadwood. He got the idea of turning up the keel from end to end, and in doing so was met by the difficulty of getting proper connection between the keel below and the keel above the tube chock. This at first was rather a trouble, but ultimately that trouble melted away in the form of a box instead of a chock. As this was rather difficult to explain on a drawing, he had prepared a model (Plate XV., Fig. 1) of it, by which you will see that the keel proper, which is sprung all the way, built of four pieces 7 in. x $4\frac{1}{4}$ in., one in the other, and bolted through and through keel floors and keelson, runs up to and stops off on a long level under the tube; a continuation of the keel runs from the post to the top side of the tube also on a long level, and the two connected by pieces on each side 17 in. x 3½ in. bolted through and through top and bottom. Now as this piece stops off at the post, and therefore got no or little connection, two pieces 3½ in. thick were fitted one on each side of it, and consequently on top of the box forming the tube swell down bolted to it, through bolted to the first middle piece, run past and through bolted to post, run on and is rabbitted into the stem, thus getting a complete connection everywhere. It turned out a real good, strong piece of work, but the drawback to it is that a very long stem tube is necessary. (The author has used the singular number for convenience, but of course both ends are alike; and his only excuse for calling the parts of the structure "pieces" is that he knows of no technical terms that precisely meet the case.)

The method of hanging the rudders is shown on plans (Plate XV., Fig. 2), being hung from a band on a ring on deck, and call for no remarks save that he saw no better way of fitting them, having regard to the position of the propellers and his anxiety to avoid everything in the shape of obstruction below. In practice they work well, give no trouble, and are amply strong for the purpose. So far the forward rudder has never come adrift while under way; the heavy iron fork securing it has been found most reliable. As it sometimes happens, the forward rudder does fly round in double-ended boats, however propelled, and as on one or two occasions serious damage and inconvenience have arisen therefrom, by way of precaution there were fitted two spring stays made of steamed hardwood, bolted at one end and free the other, so that in case of accident by the forward rudder flying round the bade will take first on these springs, and so cushion the blow before landing hard on the fixed rudder stops. We have had no opportunity of testing the efficiency of this device, but the author thought it a useful thing to have, the cost being only trifling.

The torpedo-shaped boss of the propellers was so shaped with a view to getting a clearer passage of water past it than by adopting the usual shape; it would be seen that the nut was cone-shaped; the boss proper, a continuation of that cone shape, between the inside edge of boss and outside edge of post, was a brass box, shaped as shown, and bolted to the post, then the post was shaped to carry on the form, reducing as it goes, and the flanges of the bush cast hollow and shaped to carry on right to the brass casting round shaft. This, of course, costs money, and the results are necessarily left to surmise, so whether the game is worth the candle or not the author must leave you to decide—he was inclined to think that it was. It might be mentioned that the outer or post bearing is a double bush lignum-vitæ, lined in the usual way, the inner one in halves, the idea being to be easily replaced at any time. True, the boat was new, but so far the wear seems so uniform that almost certainly it will last as long as any other shaft bearing in the boat.

The outer or tail end shaft being very long it was made in two and connected outside the tube by sleeve couplings; and herein lies one of the objections to this style of boat, the couplings are an obstruction, and look ugly, without a doubt.

So far the author has spoken only of the bow, because that is the end in most double-ended screw boats at which the trouble has been experienced. It is a well-known proverb in boat-designing, "Look after the tail, the head will take care of itself," and almost certainly no truer one could be found. There is no doubt whatever that the run of a boat is far more important than the bow, looked at from the point of view merely of a heavy body passing through a fluid, and it holds good with all ordinarily propelled craft—single or twin screws, paddle or stern wheelers,—and he thinks it arises from the fact that if you apply enough power you can drive a body of water ahead, but it is absolutely certain that no mechanical power can be applied to drawing the water in aft; we have only the atmospheric pressure and gravity available for that purpose. That pressure is uniform, and therefore the velocity due to an uniform pressure must be itself uniform, hence the enormous importance of designing the stern of such a length and shape as to coincide in period with the velocity of the water due to atmospheric pressure and gravity fixed by Nature's laws, and unalterable, for neglect of that will most assuredly result in towing big ugly seas, lifting large volumes of water above their normal height, and so wickedly wasting power that might be made good use of. But it is not his province to go into fundamental principles that are well known to you, or most of you, but rather to call into use those only that apply to this case.

It is our every day experience, then, that with the greatest care devoted to the dimensions of a boat to do a certain speed —and when he speaks of speed, please let it be clearly understood that he means speed in knots, up to or very little above the square root of the length in feet, or, roughly, the natural speed of waves of that length. He has not torpedo boat speed in his mind now, but of ordinary ferry boats for ordinary service, where first cost and economy are of deep importance. We know then that the stern can be somewhat fuller than the bow, so long as the length of the after end is not less than $\frac{3}{8}$ the square of the speed aimed at when driven by a stern screw or paddle only, and is usually much fuller where a stern wheel is used. We see boats such as this (and he thinks it is fair to presume that most single-ended boats are fuller aft than forward) that when at full speed they throw about the same weight of water in the shape of wash from both ends, which is as it should be. On the contrary, any double-ended boat when at full speed will throw much more wash forward than aft; take, for example, the "Narrabeen" as a typical two-bowed boat, and the "Iris," or any other of those two-stern boats, we find ever so much more wash off forward in both, or, he may say, all cases. This is exaggerated largely in double end screw boats, and chiefly from the fact that the boat is entering water not at rest, as is the case in a single screw or paddle boat, but actually moving at a velocity equal to the slip of the screw, and that, therefore, while the hull proper is going through the water at 10 knots, the actual bow is meeting water with a velocity of, say, 13, *i.e.*, the speed of the boat plus the slip or speed of screw. Apart from this, the natural flow of the bow wave—the one that rises to the bow, and not the one that flows off the bow, they really form one, of course—is disarranged by a sudden acceleration or velocity just at or about its crest, and that line which ordinarily would divide that wave easily and gently if it came along in its natural shape, will not do so when it is contorted in form, to some extent due to the propeller action, as just stated. To get over this difficulty he adopted the form shown, fully convinced, from observing other craft, that even such apparently undue fining would not detract from the efficiency of the stern, and so it has turned out in practice. So, also, to leave his subject for a moment, has it been shown to be the case in torpedo boats and other craft driven at speed altogether above that commonly known as the natural wave length. They cannot get the after end too long nor too fine; the greatest possible length of stern is taken; the water forced from the bow by solid brute force. That cannot, however, be done, excepting at enormous mechanical cost; but even that cost is less than would be required to tow a similar weight of water at the same speed. Although at first sight this seems to be opposed to our axiom, in reality it is not, for while the importance of looking carefully after the tail or run in an ordinary boat lies in the fact that the more easily and gradually the water can be brought to the propeller the more directly will it be driven out astern, and, consequently, the more efficiency obtained. In this case the bow has not only to be the means of dividing the water, but it has to be a run for the water off the bow screw, and the more easily and gradually it allows that water off the screw which is travelling at one speed, to mingle and blend with that past the hull at another, or that due only to the speed of the hull, the better. The ends then of a double-ended screw boat have to perform a double function—each has to be a bow and a stern alternately, and one, the leading end or bow, has to be bow and run at the same moment, and therefore wants the most careful designing in order to get the result desired. The author will not detain you with a description of the general arrangements on deck, and the other parts of the hulls and machinery of these boats—they differ only in detail from many other boats in this port,—but content himself by reiterating the few leading points.

The chief characteristics, then, of the "Lady Manning" (and he quotes her as being the one in which the deviations or departures from ordinary practice are most fully developed) are, the cambered keel, for the purpose of getting as complete a clearance as possible for the water thrown off the bow screw and passing under the boat, at the same time admitting of clean sweep round lines all the way, still providing for the necessary local fineness to absorb the increased velocity of bow screw, discharge or uneven flow due to the pressure, and, for all that, maintaining a perfectly even and fair progression when that end becomes the run or after end. The peculiar construction of the keel and stern tube trunk being the necessary outcome of the first-named; the somewhat unusual method of hanging the rudders, thus getting the greatest leverage and consequent good steering ability.

The "Lady Manning's" leading particulars are:—

Length, over all	116 ft. 6 in.
Load Water Line	100 ft.
Beam of Hull	23 ft. 6 in.
Beam of Hull, Load Water Line... ...	20 ft.
Beam, over all	26 ft.
Depth	8 ft. 6 in.
Draught	6 ft. $8\frac{1}{2}$ in.
Displacement in Tons	90
Co-efficient of Fineness	·234
Engines' Cylinders diameter ..	14 in. and 26 in.
Stroke	18 in.
Revolutions	160
Indicated Horse-power	200
Boiler, length and diameter ...	9 ft. x 9 ft. 2 in.

Steam	100 lbs. per sq. in.
Average Trial Trip Speed in knots ...	$11\frac{1}{2}$
Best run recorded in seconds	$5{\cdot}3^3/_5$

or a small fraction under 12 knots.

Before closing he thinks it may be found interesting to see what is going on elsewhere in the direction of developing double-ended screw boats.

In *Engineering*, February 16th, 1894, is an interesting description of some boats built to the order of the Hoboken Ferry Co., of New York, as follows:—

"Progress is the unwritten law of the Hoboken Ferry Co. as well as of its distinguished President, Colonel E. A. Stevens, and his able assistant, Captain C. W. Woolsley. In building this fourth double-ended screw boat these gentlemen have sought to improve on the three preceding it. The "Netherlands" was launched in April last; she is built entirely of steel, from model and specifications prepared by Colonel Stevens. She has 200 feet length of keel, 209 feet over all, 42 feet beam, and 17 feet depth of hold. Colonel Stevens speaks of this boat, contrasting it with others, thus: 'The "Burgen" was the first double-ended screw boat built in New York Harbour. It was prophesied her shaft would get out of line, her propeller blades would be broken by the ice, her bearings would become heated and there would be difficulty in stopping her. In fact, croakers lay awake at night divining disasters, using their ingenuity and, so to speak, 'cussedness' in inventing ones. None of those predictions have come true.'"

"In general shape the "Netherlands" is fuller in the ends of her upper body, thus insuring greater longitudinal stability than the others, and her lines show more power, with fairer form. The most marked change is in the greater 'cut out' at the ends. The distance between the sterns and the stern posts in the "Burgen" is 11 feet, in the "Netherlands," 16 feet. The "Burgen," it was found, after stopping the engines, could not be readily steered, and, consequently, the changes in the "Netherlands" to avoid this were the greater 'cut out' above-mentioned, and an increase in the breadth of the rudders. Another feature is the fall-out top sides. This extra beam at the gunwale shortens the overhang of the guards—a most desirable feature—while it also decreases the risk of damage below the water line in the case of collision; and it must be borne in mind that every boat has to receive many a hard knock in collision."

There, at least, is a wonderful similarity between the Hoboken ferries and some in Sydney Harbour, and it seems to the author that in the matter of this deviation from the old style, brought about by what in America they call cutting out the ends, they and we are following parallel lines, and though in doing it in the "Lady Mary" and "Lady Manning," it was partly for the purpose of getting good steering, or, to be strictly accurate, to get quick reply to the helm, that was most certainly a secondary consideration; his primary object was, as already stated, to get a better flow, therefore an easier boat to drive, and, consequently, either a faster boat or one driven more economically.

But apart from the objects we each had in view—for we seem to have arrived at much the same results—it is interesting, not to say gratifying, to find them on that side doing much the same as we are here, for, as Ko Ko, the Lord High Executioner in "Mikado," says, "glad to have my opinions backed up by so competent an authority."