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# Evening Meeting.

Monday, April 15th, 1878.

ADMIRAL SIR FREDERICK W. E. NICOLSON, BART., C.B., Vice-  
President, in the Chair.

## STEAM-POWER *VERSUS* SAIL-POWER FOR MEN-OF-WAR.

By Captain P. H. COLOMB, R.N.

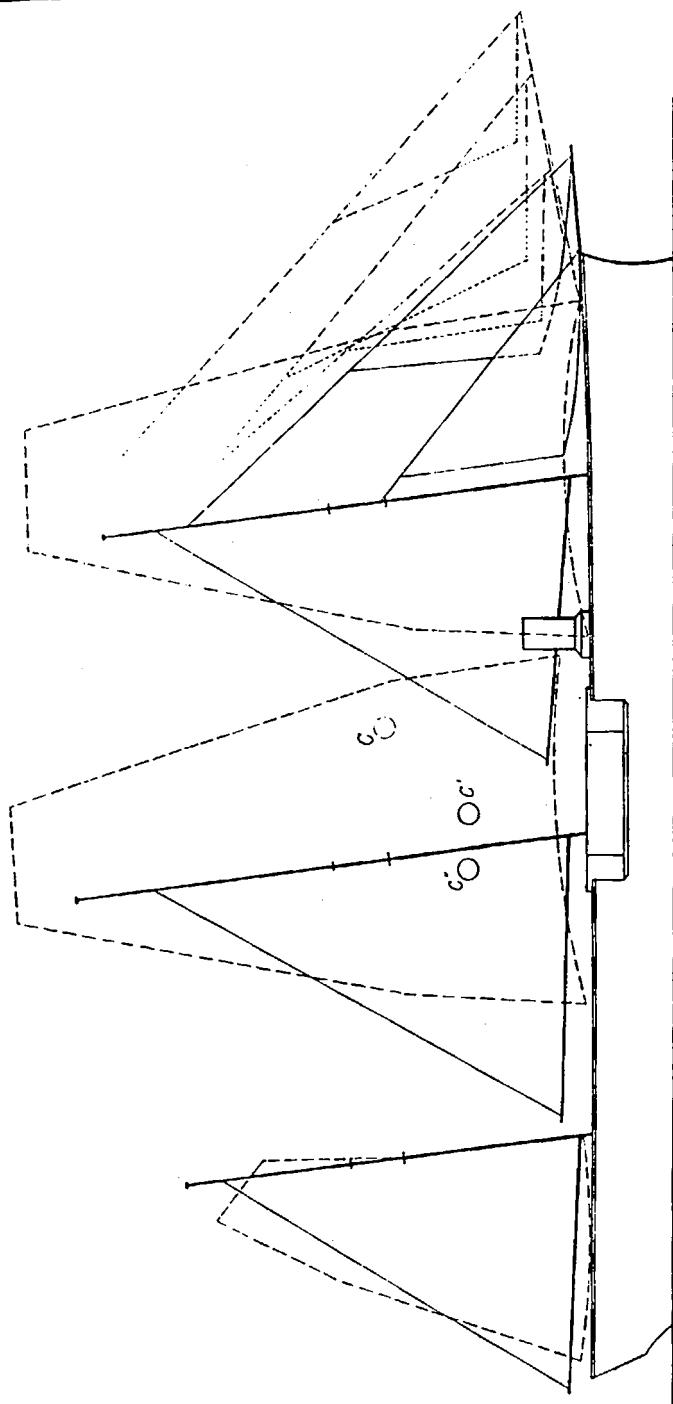
1. In my Essay on the "Development of our Maritime Power," I have rested the propulsive force of our war ships almost entirely on their coal stowage, and on the means at disposal for their replenishment with coal in our own depôts. I have proposed that the sail-power of our war ships should be reduced to the position of a true auxiliary. We should, I have assumed, build our war ships without any reference whatever to sail-power; and after the design is completed, we should then furnish them with such a rig as should give them the least possible inconvenience in foul winds, and the greatest possible assistance in fair winds.

2. So bold a proposal requires some facts and arguments to back it, and I am here to-night to offer both for discussion.

3. Though a considerable change has passed over our minds within the last ten years in the view we have taken of the relative position of steam and sail power in a war ship, I am not without apprehensions of being considered rather too advanced in my present views. But I trust that those of my brother Officers who start at what may seem at first revolutionary theories, will understand that I do not advocate any sweeping changes without due experiment; and that I do not think we can advance at all, unless we do so on certain ground.

4. On the other hand, I have reason to believe that I should now carry with me a considerable body of steadily-formed opinions, were I to confine my views of the decadence of sail-power to the ironclad—or as I hope she may in future be called, to the Fleet Ship. I have been a little surprised to find what an alteration naval opinion has undergone in this matter even since I left England in 1874. These things make me hopeful that, though I may be too advanced at this moment, I shall be perhaps behind the age in five years' time.

5. But, in any case, whether I be too advanced, or altogether mistaken, in the views I put forward, there is great value in advancing them. I do not know any method of examining the soundness of old views better than testing their strength by the advancement of new ones. And, while I would always deprecate the ventilation of ideas which are simply wild, and rest on no definite data, I am a great advocate for the publication of all views which have such a foundation,



even though the conclusions drawn may turn out to be wrong. I have, in short, a great faith in the accumulation of FACTS as a basis for argument, and believe that such accumulation is never made in vain.

6. The method I have adopted in this accumulation of facts may, I think, be relied on so far as it goes. It has involved some patient labour, but promises the advantage of being truly inductive, so that the facts established form a perfectly solid basis, whether the conclusions to which I think they point may or may not be approved.

7. Serving recently in an ironclad, I very early became impressed with the smallness of the results due to the employment of her square sails, but I was not at first prepared for the insignificant appearance their propulsive power would exhibit when investigated and compared with that of the engines; and most certainly I was not prepared to accept my present conclusions, which I may state were adopted by Captain Fisher as far back as 1871.

He then wrote:—“*Masts and sails should be done away with.* The weight and room they now represent should be taken by coal. No better proof exists of the wisdom (the economy and efficiency) of doing this, than pointing to the example of all the new ocean steamers, amongst the most successful of which are Mr. Holt's. These steamers, built more for cargo than speed, make the passage from Liverpool to Singapore in 45 days, and they carry 90 days' coal. A paper might be written to prove the actual waste of coal caused by masts and sails in squadron sailing, due to the frequent stoppages and alterations in speed; and it may almost be asserted, as a general rule, that the cost of refitting exceeds the value of the coals, which would have been used in the year's cruise had steam alone been used.”

8. I have, in fact, made a long series of the calculations imagined by Captain Fisher, and the results are, to my mind, nothing less than startling in their confirmation of his views.

9. But, for investigations of this sort, the experience of the Channel and Detached Squadrons must generally prove exceedingly misleading, for their proceedings and movements are usually governed by their interior convenience, and not by the pressure of circumstances outside them. The test which is required to finally establish the proportions of sail and steam power proper to a modern fighting ship, is that of war; but very often the ordinary service of a foreign station so closely resembles a state of war, that useful conclusions may be arrived at, even in peace time. When the movements of a ship are governed by circumstances outside herself; when she must be at certain places at certain times without any reference to her interior convenience; the real value of her propulsive powers becomes apparent, and she establishes facts relating thereto, which, if carefully investigated and recorded, become an excellent and reliable guide for the future. A Fleet Ship on a distant station, with a good deal of sea work, and almost always impelled from point to point by considerations which, if less imperious than those developed by war, still in some degree represent its demands, appears calculated to furnish some of the most useful experimental data available in peace time.

10. In order to get at some definite results, I determined to investigate very closely the value of the sail-power of such a ship during a period long enough to make a fair average. I selected two complete years, ending on the 28th October, 1876.

11. The questions to which I have endeavoured, by an appeal to the actual facts, to get answers, are the following:—

(a.) The hull, engines, and boilers of the ship being considered fixed quantities, the variable elements of her propulsive power are the coal supply and the masts and sails. The masts, yards, and sails, actually in use, represent a certain weight, and they also induce further weight in the shape of stores; and in the ship in question, a very large additional weight in the form of ballast. Do the sails in their propulsive power represent the equivalent of the weight they involve?

(b.) If it appears that they represent a power in excess of this weight in the form of increased speed, or decreased coal consumption, then it is clear that sail-power is properly arranged. But if it is found that even in peace time, and in ordinary service, the propulsion extracted from sail-power does not reach the equivalent of its weight, it would appear that a re-distribution is required.

(c.) If the sails upon the whole make a loss, instead of a gain, in propulsion, should we not look to their inconvenience to a fighting ship in time of action, and also to the increased draught of water of the ship?

(d.) Taking the lowest view of the question, that of simple saving of money, and supposing still that sail-power as arranged shows a loss stated, say in tons of coal, will not the debit side of the account be very much increased by the cost of wear and tear, and by the interest on capital sunk in the rig?

(e.) If we decided that in any particular ship the existing rig showed a loss, is there any modification of that rig which would give us the maximum of assistance when the wind was fair, with a minimum of retardation when it was foul?

12. It was some time before I succeeded in establishing satisfactory rules for calculating the value of sail-power, but I think those which I finally adopted may be applied to any ship with confidence. The rules are simple, and the process of calculation, though laborious and troublesome, is not difficult, and does not involve any abstruse problems.

13. Table I is one of forty-five which were completed for the purposes of this paper, and its construction may be now described.

(a.) The distances through the water as logged hourly are taken out and totalled, the totals being placed in the columns for distances under steam alone, steam and sail, and sail alone, opposite the number of hours occupied in passing over each distance.

(b.) The coal burnt while actually steaming is placed opposite each distance run under steam alone, and under steam and sail.

(c.) The coal expended in banking fires and waiting orders is omitted from this column, so that when the ship is under sail alone this column is blank opposite that distance.

(d.) The coal saved or lost, and the miles gained or lost by the use of square sails, are calculated in this manner. The best data which

can be had under steam alone are selected, care being taken that the time and circumstances correspond as nearly as possible with those under square sails, in order that the estimated loss or gain may be accurate; and doubts are generally given in favour of the square sails. The coal saved by the stoppage of the engines, when under sail alone, is debited with any charge against the saving which may exist on account of banked fires, waiting orders, &c. The saving or loss thus obtained is placed in the proper column with the plus or minus sign. The miles gained or lost are obtained from the same data, and are placed in the proper column with the plus or minus sign. Thus, for example, taken from the table:—The ship on the 4th June, 1875, was under sail alone for ten hours, making 37·6 miles through the water in that time. The fires being banked, 75 tons of coal were expended. Now, from a mean of the ship's performance under steam alone, under similar conditions of wind and weather on the 6th and 7th of June, it was found that she went 6 knots at 5·3 miles to the ton of coal. On the assumption that she would, had not square sails been set, have gone for ten hours at the rate of 6 knots, and an expenditure of 1·12 tons per hour, we find that the ship lost 22·4 miles in speed by the use of sails alone, but saved 11·2 tons of coal, from which the 75 ton used in banking being subtracted, she is left with a nominal gross saving of 10·5 tons of coal, and an actual loss of 22·4 miles in speed.

(e.) The method pursued in calculating the loss or gain by the use of square sails when steam is also in use is somewhat similar. Referring to the table, we see that on the 12th June the ship was four hours under steam and sail, and ran 31·9 miles in that time. Just before making sail she was going, under steam alone, 7 knots for 32 cwt., or 4·4 miles per ton. The use of the square sails in those four hours, therefore, increased her speed by 3·9 miles, and saved coal to the extent of 0·1 ton.

(f.) The value of sail-power is most conveniently spoken of in tons of coal; and throughout the tables the miles lost or gained on the passage are, at the end of it, turned into tons of coal at the rate due to each particular case. The same data are used to establish the gain or loss of miles or tons, and afterwards to convert miles into tons. Thus, the above 22·4 miles lost, at 5·3 per ton, gives 4·2 tons to be subtracted from the 10·5 tons appearing as saved, thus leaving the actual gross saving due to being ten hours under sail alone at 6·3 tons.

(g.) At the end of the Passage, all the particulars given in the tables are summed up, as in Table I. "Total consumption of coal for engines" represents the expenditure for steaming, banking fires, raising steam, and waiting orders. The "consumption of coal, steaming" is the result of the sixth column in the tables, and is the coal actually used in propelling the ship over the distance given. The "consumption of coal for all purposes" includes every expenditure of coal for any purpose during the Passage.

(h.) The times, distances, and consumption of coal, being thus summed up, are used to take out the average speeds under steam alone, steam and sail, sail alone, and under all the circumstances of the

Passage. The mileage under steam alone; under steam and sail; and understeam, and steam and sail; is then taken out from the coal burnt under those circumstances. In calculating the mileage per ton on the Passage the consumption used is that for engines, including banked fires, laying fires, and waiting orders.

(i.) The total gross saving of coal by sails is the result of the seventh and eighth columns in the table, calculated as before mentioned. The gross percentage of saving on consumption, is calculated on the expenditure of coal for all purposes.

(j.) The abstract given in Table II is a summary of twenty-eight primary tables, of which a specimen is given in Table I, with some additions. Item No. 9, for instance, is taken directly from the engine-room registers, and gives the coal used for all purposes during the whole period covered by the table. Items 12 and 13 are taken out from the primary tables specially for the abstract. The "coal nominally saved by square sails," and the "miles actually lost by square sails," are the sums of the seventh and eighth columns in the primary tables, while the "gross percentage" is taken out from the coal shown as used for the engines, and for all purposes respectively.

14. Table II thus represents the actual facts as to the relation between the propulsive values of steam-power and sail-power, in an ironclad on foreign service of a somewhat varied kind, during two full years of her commission. On these facts I base my conclusions as to the distribution of sail-power in the Fleet Ship, and I think it must be admitted that they are sufficient.

15. The most extraordinary fact brought out is given in item 26, where it is shown that on the whole no more than 7 per cent. can be put as the gross saving of coal due to the use of sails; and it is, perhaps, necessary to state that not a moment was ever lost in making sail whenever it was possible to use the square sails with effect. From this miserably small gross saving, all the *per contras* must be taken; namely, the loss due to the weight of masts, yards, sails, and ballast, the retardation due to the fixed area of masts, sails, and rigging when steaming against foul winds, as well as other losses not here to be adverted to. Thus, we see that on the face of things, and at the first blush of the matter, the sail-power *must* involve an actual loss of coal, and it only remains for us to calculate the amount of the loss as nearly as may be.

16. Let us take first the question of immersion due to weight. We know that masts, yards, sails, and ballast weighed together 520 tons—more than half the weight of the armour, and nearly half as much again as the weight of the guns and ammunition. Now, considering the speed as given, the consumption of coal may be roughly assumed to vary as  $D^{\frac{3}{2}}$ , where  $D$  = displacement. Taking the existing displacement at 6,034 tons, and what it would be were the sail-power entirely removed at 5,514 tons, we have,

$$6,034^{\frac{3}{2}} : 5,514^{\frac{3}{2}} :: 5,162 : x,$$

5,162 being the number of tons actually used in steaming during the two years. This gives us  $x = 3,861$  tons, which, subtracted from the



5,162 tons actually used, gives 1,301 tons as the loss due to the simple weight of the mast, yards, sails, and ballast. I may remark that these figures are quite confirmed by actual experiment in the ship on repeated occasions. The difference of coal consumption for a given speed, at different immersions, varied as nearly as possible in accordance with the above law.

17. But by Table II the gross saving due to the use of square sails was only 453 tons of coal. The net loss, therefore, due to the sail-power was 848 tons of coal from the item of their *weight* alone.

18. But a little reflection will show us that the case against sail-power is on this head alone still worse than these figures show it to be. In calculating the primary tables, whence the abstract in Table II is drawn, we have really put all the fair winds to the credit of sail-power, and all the foul winds to the debit of steam-power. This follows from the fact that square sail was invariably set whenever the sails would stand. Thus, we have supposed that whatever the strength of any fair wind might have been, it would not have helped the ship in the least, unless the square sails had been set. This is assuredly a most incorrect hypothesis, for a fair wind invariably makes an immediate increase of speed, as well as a reduction of consumption.

19. But passing this by, we have to assign some value to the loss of coal due to the resistance of the spars and rigging when steaming head to wind. I do not know of any precise data on this head, and I do not know of any means by which such data can be obtained, short of a long and varied trial of the same ship at first without her spars, but with a weight corresponding thereto; and afterwards with her spars complete—the corresponding weight being removed. Such an experiment we are most unlikely to have, and we must, therefore, assume some figure which will certainly be within the mark. The ship expended while under steam alone, 4,201 tons of coal in the two years. Is 5 per cent. too large an allowance? Supposing the ship going five knots, and a head wind sprang up reducing her speed to four knots, that would represent a common occurrence, in any ship of war, and would represent a total loss of 20 per cent., part of which would be due to the resistance of the spars and rigging, would it be unreasonable to say that one-fourth of the loss represented this part? I suspect that 5 per cent. is not an unreasonable allowance for loss due to resistance of spars and rigging when steaming over any considerable distance head to wind, or in calm. But to be safe, I should put it at about 4 per cent., or at 152 tons of coal. This makes our total loss of coal due to sail-power just 1,000 tons, or 500 tons a year; which, at an average foreign price, involves a money loss of £1,150 per annum.

20. As the total consumption of coal for all purposes was 6,734 tons, we find in answer to question *a*, in par. 11, that so far from the sail-power of such an ironclad as we have been considering, representing its equivalent in weight, it actually involves a loss of more than 14 per cent. We may, therefore, at once answer the second question, *b*, and say that looked at from this ground alone, a re-arrangement or re-distribution of sail-power is required.

21. We have next to consider whether the increased draught of water due to the weight of spars and sails, &c., is not a serious inconvenience to a war ship. This must, I think, be at once admitted. The 520 tons which sail-power and ballast represents in such an ironclad, is equivalent to about 16 inches of draught, and when I have said that, I have said all.

22. As to the inconvenience of full rig to a fighting ship in action, opinions will no doubt differ. We happen to have an instance before us, by way of experiment, which seems to cut so accurately both ways, as to leave the argument just where it stood. The German "Meteor," off the coast of Cuba in 1870, fought the French "Bouvet." The German planted a shell in the "Bouvet's" boilers, and, observing her helpless condition, ran down to make her an easy prey. But the "Meteor's" wounded masts fell and fouled her screw; rendering her just as helpless as her antagonist. The "Bouvet" then, by the use of her sails, crawled away into neutral waters and saved herself. On this experiment, one side will argue that had the "Bouvet" not been provided with a full rig, she would have fallen a prize to the "Meteor," while the other side will urge that had the "Meteor" been without rig, she would have captured the "Bouvet." I am content to leave these arguments where they stand, observing simply, that as each may be maintained with equal force of logic, I prefer to take up the ground put forward in my essay, which would give the "Bouvet" a second chance with her steam. If she had been so arranged that a single shell would not have absolutely paralysed her steam-power, she might have used her reserve steam-power to capture the "Meteor," rendered helpless by her supply of sail-power.

23. We come now to the lowest part of the question—I mean lowest in theory—but recent years have taught us that it may in practice become the most important of all. I mean the money question. We have already seen (par. 19) that we cannot put the direct extra expenditure of coal due to sail-power, at less than 500 tons a year, or at an average foreign price, at £1,150. We must clearly add to this, interest on original capital sunk in rig; and the wear and tear. I think I am within the mark—perhaps considerably—when I place the value of such a full rig as we are considering at £5,300, and if we allow interest at 4 per cent., we should get the annual cost put at £212. I suppose we cannot put the wear and tear at less than 7 per cent., which would give us a yearly charge of £371. We thus get the direct cost of the full rig put at £583, which, added to the indirect cost already calculated, puts the total cost of the sail-power as supplied to a second class ironclad as £1,733 per annum. When we turn to the Navy estimates for this year, we see that these figures thus applied to a single ship, cannot err very greatly when applied to the whole Navy. We find that the coals purchased at home for ships' use are to cost only £99,800, while hemp, canvas, and minor articles are to cost £137,400. It is true that much coal is purchased abroad, and that a considerable part of the £175,000 which is to cover all purchases abroad, will go in the one item of coal. But even if the whole of it went in coal, it would not upset the figures.

24. Up to this point, all the facts and arguments go to show that a re-arrangement of the rig of the ironclads is clearly desirable, if we are not prepared to send them to sea as practically mastless hulks like the "*Devastation*," which I for one am not prepared for. The question next to consider is, what should be the nature of this rig? Regarding the sail-power proper to be supplied to a ship of the type under consideration, as altogether subordinate and tributary to the steam-power, what distribution may be made of the former to give the greatest assistance to the engines at the smallest cost and inconvenience? It is to be observed that there are in the present rig two kinds of sails, the fore and aft, and the square. When the square sails are at their best, the fore and aft sails are at their worst, and *vice versa*. Here there is direct loss; for the weight of each kind of sail becomes a drag when the other kind only is in use. Hence we should aim at such a description of sail as might be equally used whether before or close to the wind. Regarding the possible improvement of the rig of our ironclads from this point of view, we come to the question of areas of sail, which gives us some pretty subjects for thought. We may remember that "*area of sail*" is, for a given wind, an expression for sail-power exactly corresponding to the "*indicated horse-power*," for steam-power. Reductions, or increases in area of sail, must be expected for any given wind, to represent reductions or increases of speed under sail, exactly corresponding to those due to equivalent reductions or increases of indicated horse-power, when under steam. This makes us recall to mind that a reduction in the area of sail will not effect a corresponding reduction of speed under sail. Then, if we start with the understanding that sail is not to be considered as a substitute for steam, but rather its assistant, then we can say that it is possible a reduced sail area will affect an increased speed, first under steam alone, and secondly under steam and sail, both because of the reduced displacement of the ship to be propelled. If we reduced the area of sail by one half, and found that we were thereby able to reduce the draught of water by one foot, it might turn out that the increase of speed due to this reduced draught was greater than the reduction of speed due to decreased sail area.

25. It must not be forgotten that a very great part of the weight of present spars and rigging is due to the existence of light and lofty sails. But practically these—unless we could adopt the sound policy of the mercantile sailing marine, and make our top-gallant sails the largest sails in the ship—are of exceedingly small propulsive power. At a time when such sails could be taken into account, as sensibly assisting propulsion, they must come in. Neither the canvas, nor the spars, are capable of meeting a fresh breeze. So that if we decided to considerably reduce the area of sail in an ironclad, we might, in the first place, not decrease the speed sensibly in light winds, while we might even increase it in strong winds by showing a greater area of sail than is possible under the present system.

26. Let us apply these considerations to the case in hand. The ship in question spread an area of plain sail equal to 24,092 square feet. With the wind abeam under sail alone, and when plain sail—

less royals, flying jib, and spanker—strained the spars to their utmost, I got a speed of 8·2 knots out of her, being the best she had ever done. The area of sail was then 19,169 square feet. If it had been reduced to 14,500 square feet, we should have had the following results, considering the areas of sail, as corresponding to their equivalent indicated horse-powers.

$$V^3 : v^3 :: A : a,$$

where  $V$  and  $v$ , are the speeds due to the original and reduced areas of sail; and  $A$  and  $a$ , are the areas themselves, the force of the wind being constant. Therefore:—

$$(8\cdot2)^3 : x^3 :: 19,169 : 14,500, \text{ and } x = 7\cdot47 \text{ knots.}$$

Then it has to be remembered that as this reduced sail area involves a decreased displacement, the loss of ·73 knots would very likely be lessened by the decreased area of immersed midship section. If, for instance, we reduced the weights carried by 460 tons, we should expect to reduce the loss to only ·6 of a knot.

Perhaps the most effective sail area is spread under the present system, when all studding sails are set on one side, with the lee clue of the mainsail. The area is then about 22,790 square feet, of which about 5,780 feet belong to the studding sails. When the strength of the wind is such that the royals and top-gallant studding sails cannot be set, and when topmast studding sail booms begin to go—the ship will make 8·5 knots, the area of sail being 19,862 square feet. A sail area reduced to 15,500 square feet, and a correspondingly reduced displacement, would give a speed under sail alone of 8·08 knots.

27. Actual experiments as to this, the equivalents of sail area and indicated horse-power, would form exceedingly valuable data, for we can say of no theory that it can be applied to practice until actual practice has taught us the fact. The few experiments I have been able to carry out give me no cause to doubt the practical utility of the theory. Thus, I found that when an area of sail equal to 25,617 square feet gave me a speed of 6 knots, an area of only 6,986 square feet gave me a speed of 4 knots. Increasing the area to 17,595 feet only increased the speed to 4·8 knots; and increasing it to 21,815 square feet brought the speed up to 5·5 knots.

28. Supposing, therefore, that on all the grounds set forth, it were determined not to withdraw sail-power altogether from the ironclad, but only to modify it, what is the best modification? I have, till better advised, pinned my faith on leg-of-mutton sails, arranged in a similar manner to those shown in the diagram. The main feature of the proposed rig is the abandonment of yards and gaffs, and the substitution of booms. In the diagram I have given in dotted lines the present rig of the example, and in black lines the proposed rig. The lower masts would be of iron, fore and main 78 feet from deck to cap, mizen 6 feet less, and all three of a diameter suitable to the greatly reduced strain which will be thrown on them. The booms should also be of iron, fore and main 76 feet long, mizen 69 feet long and of suitable diameter. The topmasts should be wooden, slight, in

correspondence with the small strain they are to bear. The booms, instead of resting on a saddle, with jaws round the mast, would work on a universal joint on an arm extending some little distance abaft each mast, and well stayed and supported. The object of this arrangement is to allow the booms to come perfectly square when against the after swifter. By means of these masts and booms, three triangular sails would be set, to be made say of No. 2 canvas. The fore and main alike, with an area of 4,270 feet to each, the mizen with an area of 3,379 square feet. Forward, a jib-boom without bowsprit would be rigged out 27 feet from the knight-heads, and carrying a jib of about 1,392 square feet in area. A staysail would set on the fore-stay as at present, with an area of 1,193 square feet. The total area of these sails would be 14,504 square feet, which, considered as a fore-and-aft rig, compares favourably with the present one, which is but 9,592 feet in area. To these standing sails would be added a single studding sail forward of a triangular shape, the tack to go to the lower boom end, the head to the topmast head, and the sheet inboard. The lower masts should be supported by three shrouds of a side, one carried well forward to act as stays, and one carried aft, but only to the line of the jaws of the boom. Each lower mast should also have the after support of a shifting backstay on each side to set up with a screw and slip, so that the weather one could always be in use. Topmasts would be secured in like manner.

29. So far as I am able to judge, the chief objection to this rig would be its novelty. We should find it difficult to divest ourselves of a longing for our accustomed spars and sails, and for our pretty morning and evening evolutions. No naval man can part with these old friends without a pang, and without sincere wishes that the progress of time, and of busy—perhaps too busy—brains would let us alone. But if these too busy brains *will* establish new conditions, it is most certainly the duty of the naval Officer to cast aside any regrets, and to bravely suit himself and his ideas to the new conditions which others have established for him. We did not of ourselves invent the steamship, nor yet the ironclad and her many-tonned guns; but these things being the tools put into our hands, it is idle to cast longing looks at those so familiar to us in a past age. We must resolutely set our faces and bend our minds to the task of fitting ourselves to the new implements, and we must not fear to forsake old methods and old ideas, so soon as they are shown to be obsolete. My experience of the naval Officer is that he can fit himself to anything, and that no material changes in his tools will alter his character, or make him less “naval” than he always was, and is now. Hence, although few in the Navy have the opportunity or the leisure to make such calculations as I have put before you, and although the many would not, for a long time, perceive the full bearings of my case, I am more deeply in error than usual, and have forsaken my ordinary methods of reasoning, if the idea of novelty attaching to the new rig would be very lasting.

30. But in order to meet such objections as may be raised at the outset, I may observe that I do not anticipate much difficulty in

working these sails, for, large as they undoubtedly are, the fore and mainsails only contain 530 feet more area than the present square mainsail, and any one who has had experience of a brig's boom mainsail, will recall to mind that the largest sail in the ship was the easiest to manage. I should propose that the feet of these boom sails should travel out with clips upon a T-iron feather running the whole length of the boom; and if there ever were difficulty in taking the sails in by an inhaul and brails, easing the boom sheet over would spill the sail and allow it to come in. Permanent braces, representing "lazy guys," would lead from forward aft to each boom on each side of the ship, but would not be brought into use until the booms were eased well over. The boom sheets would be double, one on each side, so as to steady the booms when near the wind. Both braces and sheets, instead of being attached in the usual way, would be run out to the boom-end, or to suitable positions by means of outhauls; the blocks being hooked to clips travelling on T-iron feathers on each side of the booms. In this way, braces and sheets could be hooked and run out, or run in and unhooked as might be necessary. Topping lifts would be fitted double, in the usual way.

The main and mizen booms would form the derricks for hoisting boats in and out. The fore boom would require topping to clear the funnel whenever the tack was changed, but I believe this would not be a serious inconvenience.

The boom sails would have the usual three reefs, but I think it would be preferable to fit them as the reefs of square sails are now fitted, with becketts and toggles on the travelling clips, the slab reef being gathered in by slab lines, as in the square sails. I should not think it necessary to fit storm sails, as the reduction of sail due to reefing would be so great. The luffs of the boom sails would travel with hanks or lacings on a wire jackstay coming down from the topmast head, set up to the deck, and supported at intervals by arms from each side of the mast.

31. Having thus detailed the facts of the relations between steam and sail power in our existing Fleet Ships, and having described the modifications I propose in the arrangement of sail-power to agree with these facts, I may pause a moment to recapitulate. In reducing area of sail, and altering the rig, I have, in the first instance, reduced the heeling power of the sails; and, secondly, the length of the lever at which that power acts. The centre of effort in the new rig is 23 feet below its place in the old one. All this means that the 360 tons of ballast placed in this class of ship may come out if the new rig is adopted, and as the latter will weigh about 100 tons less than the old rig, we find that we have freed the ship of no less than 460 tons of dead weight. Under present arrangements, such a ship is unable to steam 1,500 miles against a head wind, by reason of her short coal supply; I should certainly look on the work as but half done if none of this spare weight were taken to increase the coal supply. Say that the ship now carries 460 tons of coal and steams 4 miles per ton, she then has 1,840 miles in her bunkers; add 100 tons, and we give her 2,240 miles. But then, as we remove 360 tons of dead weight, while

we give her this 100 tons more coal, it is certain that we shall increase her mileage per ton very largely. But if we increase her mileage per ton, it is also certain that we shall increase her speed per ton, and hence she can either steam a longer distance at her present speeds, or the same distances at increased speeds. Hence, if the power of locomotion is an important factor in the Fleet Ships, the appeal I have made to fact shows us how to get it. In the matter of mere money saving, the case is perfectly clear in the new rig. It will cost less to begin with; its wear and tear will be less; and its drag upon the steam-power will be insignificant. Whenever the wind is fair and strong, the new sails will give her very nearly, if not quite, as much help as the old ones, but the loss when the wind is foul and strong will not be noticeable. This is the favourable side of my argument. There are very important *per contras*, as every one knows, but I shall not advert to them at this moment.

32. In my essay I have taken up the strong ground of recommending the new rig for every ship in the Navy. That I have done in order to raise a distinct issue, and I should have held myself in order had I raised it without any more facts than those already stated at my back. But though my facts are by no means complete, I can produce some which go far to justify me in believing that those which I have given in relation to the Fleet Ship will be found more or less applicable to every ship in the Navy. That is, that in general, the propulsive power of our square sails, put into competition with the steam-power, does not reach the loss involved in their weight, in their retarding power in foul winds, and in the consequent diminution of coal supply.

33. I have taken as my example a sloop whose steaming powers were low, but whose sail-power was about four times as great in proportion to displacement as that of the Fleet Ship, and I think that she must under these circumstances give data which will at least go to justify my views. In the first passage of this ship examined by me she went from Malta to Port Said, 1,029·8 miles through the water, of which 614·1 were done under steam alone, and 385·7 under sail alone. She burnt 22·6 tons on the passage, and her nominal saving of coal by the use of her sails was 19·1 tons; but she lost 241·0 miles in speed by her sails, so that her gross saving was only 7·6 tons. In her next passage from Suez to Aden she made 617·8 miles under steam alone, and 805·3 miles under sail alone. She nominally saved 33·5 tons of coal, but as she lost 374·7 miles in speed by using her square sails, her gross saving was only 11·3 tons. Her next passage from Aden to Trincomalee is the most favourable for sail-power that I have yet met with. She only steamed 494·9 miles, while she sailed 2,051·6 miles. She saved 94·2 tons of coal, and gained 64·1 miles in speed, so that her gross saving of coal was 97·1 tons; and while she only burnt 22·7 tons on the passage, it may be said that she must have burnt 119·8 tons had she not had sail-power. But this is just the point which I offer for discussion. The ship on this passage ran before the strength of the monsoon for fourteen days out of the twenty-two occupied in all. She never had, from first to last, any headwinds unless they were very light, and so she had all the advantages of her sail-power, and none of its disadvantages. Now I must observe

that the exigencies of war cannot wait for fair winds, and that had this ship been ordered by such an exigency to retrace her steps, she could not have done it, and the reason why she could not have done it was because of this very sail-power which has here so much benefited her.

34. But passing this by, let us note how exceedingly unfair on the side of sail-power we have been in our estimate of her gross saving of coal. The datum on which it is calculated is the steaming power of the ship against a light foul wind. If the ship had crossed in the north-east monsoon instead of the south-west, and had met light foul winds the whole time, then she could have steamed at the same speed as she now ran before the wind, from Aden to Trincomalee, for 119·8 tons of coal. It is clear, however, that even if my example had had no sail-power whatever, she would not have used that amount of coal in the south-west monsoon, for the fair wind would have both quickened her speed and reduced her consumption. On the other hand, with the lighter and reduced rig which I propose for her, her speed under sail alone would not have been greatly reduced, while had she made the passage under steam and sail, which would, in my view, be the normal condition under the circumstances of this passage, she would have spent but little coal, and would have greatly increased her average speed. The ship was a twin screw, and I believe it may be assumed that with a single screw going, and fore-and-aft sails set, a twin screw may expect to double her mileage per ton at ordinary speeds. In the Fleet Ship it was so, and if it would be so in my present example with her new rig, we must suppose that she would have got 44 miles per ton of coal, and would have spent but 57 tons on the passage. Probably, also, her average speed, instead of being but 4·8 as it was, would have reached 6 knots or more. But the strong point of all is that the ship as she stood would have been unable to steam from Aden to Galle in a calm, whereas with the reduced sail area and increased coal supply, which I propose for her, she would have done so with ease.

35. As I have pointed out in my essay, I found that the sail-power of this vessel when traced through a distance of 6,100 miles actually reduced her speed 14 per cent., and that it was impossible to raise the gross saving of coal—even allowing nothing for her reduced speed—above 37 per cent. If we consider that this ship was unable to face, under steam alone, a breeze to which she could show all plain sail, we get a very strong feeling that the gross saving—even were it nett—would be too dearly purchased. When again I extended my investigations to fifteen months of this vessel's service, I found that her gross saving kept continually falling, and could not be raised beyond 5 per cent. for general service. Against this must of course be set the *per contras* already mentioned, so that we are able to say with some confidence, that the sail-power of this ship reduced her speed, and cost the country more than if it had not existed, and the ship had been mastless.

36. I have another set of eight tables taken for a single screw ship of rather under 900 tons, whose sail area was about 9 square feet per ton of displacement. The sacrifices she made in favour of sail-power



were draught of water and armament. She drew 5 feet more water than the ship just examined, was half as large again, but her armament only weighed 16 tons 2 cwt. against the other's 11 tons 7 cwt. In calm this ship could get 4 knots, with a mileage of 30 to the ton, but in head winds she fell off to 14, and  $8\frac{1}{2}$  miles per ton. The ship had a lifting screw, and perhaps it may be said that in her, sail-power *versus* steam-power had their case dismissed, each being as fully developed as the interest of the other allowed. A fair wind without sail would raise her steaming powers to 7 knots, and 43 miles to the ton. I traced this ship over about 10,800 miles of water, and got a gross saving of 111 tons of coal out of 441, or a gross saving of 25 per cent. But as to effect this gross saving, she lost 722 miles, or nearly 7 per cent. of her speed, it is more than probable that the real gross saving of coal was inconsiderable, and that there would be no nett saving, or perhaps a nett loss, when the increased displacement due to at least 30 tons of rig, and its retarding effect in head winds, was brought to account.

37. On the whole, it must I think be admitted that though I may be rash in committing myself to the abandonment of the square rig of our ships of war, my rashness has some method in it, and that it is not altogether impossible that I may be right.

38. Some paragraphs back (par. 31) I spoke of the facts and arguments which lie against the position I have taken up, but I have thought that those would come better out in discussion, and in this paper I shall not raise them.

TABLE I.

Date.	Hours under weigh.	Distance under			Coals burnt.	Coals saved or lost.	Miles gained or lost.	Remarks.
		Steam alone.	Steam and sail.	Sail alone.				
June 2	19	101.1	..	..	Tons. 17.6	Tons. ..	..	1 Two hours steaming round target. 2. <i>Data.</i> Understeam alone in calm on 6th and 7th, 6 knots for 35 revolutions, and 22.5 cwt. = 5.3 miles per ton.
" 3	24	74.8	..	..	23.7	..	..	
" 4	14	47.7	..	..	13.8	..	..	
" 5	10	..	..	37.6	..	+10.5	-22.4	
" 5	3	..	..	5.5	..	+3.3	-12.5	3. <i>Data.</i> Just before making sail, 7 knots for 42 revolutions, and 32 cwt. = 4.4 miles per hour.
" 5	1	..	5.0	..	0.9	..	..	
" 6	12	57.7	..	..	11.9	..	..	
" 6	8	43.0	..	..	8.4	..	..	
" 7	11	61.6	..	..	11.7	..	..	
" 8	4	19.0	..	..	3.9	..	..	
" 10	16	91.1	..	..	16.6	..	..	
" 11	24	132.6	..	..	26.5	..	..	
" 12	13	79.8	..	..	19.1	..	..	
" 12	4	..	31.9	..	6.2	+0.1	+3.9	
Totals	163	713.4	36.9	43.1	160.3	+13.9	-31.0	

Total distance through the water .....	793·4 miles.
Time under steam alone .....	145·0 hours.
"    "    "    and sail .....	5·0 "
"    "    sail alone .....	13·0 "
Total consumption of coal for engines .....	181·0 tons.
Consumption of coal steaming .....	160·3 "
"    "    for all purposes .....	196·2 "
Average speed under steam alone .....	4·9 knots.
"    "    "    "    and sail .....	7·4 "
"    "    "    sail alone .....	3·3 "
"    "    on passage .....	4·8 "
Mileage per ton under steam alone .....	4·6 miles.
"    "    "    "    and sail .....	5·2 "
"    "    "    "    and steam and sail .....	4·6 "
"    "    on passage .....	4·2 "
Total gross saving of coal by sails .....	8·2 tons.
Gross percentage of saving on consumption .....	4·1 "

TABLE II.

*Abstract of Tables showing the Value of Sail-Power in H.M.S. "Audacious," for the two years ending 28th October, 1876.*

1. Total distance through the water .....	23,304 miles.
2. Distance under steam alone .....	16,039 "
3. "    "    "    and sail .....	5,430 "
4. "    "    sail alone .....	1,835 "
5. Total time under weigh (4,853 hours) .....	202½ days.
6. Time under steam alone (3,351 hours) .....	139½ "
7. "    "    "    and sail (920·5 hours) .....	38½ "
8. "    "    sail alone (576 hours) .....	24 "
9. Total consumption of coal for all purposes .....	6,734 tons.
10. Consumption of coal for engines .....	5,568 "
11. "    "    steaming .....	5,162 "
12. "    "    under steam alone .....	4,201 "
13. "    "    "    "    and sail .....	962 "
14. Average speed under steam alone .....	4·78 knots.
15. "    "    "    "    and sail .....	5·89 "
16. "    "    "    sail alone .....	3·19 "
17. "    "    "    all circumstances .....	4·79 "
18. Mileage per ton under steam alone .....	3·81 miles.
19. "    "    "    "    and sail .....	5·60 "
20. "    "    "    "    and steam and sail ..	4·15 "
21. "    "    "    all circumstances .....	4·18 "
22. Coal nominally saved by square sails .....	553 tons.
23. Miles actually lost by square sails .....	530 miles.
24. Gross saving of coal by square sails .....	453 tons.
25. Gross percentage of saving on consumption for engines .....	8·13 per cent.
26. Gross percentage of saving on consumption for all purposes .....	6·72 "

TABLE III.<sup>1</sup>

*Abstract of Tables showing the value of Sail-Power in H.M.S. "Hart," a twin-screw gun vessel. From April 1st, 1874, to June 30th, 1875.*

1. Total distance through the water .....	11,921·8 miles.
2. Distance under steam alone .....	6,588·9 "
3. " " " and sail .....	754·8 "
4. " " " sail alone .....	4,578·8 "
5. Total time under weigh (2,473·5 hours) .....	103 days.
6. Time under steam alone (1,222·5 hours) .....	51 "
7. " " " and sail (165·0 hours) .....	7 "
8. " " " sail alone (1,086·0 hours) .....	45 "
9. Total consumption of coal for all purposes .....	613·6 tons.
10. Consumption of coal for engines .....	496·4 "
11. " " " steaming .....	431·9 "
12. " " " under steam alone .....	390·1 "
13. " " " steam and sail .....	41·8 "
14. Average speed under steam alone .....	5·3 miles.
15. " " " and sail .....	4·5 "
16. " " " sail alone .....	4·2 "
17. " " " all circumstances .....	4·8 "
18. Mileage per ton under steam alone .....	16·8 "
19. " " " steam and sail .....	16·8 "
20. " " " steam and steam and sail .....	16·8 "
21. " " " all circumstances .....	21·0 "
22. Coal nominally saved by square sails .....	229·0 tons.
23. Miles actually lost by square sails .....	1,109·2 miles.
24. Gross saving of coal by square sails .....	163·6 tons.
25. Gross percentage of saving on consumption for engines .....	32·8 "
26. Gross percentage of saving on consumption for all purposes .....	26·6 "

NOTE.—On the last 5,824 miles, which represent "General Service," the ship burnt 338·4 tons of coal for her engines, and only saved 6·4 tons, or less than 2 per cent., by the use of her sails.

TABLE IV.

*Abstract of Tables showing the Value of Sail-Power in H.M.S. "Egeria," a single-screw sloop, with a lifting screw. From November 2nd, 1874, to June 30th, 1875.*

1. Total distance through the water .....	10,832·0 miles.
2. Distance under steam alone .....	6,708·2 "
3. " " " and sail .....	471·0 "
4. " " " sail alone .....	3,652·8 "
5. Total time under weigh (2,127·5 hours) .....	89 days.
6. Time under steam alone (1,275·5 hours) .....	53½ "
7. " " " and sail (63·5 hours) .....	2½ "
8. " " " sail alone (788·0 hours) .....	33 "
9. Total consumption of coal for all purposes .....	441·3 tons.

<sup>1</sup> Tables III and IV have been added by Captain Colomb, since the paper was read, in order to make it more complete.—ED.

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10. Consumption of coal for engines .....	339·7 tons.
11.     "     "     steaming .....	306·2 "
12.     "     "     under steam alone .....	292·6 "
13.     "     "     "     "     and sail .....	13·6 "
14. Average speed under steam alone .....	5·2 miles.
15.     "     "     "     "     and sail .....	7·4 "
16.     "     "     "     sail alone .....	4·6 "
17.     "     "     "     all circumstances .....	5·0 "
18. Mileage per ton under steam alone .....	22·9 "
19.     "     "     "     steam and sail .....	34·6 "
20.     "     "     "     steam and steam and sail ...	23·4 "
21.     "     "     "     all circumstances .....	31·3 "
22. Coal nominally saved by square sails .....	124·1 tons.
23. Miles actually lost by square sails .....	723·5 miles.
24. Gross saving of coal by square sails .....	111·0 tons.
25. Gross percentage of saving on consumption for en- gines .....	32·6 "
26. Gross percentage of saving on consumption for all purposes .....	25·1 "

Admiral Sir SPENCER ROBINSON: I am sure we have all listened with the greatest interest to the very valuable, well written, and well considered paper that Captain Colomb has been so kind to read to us. The calculations that he has entered into, and the figures on which his theory is founded, fully justified what he said just now, that if he was a little rash, there was method and very considerable method in his rashness. I am sure all of us who have the pleasure of knowing that Officer, and who have heard him lecture and discuss subjects in this theatre, must have been perfectly prepared for something extremely valuable and interesting when we knew that he was to come here to-night. For my own part I felt perfectly certain that I should hear something which would be exceedingly instructive, and would powerfully aid either in confirming or disproving certain theories which I myself had held for a considerable period, and had had some power of carrying into practice. Captain Colomb began by observing what I know to be perfectly true, that he was particularly struck by the change that had come over the minds of most Naval Officers during so short a period as four years relative to the utility of sail-power, and to the principles to be adopted in masting our ships. I for a long time, far longer than the time he mentioned, have held very much the theories that Captain Colomb has so ably set forth to-night, and I have long been persuaded that the time was certain to come when that love of our spars and sails, that certainly does belong to every sailor, and from which, as he so justly said, we cannot part without regret, must be dismissed as a thing of the past. Such lectures as we have heard to-night will go further to establish in the minds of all those who reflect, and who are not led away simply by mere verbal expressions, that we may pay very much too dearly for our masts, and we may by the adoption of wrong principles deprive ourselves of the very special and far greater power without which our ships of war are entirely useless—even when we apply only such masts and yards, and make such moderate use of sail-power, as our ironclads are of necessity reduced to. I have no doubt myself, that although not likely for some little time to find favour in the naval world, the theory and principles which Captain Colomb has laid before us will go further than he as yet is willing to go, and having found him come round to the ideas that I held some twelve or fourteen years ago, I am perfectly sure that in process of time he will advance to its full application, to which I will just advert in passing. Captain Colomb stated, that he was not an advocate for absolutely mastless ships, whereas I believe and am confident that, for certain purposes of war, the absolutely mastless ship will prevail over all others. I am certain of this, that the misery and distraction of insufficient coal supply, and the absolute incapacity an Officer often finds himself under to work to the best advantage the powerful engines that are now put into the modern iron-clad, are often owing to this: that these masts prevent the engines, as Captain Colomb has shown us very clearly, from doing the work which they ought to do, and

that in the hour of action and the day of need, far from being enabled to trust to these masts and spars taking us out of action, they will destroy that efficiency of our propeller and of our artillery through which alone we can hope to win the naval battle of the future. Many of the points touched upon by Captain Colomb I can corroborate in a very marked way. During the time I was at the Admiralty we had repeated trials of ships without masts, and trials of the same ships masted. The comparison was remarkable in the sense that he has laid before you to-day; the loss from masting the ship was extraordinary, and the actual loss of speed at the measured mile in many instances amounted to far more than the 5 per cent. that Captain Colomb has stated. The only point connected with the masting of ships, and with the increased displacement consequent thereon, that Captain Colomb adverted to which I do not feel perfectly sure about is this: it is not always the case that lightening the ship, and diminishing the immersed area of midship section, causes the speed of the ship to be increased, or causes the mileage per ton for weight of coal burnt to be increased. In some instances, though by no means in the majority of cases, quite sufficient is known to make one feel the impossibility of agreeing with the theory that every time you lighten the displacement of the ship, you add to her speed and diminish her coal consumption, because there are so many cases in which we find that ships more immersed, that is, with greater load as it were to drive through the water, greater area of midship section, go faster than they did in their light state, and the reason is not far to seek. Owing to Mr. Froude's experiments, and owing to the scientific analysis and investigation of such gentlemen as my friend Mr. Scott Russell, we are much better acquainted than we were with the resistance offered by the water to propulsion, and have seen that the screw working in deeper water has sometimes a greater propelling and a more efficient power notwithstanding the greater load that it has to propel. But though I say that there are many instances, and there appears to be a good reason in many cases for what I now say, that the absolute displacement of a ship will not always be the measure of her speed and coal consumption, and that lightening the ship may not absolutely produce the best result in propelling her, yet the advantages Captain Colomb has put before you of removing the enormous weight of two or three hundred tons of masts, rigging, sails, and stores will, in the majority of cases, be found to exist, and even retaining the same amounts of weight, two or three hundred tons applied either in armour, coals, or armament, would give us advantages of which we are entirely bereft by the application of sail-power. The safety of ironclads has often given us some concern. Doing away with the masts of these ships at once removes all fear as to the comparatively high position of their centre of gravity, which has been often entertained with some little reason for doing so. The load upon all ironclads is necessarily higher, and necessarily raises the centre of gravity more than it is raised in ordinary ships, and if we add to that, sail-power, we may perhaps place our ships, when their angles of inclination are large, in an uncomfortable and dangerous position. By doing away with these masts and yards, we need not hesitate to put our weight exactly where it is most convenient, in order to make a formidable ship for offensive or defensive purposes. I quite follow Captain Colomb's very lucid tables, which explain precisely the data on which he calculated that the square sails of a ship did not afford any saving of coal, inasmuch as the saving of coal was more than counterbalanced in some instances by the reduced speed. There was one case I thought had escaped him, that is of a ship making a long passage with a fair trade wind—a case that will be familiar to all of us yet I think. The description of that vessel that went from Aden to Trincomalee very much met what had occurred to me, and removed, as I thought, an objection which I should have taken to some of the calculations that Captain Colomb brought forward. The fact is this: take, for instance, the flag-ship in the Pacific; she had a passage to make from Valparaiso to Callao. She has during that 1,400 miles run an invariable fresh strong wind, and I thought he had rather overlooked the use of sail in such a case. She would never light her fires, but the use of her sails would take her that journey with a complete and thorough saving of coal. I thought that proved that there might be cases in which the square sails of a ship, baneful as they are to her in various ways, might still in some circumstances prove an actual advantage; but when I heard Captain Colomb's lucid manner of turning those miles into tons of coal, I began to think he

had not overlooked any part of the argument, and as far as I could follow him, his deductions about coal power, the number of miles due to a ton of coal, saving of coal, and loss of speed, were fairly stated. He has not been tempted to overrun his argument by taking only the favourable side of the question, but he gave us in that case of a ship running before a monsoon, precisely the case that had occurred to me of a ship running before the trade wind; and on a review of the whole subject the question is settled entirely, in my opinion, in favour of the non-carrying of square sails—not carrying sails at all I should like to say, but it is too early at present to insist on that—those who come after me will, I believe, advocate that course, but I do not expect to see it adopted in my time. The last thing that I shall revert to is this. I know by the description Captain Colomb has given, that in almost all the cases in which he has been trying the speed of ships under sail, there has been that miserable drag of the screw to contend against. In the case of the ship he himself commanded, I think there were two screws, which had to be dragged after her, and all the sail-power in the world is fruitless and helpless to get anything like the proper speed of a ship from her while dragging her two screws, together with the various contrivances which I think I know pretty well were not perhaps as good in that ship as they might be made; she was constructed in the early days of twin screws, so that she is not a very favourable specimen of what a ship could do under sail. When, for instance, something in the course of the argument as to sail-power *versus* coal, Captain Colomb had to state that under favourable circumstances no more than  $8\frac{1}{2}$  knots could be got under sail out of the ship while dragging the screws; there is no doubt that with those screws raised he could have got  $11\frac{1}{2}$  knots, but the nature of the case which rendered that impossible to do, also made the comparison less favourable than it might prove in ships possessing that power. I am sure I need only say that we have had the greatest possible pleasure in listening to what Captain Colomb has said, and as far as I am able to judge of such matters I concur most heartily in the principles he has urged.

The CHAIRMAN: I think it would be desirable if some Officers present this evening, who have recently commanded ships, will favour us with their views on this subject. I see Captain Tryon present.

Captain TRYON: I had recently the honour of commanding a frigate that would steam 15 knots and sail still faster. The only part of this very able lecture which I shall somewhat venture to criticise relates to the tables which I see before me. The speed is so miserably slow. I see the speed "under sail" is 3·3. If those are the conditions under which sail is set, it is hardly worth counting, considering the great disadvantages attached to carrying those yards and spars with their excessive weights and incumbrances. Looking at Table II there is a gain of coal of somewhere about one-tenth, owing to the use of sails, but there is a column here set down as "miles actually lost through sails"—580 miles. It appears to me just possible that you do not want to go that distance. A man-of-war is not always making passages; she is sent out to cruise; it is necessary for her to retain in her bunkers that amount of coal in order to chase an enemy, therefore I do not think it is quite fair to write off that coal. It appears to me that the question raised to-night is one of the most difficult problems we have to deal with in constructing men-of-war, and I think, so far as young Officers in command at the present day are concerned, that immediately we heard it was time to look around us on service, we nearly all of us asked to get rid of everything above the outer works. We do not like the masts at all; we go as far as Sir Spencer Robinson, and say we want no masts whatever. I think that is the opinion of a very large number of us, that they will be of no assistance whatever to us in action, and that is the time when we have to consider what is best for our ships. On the other hand, there are circumstances on very long cruises, such as Sir Spencer Robinson referred to, where the sails in a frigate, such as that I had the honour to command, are undoubtedly of enormous value. I could go from England and make a very rapid passage, not at these 3 knots, but at a very high speed, right away to the Pacific, and carry the larger portion of my coal in the bunkers. It is perfectly true if I had not had these spars and 20-ton masts the weight would have been put in the ship in the shape of coal; but still that coal would not have taken me that distance, and would not have kept me so long at sea, had I been cruising, and that coal I should have had, could be replaced by floating coal depôts in the shape of

powerful colliers. I think we do want for the great Navy of England, vessels that will have sail as an auxiliary power, to keep them at sea for long cruizes; but for our men-of-war in the Mediterranean and near at home we want nothing beyond flag-staffs higher up than our bulwarks.

Sir SPENCER ROBINSON: I entirely agree with what Captain Tryon said. I meant to confine the remarks I made to ironclads and not to men-of-war generally, such as cruising ships.

Admiral HAMILTON: The few observations I have to make will apply to cruising ships and not to ironclads, and with regard to those I will give a few cases in my own experience. It was my misfortune to get my ship on shore on one occasion at a distance of 600 miles from Havana, the nearest coaling station. We were obliged to throw nearly all the coals overboard to get her off, and then if she had had no sails I do not know where we should have been; we should certainly have been in a mess. On another occasion we got on shore on the Labrador coast, and there we had also to throw the coal over. If we had not had sail-power to fall back upon, we should very probably in that case have landed on an iceberg, or been frozen in for the winter. Of course, if any of us take up a hobby, you know you may prove almost anything from figures, and it is impossible for us to gainsay those figures now before us. Everybody knows the mathematical paradox  $\frac{0}{0} = 1,000$ , or

any number you please; but practically you divide nothing by nothing and it is equal to nothing. Although those figures may apply to the twin screw ironclad which Captain Colomb commanded, I do not at all think they apply to our ordinary cruisers. I myself do not think the day has yet come for the abolition of sails for vessels on foreign stations. I should like to know what our gallant lecturer could have done to put down slavery on the coast of Zanzibar without the use of sails, because we know that boilers and engines of ships do break down occasionally. There are some very important lines of Transatlantic steamers going out of Liverpool, and every one of these liners is sparred and masted to a very fair extent. I have made six passages across the Atlantic in them, and I found they never lose an opportunity of making or shortening sail. In these, the Cunard, the Inman, and the White Star lines, we find more attention paid to making and shortening sail in full power steamers than we do in the Royal Navy. Depend upon it, it is an economic gain to these firms, or they would not keep those sails and make use of them as they do. Not only that, but in going out to the westward in the winter time they never send down the topgallant mast, as they said, "The stick aloft makes no difference; it is the sea that brings ships up to a great extent, and not the wind." I think there is another point in which the use of sails is still beneficial, and that is when we have to make our sailors or keep the knowledge. We do not want them to be mere drilled machines. In war time the work the seaman has to do develops his individuality, but in peace time, you want masts and spars for the purpose of drilling men in their own line. Before masts and sails can be abolished, we must have a sufficiency of coal stations to meet all wants and exigencies, which we have not at present, and boilers and engines ought never to break down. Scarcely a quarter of a year elapses without our reading accounts of broken-down engines and the vessels returning under canvas.

Admiral REEDER: I have very few observations to make, and I, for the last three years, have sailed in the ship the lecturer has been speaking of, and we have very often talked this matter over. He would like to unrig the "Audacious," or partially unrig her. If her hull had been so designed as to enable her to carry more sail, I should have liked to have seen her more fully rigged. But as she was designed, she could not have been more fully rigged, because she would not have been safe. I have not yet heard from designers of ships that they cannot design a vessel that would be a good ironclad, and suited for foreign cruising. I am not talking of "Devastations" for Channel work; but for vessels to go to the Pacific I believe our designers (Mr. Reed has assured us in his evidence before the Committee of Designs that he can do so) can design a thoroughly useful cruising ironclad—which will also be a full rigged ship—capable of working to windward at least one mile an hour under all plain sail. The "Audacious" as she was rigged (I quite agree with Captain

Colomb), could not do so. I remember his getting her under weigh in an open anchorage, and being unable to have her under sail alone because she was quite unmanageable; but that is not a sufficient proof that an ironclad for distant foreign service cannot have a proper sail equipment if she is so designed as to carry it.<sup>1</sup>

Admiral SELWYN: There is no earthly reason why we should have such failures both in steaming and in sailing, as that vessel brought before us. All the percentages would come out totally different if we had had a decent performance either under sail or steam. I quite join with the writer of the paper in thinking that we might easily substitute fore-and-aft sails of great power, and fore-and-aft masts for the heavy yards we carry now; and if those masts were made of steel, and therefore without the necessity of rigging to support them, if they were made telescopic in shape, so that they could be lowered in the event of your going into action, then I say you would get a perfect sailing ship and a perfect vessel under steam. In the item of steam, I am happy to say, I know perfectly well that this year you will see the power of your coal doubled; but I do not know when you will see steel masts put into ships with proper sails, such as will drive a ship well shaped as she generally is under water, in spite of her screws, at a very fair rate, certainly not less than 10 knots on a wind, and probably from 12 to 13 off the wind. That is a result which you ought to get, which you can get, which there is no earthly reason why you should not get, except a bad disposition of weights on board the ship which makes her liable to capsize; you put sail on her. I join with Admiral Ryder in saying that our naval architects will tell us with one voice, that whatever we ask them for in that way they will give us. Mr. Scott Russell has very often said, "It is for the naval men to tell us what they want, and it is for us to do it." And I am quite sure he and others have sufficient talent to give us a good ironclad capable of steaming not less than 15 knots, and of sailing 10 knots on the wind, and from 12 to 13 knots off the wind. Then I think we shall acknowledge that the sail is worth having, but put before us in this way, the sail is not worth having, it is a doubt whether even the steam is worth having which the vessel did carry. Who on earth since Noah's ark was built, ever thought of going about the sea at four knots an hour? I say it is a ridiculous failure, and in that way we ought to look at it and to be ashamed of it, and to say we can do much better. Does anybody believe the existing mode of putting armour on above the water is likely to be of any great use to us? For what purpose do we raise the weights in a ship until the ship is scarcely able to stand on her legs? Simply to put armour round guns which would be much better under water where the water as armour would be efficient against guns of whatever size, and at all times. I admire very much the accurate observations Captain Colomb has given, and the way he has put his figures together; but I demur entirely to the conclusions he deduces from them. I demur entirely from drawing any such conclusions as Captain Colomb draws, namely, that the ship was a fair representation of a steam or a sailing ship. Turning to the rig that Captain Colomb proposes, I admire very much indeed the idea of fore-and-aft rig; it has been a favourite of mine for many years, but I do not like his taking away the body sail of the ship, and that is what you do if you put three jury masts with fore-and-aft sails into a large ship; you make her incapable of turning or doing anything else under sail. I had a very interesting instance of it in a screw steamer, which I commanded on the coast of Africa. Her speed under sail with screw down—it was always screw down—was  $7\frac{1}{2}$  knots on the wind, and she got to 9 or 10 knots off the wind. The Admiralty allowed me on coming home

<sup>1</sup> I desiderate to the same extent as Captain Colomb a sufficient coal stowage. 6,000 miles in the bunkers at 5 knots is what I should insist on. The "Audacious" had not 2,000; but until our coal depôts are properly distributed and protected, I ask for an *efficient rigged* type of ironclad for distant cruising—say a full rigged "Northampton." A few feet more beam would probably give her the required additional stability, and the additional displacements to carry the additional weight of masts, stores, men, and provisions required, without lessening her stock of coal or her speed under steam. According to Mr. Froude's dictum, the steadiness of platform, the "Audacious'" distinguishing merit, would have, perhaps, to be secured in a full rigged "Northampton" by larger side keels.—A. P. R.



to put a centre mast placed very nearly as that is; but instead of having small sails the sheets of the fore-and-aft sails that I had, came one-third of the distance abaft the next mast aft of it. That ship afterwards, with her screw still down, beat the fastest Symondite brigs on the coast. She would always do her work perfectly well, having a beautiful bottom with very fine lines. There is no doubt whatever that if you give them proper sail every one of our ships will go as fast as the fastest ships that we ever had before. As to the placing of the ballast it is not entirely on account of the masts and yards, but because the initial stability of the ship is too small even without taking into account, &c., the sails, and therefore cement and bricks had to be put in to keep these vessels on their legs. There was the error, and it is an error which I hope will never be repeated again. I am perfectly certain when we get fore-and-aft sails—of which the fore and mainsails shall occupy nearly the entire space up to about 60 feet from the deck between the two masts, which is what they ought to do—you will then return to your ironclads which will wear and stay quite as well as our old ships used to do in spite of the screw and all the other disadvantages. I ask the Naval Architects for a perfect sailing ship and a perfect steamer as an ironclad, and I do not recognize any difficulty in supplying it.

MR. SCOTT RUSSELL, F.R.S.: I prefer, very much, on these subjects to have the opinion of naval men rather than to intrude the opinion of a ship-builder. You will, perhaps, be horrified to hear that I am a great lover of sails, and I should infinitely prefer making a voyage in a sailing-ship to making a voyage in a steamer. But I am bound to say to you that I can contribute what I said the reader of the paper is very fond of, facts derived from experience in merchant steamers of the substitution of steam-power for sailing-power, which are much more in accord with Captain Colomb's paper than I like them to be. I was asked to build a steam ship for trying the experiment of substituting steam transport entirely for heavy cheap materials, instead of sail transport. I am obliged to confess what I do not like. I am obliged to confess this to you, that for such common purposes as sailing between England and ports of 400, and 500, and 600 miles, in common vulgar trade, we very soon found out that a steam ship, trusting entirely to her steam, and having scarcely any sails, cost far less money per voyage, and earned much more money per annum, than all her additional coal expenses. And the result I can tell you, in a few words, to be this, that on those trades average sailing vessels only made a voyage once a month in the average of the whole year, steam ships made a voyage once a week all the year round. I therefore say, as a conclusion of experience, that, if a ship is going on a voyage on which steady speed is of any value, then on such work as that, steam does answer the calculations which have just been made, and steam is much cheaper than sail. But, at the same time, let me go back to my old prejudices. Captain Colomb does not propose to do away with sails altogether; he proposes to have sails, and to use those sails in such a manner as shall give the greatest advantage with the least inconvenience. Allow me to add my opinion, as a sailing-ship constructor, to Admiral Selwyn's opinion, that it is possible—if you will allow me to say so, it is easy—if you abandon certain existing plans, to build a man-of-war which shall be able to carry a very large quantity of canvas so conveniently, and with so little impediment, that if you will only give up your present modes of carrying that canvas, and will carry it in modes suitable to the new conditions which steam has raised, you can make a vessel carry a good deal more canvas than Captain Colomb has shown in his proposal, but on something like the same principle, with great advantage and with no inconvenience. While, therefore, I am sure that trusting more and more to your steam will be an enormous advantage to the fighting power of your ships; while I think, trusting much to your present system of sails for practical work, when you come to want it, is very likely to prove untrustworthy, and to lead you into difficulty, I would seriously suggest to you, while you improve your steam power to the utmost, not to run away from the sails without making a very great effort indeed to simplify all their arrangements as much as possible, to have as little impediment as possible from the plans that have been taken, and to enable you to utilize them, as a third resource, when necessary. Allow me to make one final remark, which I think is of great consequence to you in the practical use of your steam ships. I do not like twin-screws. I prefer one very much, but I recommend you to have all your steam ships with two screws, and for this reason only: when

one screw is disabled, I like to have another, therefore I recommend you to use what I do not approve, but what I think is entirely for your interest, and entirely consistent with prudence. The other point I would just allude to, for a moment, is this, that I think you may dismiss from your minds all concern about ballast, and things of that kind. I do not think anyone has any right to build a war steam ship that has anything to do with ballast, and I will give you a conclusive reason why you should not. I want the ballast in a useful shape, instead of in a useless shape, and when you have got on board your ship 500 tons of iron, in the shape of machinery and boilers, or perhaps 1,000 or 1,500 tons, what a goose you must be if you cannot put that in the place where it will serve all the purposes wanted for ballast and stability. A man who builds a ship for you, and fails to do that, knows nothing about his business.

Captain COLOMB: I think I have, in the first instance, to congratulate the Institution on the fact that every speaker has stuck to his point, and that the paper put before this Institution has been really discussed. It has been my unfortunate lot occasionally to read papers at this Institution which have not been, by any means, properly discussed. I am sorry to say, sometimes speakers so far forget themselves as not, for one single moment, to allude to the subject of the paper, but to ride—as we are all, of course, liable to do—off on their own little hobbies. I think, for the credit of the Institution, we might all try to keep the discussion as it has been kept to-night, strictly to the point. I have to thank Sir Spencer Robinson, and generally the speakers, for the very flattering way in which they have received the paper. Sir Spencer Robinson, in one way, is further in advance than I am; he would take away the sail-power entirely from a fleet-ship or ironclad; but so far as I understood him, Captain Tryon's old ship, the "Raleigh," more nearly meets his view of a cruising ship than the ideal I have attempted to put before the meeting. So far as the ironclad herself goes, I suspect it may be I have not got quite the pluck to go as far as Sir Spencer Robinson has. I must say I waver very much upon that point. So far as the other point goes, I must say I have taken the figures out as far as I could. The figures referred to have been, in the main, based on the table before you. But, as I reminded you, that table was drawn from twenty-eight primary tables, similar to Table I, which is entirely drawn from the ironclad spoken of; but there are still the remaining number of the forty-five tables, which are drawn in one case from a non-lifting twin-screw sloop, and in the other case from a lifting screw sloop. I quite agree with Sir Spencer Robinson, it is apparent, on the figures furnished from time to time by the Admiralty, that less displacement does not always increase speed; but still I think it may be taken in any ship of the Navy now afloat, the rule will be that, if you take some of her weight out of her, she will go faster. I think the great mass of steam trials of our ships on the measured mile shows, on an average, that they have run better at their light than their deep draught. But, of course, Sir Spencer Robinson's question is entirely bounded by the immersion of the screws, not actually by the displacement of the ship, and you might get immersion of the screws by great draught at the stern, without increasing the immersed area of midship section. Sir Spencer Robinson also spoke of the Pacific. Now, the Pacific is a trouble to me; it always has been a trouble. I own I do not quite see how to manage it at present, but when I come to think of the fact—which I believe, as far as I can make out, is quite certain—that, with the twin-screw under anything like decent sail-power, such as we could give her, say two feet per ton of displacement—with one of the screws only going, pretty close to wind, and moderate sail-power of this kind, you immediately double your mileage per ton, and, I think, in the Pacific the twin-screw, with fair coal supply and a fair amount of sail-power, would make those long passages more easily and quickly than with the present coal stowage and full rig. Sir Spencer spoke of the drag of the screw. I was bound to go to some ship which had not the drag of the screw, and I went to a ship with a lifting screw. Some twelve or fourteen tables, covering 10,000 miles, are taken from a ship which lifted her screw. It is quite certain your greatest gain with your sail-power is when you lift your screw and get the ship under sail alone. When you can do that, you get an enormous gain, and if you could have shown that there are figures extant to prove my figures here are overthrown by such a ship, then I must admit the fact. But in the ship I have examined, although she gained

by lifting her screw, she does not gain sufficiently to overstep the figures. She shows some 25 per cent. of gain. The Officer commanding her, although exceedingly fond of his sails, assured me that, if I had pursued my inquiries further, her percentage would have continually dropped, because she happened to go to places where her sail-power was not so available. Captain Tryon spoke of the slow speed. Well, I am as much against slow speed as he can be; but examining, as I have done, a great many of our ships, the slow speed is an absolute necessity for us. As we stand with our present coal consumption and stowage, the slow speed, when we want to get from point to point, is a thing which we cannot get over, and I think there is one point which we always forget. I tried to bring it forward in my essay; that is, that we start from certain fixed geographical facts. Except in the Pacific, it is a fact that there are no two coaling stations on British territory that are further apart than 3,300 miles. I think that is a thing that lies at the base of the whole of our shipbuilding policy. We have to recollect, if we have 3,300 miles of coal in our bunkers, we can always go from point to point with the certainty of a coal supply, provided we take care to keep the coal up. Admiral Hamilton was a little against me. I know quite well that, in reading a paper of this kind, I am in one sense throwing an apple of discord into the Navy. I hope it is a good apple of discord, and that we shall have many discussions, over it—and no doubt a great many fights—because out of these fights and discussions, truth comes forward at last. He spoke of the difficulty in which he would have found himself had he been deprived of his sail-power. Well, now you know I could not meet his remarks or answer them unless I had the facts relating to his ship. If I had the tables, such as I have there, of the whole of her commission, I should probably be able to answer the whole of his observations.

Admiral HAMILTON: I was alluding to the special case of being ashore, and having to throw the coal overboard.<sup>1</sup>

Captain COLOMB: That is quite fair; but still I could not answer your question unless I had the whole of the facts of the ship before me, which I have not. The difficulty is this. We are at present, in spite of ourselves, sending ships to sea, and the most valuable ships in the service, in the condition in which you would have found yourself under my proposals. If the "Devastation" goes on shore to-morrow, where is she? And of course every other nation is doing the same thing. There are several ships in the Mediterranean without sail-power.

Admiral HAMILTON: I was referring to cruising vessels: I give up the ironclads to a certain extent, not altogether.

Captain COLOMB: I think Admiral Hamilton drew attention to a previous command of mine, and asked how I should have got on without sail in her. When I commanded a previous ship, which was more capable of acting under sail than my last command, I certainly was not prepared to go as far as I now do; but at the same time doubts used to raise themselves in my mind. The ship I commanded, in order to establish her sail-power, had great draught of water. She was exceedingly lightly armed, and she gave up her armament and her draught of water, for the purpose of carrying her sails. A very much smaller ship would have carried the same armament on a very much less draught of water, and would, with a little increased coal supply, have done all the work we had to do. If there is a break-down of boilers and engines, of course there we are. That is the point. Every person who considers this question is bound to raise and think it out: and the way I have thought it out for myself is this: we have had steam and sail fighting a battle in our ships for thirty years. It is a battle in which steam has been constantly winning, and sails constantly losing. In all those thirty years, who can produce half-a-dozen cases where the sail-power really took the ship out of a danger or brought her safe home when the boilers and engines broke down? There are such cases no doubt, but on the other hand you get cases exactly the opposite way. The "Thetis" the other day—a full-rigged ship—got away from Port Said, jammed her screw, broke down in her engines, and you had the whole country in alarm about this full-rigged sailing ship.

<sup>1</sup> My debating powers were not quick enough to give the true answer to Admiral Hamilton, which is this: if he had had less masts and sails, he would have kept coal on board equivalent to the weight gained.—P. H. C.

They sent the "Devastation" out to pick her up, and she had to be brought in to Malta by a steam-ship without sail-power. A sister vessel to my former command stood across from Zanzibar to the coast of India and burnt the whole of her coal. She touched at a little port, the only one she could fetch in the south of India, and telegraphed up to the Commodore to say they were starving, their coal was out, their rum was out, their biscuit was out, everything was out. I received orders to go down and take this fully rigged sailing vessel in tow, and bring her to Bombay. I found her in a starving condition, and towed them the 300 miles to Bombay. If that ship had had a large coal supply I should not have had to go after her. The area of sail in mail steamers is another point which must occur to anybody putting forward a thesis such as I have put forward. I have made a good many inquiries about it. Coming home in a Peninsular and Oriental steamer the other day with some of the most intelligent men I have met, I had very long conversations with them. They told me the Peninsular and Oriental Company were quite at their wits' end as to whether sail is good or bad; that they make sail because they are bound to, but they do not in the least know whether it does them good or harm, and nobody ever made any calculations to ascertain which. It may be that they are good, but the facts nil, we have not got them. Admiral Ryder said he would like to have had some more rig in the "Audacious."

Admiral RYDER: Not in the "Audacious."

Captain COLOMB: In a particular ship which might be designed, and of course this brings out the whole question of stability. The ship in question had four square feet per ton displacement. You might, of course, by reducing your centre of effort, have got more sail upon her; but that is one of the questions in point. Admiral Selwyn has also made some observations. I think I should not have gone quite so far as he did as to speak of the ironclad in question, or her class, or in fact any of our ironclads, as "failures." I think it is a pity that strong expressions should be used. I think we should recognise the fact that we are in the midst of immense changes, and that not one of us knows whither they are leading us, and what is to become of us all. With compound engines, if Admiral Selwyn will produce us a ship which will steam thoroughly well and go 10 knots on the bowline, and 12 to 13 knots under sail, I am perfectly certain we should recognise her as a very perfect ship, provided she was not capable of being met at sea by a ship of the same displacement with heavier armament which would beat her. Admiral Selwyn also spoke of "Noah's arks." I am not prepared to admit that any of our ships are "Noah's arks." I think, having gone as an amateur into the figures, and made a very rash attempt at inquiring into the conditions of our ships, the conclusion I arrived at is very far from that of the gallant Admiral. They are, as a rule, the class of ship which every naval architect in Europe copies.

Admiral SELWYN: I spoke simply of the speed—the speed of a Noah's ark.

Captain COLOMB: The speed is practically the same. If you have to do the same work, the whole of the navies of Europe are in precisely the same condition, and I am not prepared to say that human brains are able to go further than they have shown themselves capable of doing in the designs of our ironclads at the present time. Admiral Selwyn also brought up the whole question of stability and rolling. A great many people think that I am one of those who imagine that this rise in the centre of gravity which has taken place at present, is a thing which I deprecate. The question before the naval architect is this: "I want a steady gun platform," says the Naval Officer. Says the architect, "I cannot at present give you that, unless I bring your centre of gravity up—unless I make your initial stability small. I do not make your *stability* small, because the arm of my lever extends very rapidly as the ship heels over, but I cannot give you a steady gun platform unless I make my initial stability small." The only question is how small may he make that with safety. When you find fault with ballasting this ship you must recollect she was in some degree an experiment, and all you can say when you have said all that can be said, is that "they cut it a little too fine;" but the gallant Officer is, I think, wrong in supposing the ship would be unstable without ballast if the masts were taken out of her. I must quote one or two figures to show how mistaken those are who speak as Admiral Selwyn has done. "Fore and main yards weigh, in round numbers, 9 tons, and are 70 feet above the

" present centre of gravity. Their moment is thus 630 foot tons. The topsail yards weigh 3 tons, and when hoisted are 122 feet above the centre of gravity. Their joint moment is thus 366 foot tons, or for both lower and topsail yards 996 foot tons." This is the equivalent of 50 tons of ballast.

Admiral SELWYN: You are talking of dynamics; I call them statics.

Captain COLOMB: There is the whole point. Mr. Scott Russell was kind enough to agree with me on general points. He objects to the twin-screw for certain reasons, but upon the whole he thinks its merits for other sufficient reasons outweigh its demerits. I can only say, in conclusion, I am very much obliged to the meeting for the kind way in which they have received my paper.

The CHAIRMAN: At this hour I need not detain the meeting by any words of my own. I think we have to thank Captain Colomb for the great pains he has taken, not only in the lecture he has put before us, but also in his reply, which really almost comes to a second lecture. I therefore offer him on the part of the meeting our double thanks. It must have been an extremely interesting evening, especially to Naval Officers, and I hope we shall have many such discussions.